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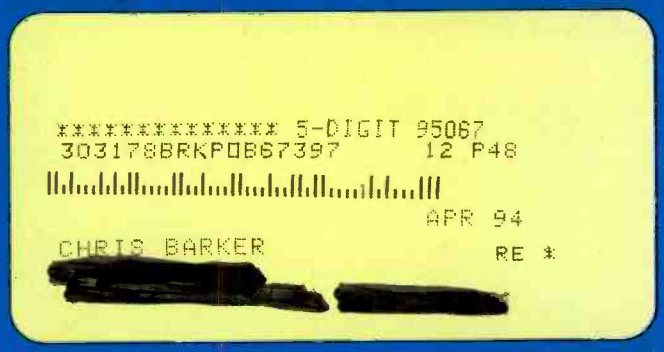

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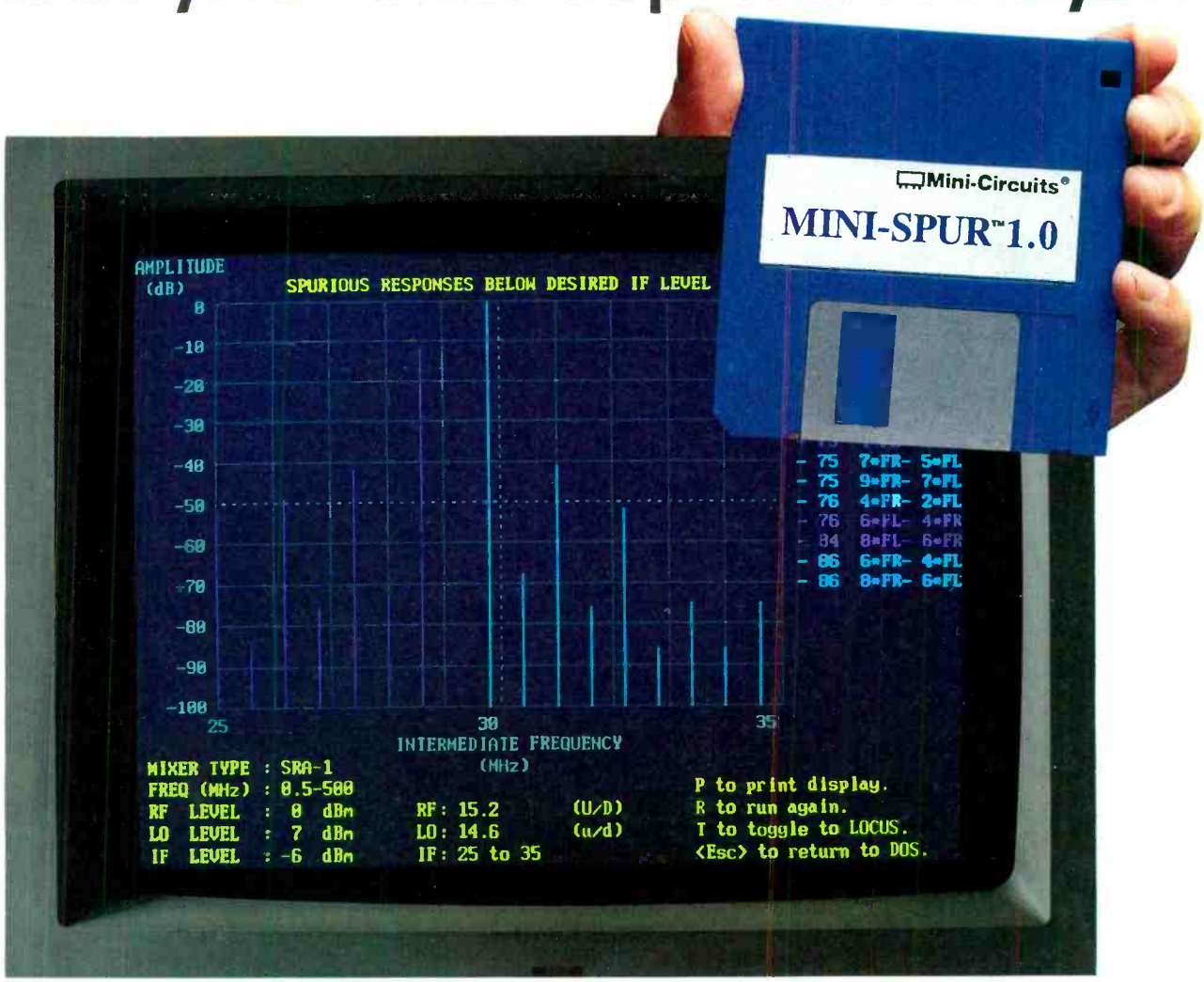

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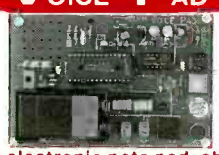

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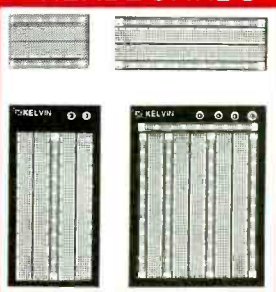

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Vol. 64 No. 12

ON THE COVER

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Prevent eavesdropping by scrambling and descrambling your telephone conversations.

WILLIAM SHEETS AND RUDOLF F GRAF

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Learn how to use the photo-resist method for making your own PC boards.

JOHN BERCIK

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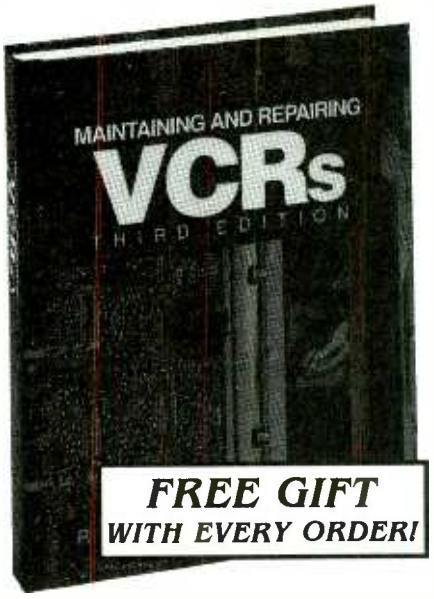

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WHAT'S NEWS

A review of the latest happenings in electronics.

Smart Card Forum

To accelerate the use of Smart Card technology, representatives of the telecommunications, entertainment, software, publishing, computer, health-care, and financial-services industries have banded with government agencies to form the Smart Card Forum. The Forum's goals are to address compatibility issues across business applications, and to facilitate the market tests of multiple-use cards. A technology committee will provide advice on technology, systems, security, and interoperability issues to the various business-applications committees.

Smart Card technology was invented in 1975 and has been used successfully throughout Europe and Asia in banking and telecommunications applications. Prepaid cards "contain" digitized money that can be used as cash wherever a Smart Card reader is available. It is predicted that by 1995 more than 1.25 billion Smart Cards will be issued worldwide for such purposes as making phone calls, paying tolls, paying bus or subway fares, and buying convenience items.

The Forum is open to pubic and private-sector organizations with a user- or business-applications focus. Various categories of membership, with fees ranging from $1000 to $15,000, are available. For membership information, contact 800-393-6786 (813-286-2339 outside the U.S.).

Robot Contest

The Science Center of Connecticut is sponsoring the International Robot Contest on Sunday, April 17, 1994. The day-long event will be the culmination of a four-month robotics exhibit at the Science Center. The contest is open to everyone and has different categories to allow people of various ages and experience levels to compete. All entrants will receive an award. The top winner will receive a $1000 check and additional prizes will be awarded to other winners.

The challenge is to build a robotic device that can move through a model of a single floor of a house (measuring 8 × 8 feet and divided by walls, hallways, and rooms), look for fire (a lighted candle), and extinguish it. The robot that completes those tasks in the shortest amount of time will win. Robots must be less than one foot on a side and can be tethered to a personal computer or controlled by a built-in microprocessor.

Anyone who is interested in competing can receive the complete rules of the contest along with the exact layout of the model house, by contacting Jake Mendelssohn, Science Center of Connecticut, 950 Trout Brook Drive, West Hartford, CT 06119; Phone: 203-231-2824, extension 46; Fax: 203-232-0705; Prodigy: KJRP71A.

Amateur TV awards program

Amateur Television Quarterly offers an award program for TV DX'ers. TV Quest is open to hams and SWL's who engage in two-way or one-way TV activity. Certificates are awarded to those who receive ham or commercial television stations from long distances (in 100-mile increments starting at 100 miles), and to those who catch a specific quantity of stations (starting at 25).

Upon joining TV Quest, hams receive a certificate of membership imprinted with their call sign and a personalized Q number; non-hams are assigned a Q number for SWL purposes. The colorful DX Quest Award for distance and Quantum Award for number of stations are both suitable for framing. Figure 1 shows a sample award.

Subscribers to *Amateur Television Quarterly* receive automatic membership; non-subscribers can joint the Quest TV Society for a modest fee. Only contacts and stations received after October 1, 1993 count toward the certificates. For information, send a self-addressed, stamped envelope to ATV Quest, 1545 Lee Street, Des Plaines, IL 60018.

FIG. 1—A SAMPLE QUANTUM AWARD certificate.

Digital video compact discs

The basic specifications of the "Video CD" format, as well as a logo mark that signifies hardware and software compatibility based on the format, have been established by Matsushita, Philips, Sony, and Victor Company of Japan, Ltd. (JVC). The Video CD is based on the Karaoke CD format that was established as a standard in March 1993 by JVC and Philips and which is already well established in Japan's professional karaoke market. The format has the capability to store 74 minutes of audio and digital full-motion pictures on a 12-cm compact disc. It is based on the MPEG-1 standard.

The four companies have agreed to include in the Video CD format two optional features: two levels (normal and high resolution) of still picture playback functions and playback control. The optional functions are expected to broaden the number of possible applications, particularly in education, training, and information.

Hardware and software manufacturers have begun to apply the Video CD format to a range of applications including movies, mu-

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sic, and educational programs. Video CD discs will play on a variety of video products, such as Video CD players, CD-I players equipped with digital-video cartridges, computers with CD-ROM drives and MPEG decoders, and CD players (with a digital data output) with an add-on Video CD adapter. Licensing will be available worldwide.

Community information network

Zenith Electronics Corporation (Glenview, IL) introduced an innovative interface for personal computers and cable television systems at INTEROP '93 in San Francisco. Part of its growing Metropolitan Community Network strategy, the residential PC local area network (LAN) gateway—called "HomeWorks"—will offer cost-effective connectivity over standard cable-TV home-subscriber facilities. HomeWorks provides a multimedia communications conduit that allows LAN data to be transmitted on fiber-optic or coaxial cable and coexist with other services, such as video, manufacturing networks, video teleconferencing, and point-to-point data.

Zenith's "information highway" is intended to support a range of interactive applications, including work-at-home and electronic resource services and distance learning. HomeWorks also supports computing needs for health-care, legal, and financial businesses. Selecting a service will be as easy as tuning in a television channel.

The HomeWorks system consists of a PC gateway card and external RF modem that transmits and receives on standard cable-TV channels, sharing the cable with video channels. It transmits at 0.5 megabits per second, significantly faster than telephone modems and ISDN. Four 0.5-Mbps sub-networks can be configured on a single 6-MHz cable-TV channel for an aggregate data rate of 2 Mbps. The gateway card provides software driver support for many popular network operating systems, including Novell (PX and ODI), Microsoft NDIS, TCP/IP, and IBM NetBIOS. The HomeWorks model PCTV-R is available for less than $500. Ω

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	VOLTAGE									CURRENT				
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Analog Bar Graph Simulates an analog meter to indicate trends and changes.	✔	✔	✔	✔	✔	✔				✔	✔	✔	✔	✔
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Peak Hold™ Measure and store peaks as short as 1ms. Detect transients, measure inrush currents, and determine crest factors.	✔	✔	✔	✔		✔				✔	✔	✔	✔	✔
Auto Min Max™ with Averaging Record the minimum, the maximum and the average reading, *unattended*. Fully autoranging for maximum resolution.	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
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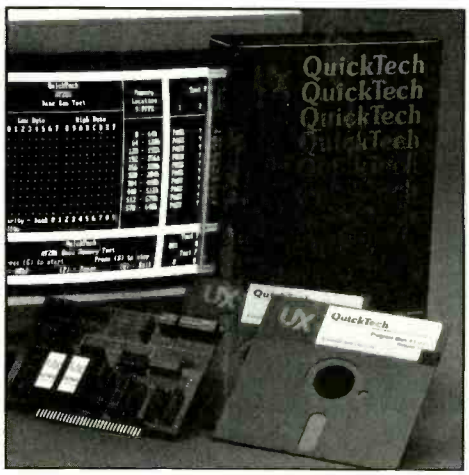

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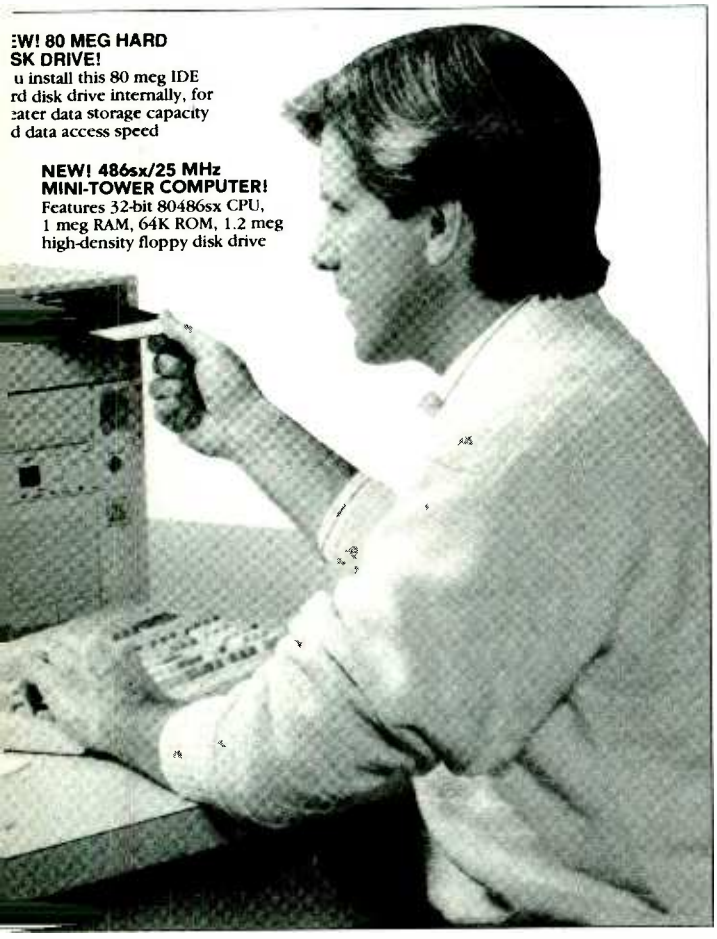

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VIDEO NEWS

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

DAVID LACHENBRUCH

• **Europe's TV dilemma.** The audio-video fair in Berlin has served as a launching pad for Europe's analog high-definition TV system, HD-MAC, for the last six years. In 1993, the every-other-year event was without any high-definition mooring for its 450,000 attendees, as British politics and American technology combined to kill off the European expectations for a quick transition to HDTV. With an eye on American development or digital HDTV and a second eye on the recession in England, the United Kingdom refused to subsidize the proposed analog HD-MAC system or its anticipated predecessor, D2-MAC. The British decision was strongly influenced by the existing satellite broadcasters, who preferred to continue broadcasting in the PAL system, as opposed to MAC, which virtually nobody could receive.

So Berlin 1993, which had been intended to mark the introduction of European HDTV, turned into a sort of conglomeration of watching and waiting as broadcasters and manufacturers watched the progress of digital HDTV in the United States and waited for the recession to lift.

• **Widescreen fever.** Instead of HDTV, the emphasis of the 1993 Berlin fair was on widescreen TV, with 16:9 aspect ratio. Virtually every TV manufacturer exhibiting there showed at least one widescreen set, and the developers of the ill-fated HD-MAC touted widescreen as an interim step before a new HDTV system could be developed. A compatible improved-definition HDTV system was being pushed hard by German broadcasters, and there was a strong possibility that that technology could be implemented in the near future—if the European Community Council appropriates money for a start.

The system is called "PALplus," and it's an ingenious method of bringing the resolution of letterboxed TV transmissions up to the standards of regular PAL broadcasting. Under the PALplus system, stations would broadcast compatible letterboxed programs—that is, widescreen programs that can be displayed on standard sets but with black bands above and below the picture area. On these standard sets, the widescreen picture, displayed full width, results in only 432 of the PAL system's 576 active lines being used for the actual picture, the remaining 144 lines making up the black bar.

However, when a widescreen picture is displayed on a widescreen PALplus receiver, all 576 lines of picture information are displayed. PALplus achieves this by adding "helper" signals in the black bands above and below the letterboxed picture transmission. While a conventional TV set will display a 432-line letterboxed picture, a PALplus set displays the picture in full detail. As explained by its proponents, PALplus "vertically low-pass filters the 576 lines of picture information to produce the 432 used for the compatible letterbox display on conventional 4:3 sets, and using the remaining 144 lines to carry information, derived from vertically high-pass filtering the picture information, to enable PALplus sets to restore the full detail contained in the original 576 lines."

PALplus is backed by Europe's four largest TV manufacturers—Philips, Thomson, Nokia, and Grundig—as well as Germany's state-owned broadcasters and, perhaps, by Britain's BBC.

• **Digital search continues.** Despite half-way solutions, European broadcasters and TV manufacturers, like their American counterparts, are convinced that a digital system is the ultimate solution. The first European digital proposal was developed by Swedish broadcasters and is espoused also by Finland-based Nokia, Europe's third largest TV manufacturer. There could be tests of this system before 1994 is over. It is expected to be only one of many proposed digital systems, and Europe's quest for digital HDTV gives promise of true worldwide compatibility.

• **Laser TV.** One of the Berlin fair's real show-stoppers was "Laser TV," demonstrated by German TV manufacturer Schneider as the future of television. Schneider promised to have laser TV on the market in three years and claimed it had patent protection for the system. (Zenith demonstrated laser projection TV in the U.S. about a decade ago.) Schneider's demonstrations featured a theater-sized rear-projection system and a front-projection system with a screen of about 30 inches.

Schneider claims that the laser is the perfect medium for HDTV because of size and resolution constraints of cathode ray tubes. In addition, Schneider argues, laser TV eliminates any problems of X-radiation hazards and reduces material and energy requirements of CRT systems because it "dispenses with the picture tube and screen." Because laser light is coherent, focus is no problem. "The light beam emitted from the laser TV system and deflected by a scanner unit carries all the picture information in the TV colors red, green, and blue, and is thus capable of representing any TV or video picture on any front- or rear-projection surface," says Schneider, "without essential light loss, without convergence problems, and in any desired size with laser precision."

Laser TV can provide "the highest definition pictures in the world," with only 20% the power requirements of CRT TV. Ω

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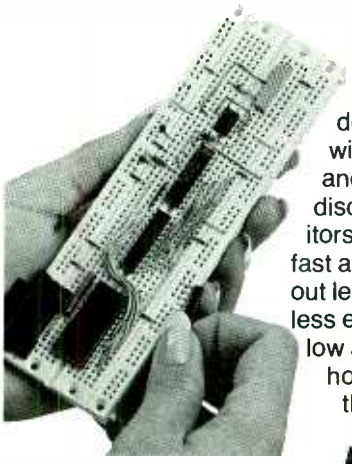

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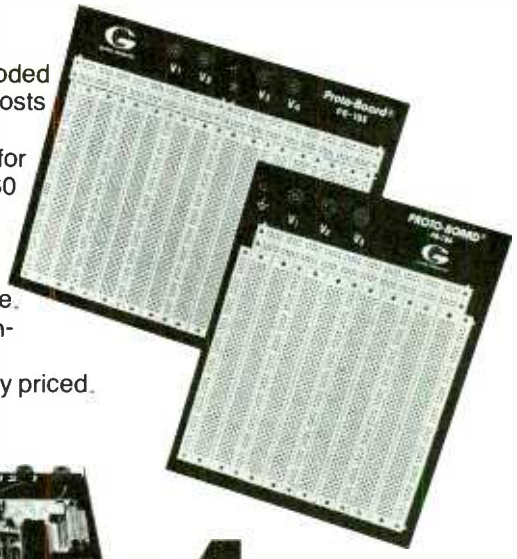

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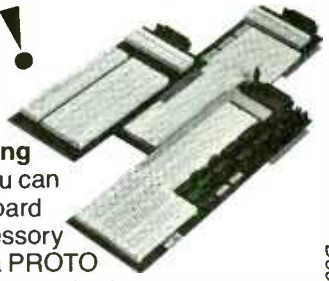

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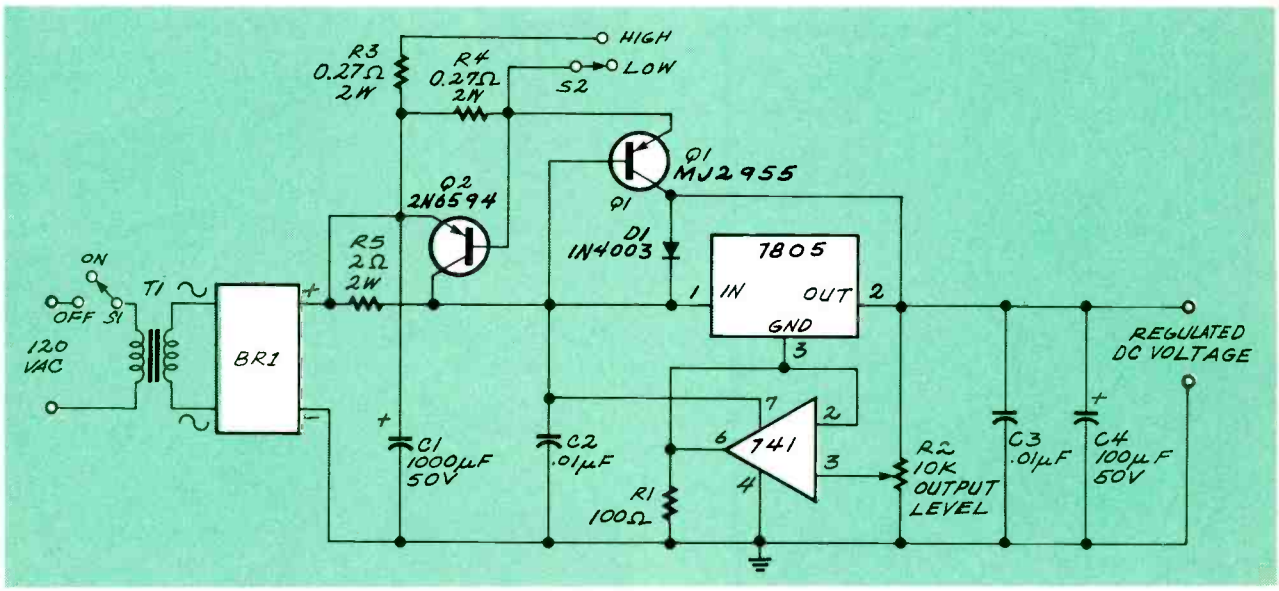

FIG. 1—THIS CONSTANT VOLTAGE SUPPLY has a variable output. It can supply more than 5 amperes, and has two switchable current limits.

CONSTANT REGULATOR?

Could you please explain what a constant voltage regulator is and draw a schematic of one. I'm not sure what they're used for and how they are made.—D. Ha, Pearl City, HI

This is an easy question to answer. The best way to describe a constant voltage regulator is to say that it is a circuit that provides a constant voltage output regardless—within limits—of the input voltage. The schematic for a regulator depends largely on the kind of regulation you want, and the amount of power that must be regulated.

Figure 1 shows a constant-voltage supply with a few bells and whistles thrown in. The output voltage can be varied over a fairly wide range. It can supply more than 5 amperes, and has two switchable current limits. Perhaps you'll find an application for the circuit in Fig. 1.

SAFETY CUTOFF

I have an electric welder that's powered by a 4-cylinder gasoline engine, and I'd like to install a safety cutoff that is triggered by the speed of the engine. I have a universal electronic tachometer and a plug-in relay with a 12-volt coil. The tachometer has five wires coming from it, and I think I've identified the signal, ground, and power lines. Is it possible to pick the signal off the meter on the tachometer and use that to trigger the relay and cut the ignition to the engine? I would appreciate any help you can give to me.—C. Moren, Bonnyville, Alberta

You haven't gone into great detail about the tachometer and, from what I can tell, you don't know much about how the tachometer works. It's never a good idea to build a circuit around something you don't completely understand, and this is especially true if you're trying to control something that can be as potentially dangerous as an electric welder.

To start off, the cutoff switch should interrupt the power going to the welder, rather than the ignition of the engine. Remember that even if you cut the ignition, the engine will still have to shut down, and it will continue to generate power while it does so. That can damage the welder because the power generated during engine turn off will be progressively less and less; some welders can be damaged just as easily if they are underpowered as if they are overpowered. The cutoff circuitry should be designed to supply power to the welder only as long as the engine is running at the correct speed.

The key to the safe operation of the system is the tachometer. Many tachometers will produce a signal at a settable RPM, and they're the units I would use. You can find them at your local auto parts store, looking through the J.C. Whitney catalog (they're located at 1917-19 Archer Ave., PO Box 8410, Chicago, IL 60680), or reading the classified advertising pages of a good automobile magazine.

It's also possible to build your own tachometer. If you look back in the June 1987 issue of **Radio-Electronics** you'll find a tachometer project that just might be useful to you. If nothing else, do keep in mind my suggestion to cut power to the welder, and not the engine. Ω

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LETTERS

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KEEP IT SIMPLE

I enjoyed reading Jon Bek's article, "PC-Based Universal Remote Control," in the June 1993 issue of **Electronics Now**. It must produce fabulous delusions of grandeur, at least, to be able to turn off your TV with "SILENCE, PEASANT!"

But, do I just not get it? If the 4051 really does connect the I/O pin 3 with input channels 0 through 7 on pins 13, 14, 15, 12, 1, 5, 6, and 7, respectively, based on the address supplied to pins 9 through 11, and if it is bidirectional as I/O implies, why not just use two of them?

First, connect the eight input-channel pins of one 4051 to columns 1 through 8 of the keyboard. Then connect five of the input channel pins of another 4051 to rows A through E of the keyboard, and connect their I/O pins 3 together. Next, connect the address lines of the first 4051 to parallel port output bits 0 through 2 and its enable pins 6 to 3. Finally, connect the address lines of the second 4051 to parallel port output bits 4 through 6 and its enable pin to 7.

Then, one can connect any row to any column by sending column + row * 16 to the parallel port and disable it with 255, all assuming pull-up resistors, etc., as shown in the schematic.

So, what am I missing?

R.S. FLEISHMANN II

Delta, PA

Of course! I'm embarrassed that I didn't see that myself. Your suggestion greatly simplifies the circuit. You are henceforth invited to peek over my shoulder anytime—preferably before I wire-wrap another unnecessarily complex design! I offer the poor excuse that the 1×8 mux I originally had in mind was a unidirectional device. My favorite surplus parts house was out of that chip, but my trusty dog-eared copy of Don Lancaster's CMOS Cookbook *was in my back pocket, and the 4051 device described therein seemed the ideal replacement. The fact that the device is bidirectional didn't really register until I received your note. I've been kicking myself ever since.*

I've received additional requests for a serial-port implementation of the interface. One way to add this would be to add serial-to-parallel conversion ahead of the existing interface. It should be fairly straightforward to add a UART here to perform the conversion, and a Maxim MAX-232 chip to convert the PC's RS-232 signal levels to ordinary logic levels. The MAX-232 is neat because it runs off a 5-volt supply, which keeps things simple.

I've also recently discovered two companies that market smart remotes with serial interfaces built in. The OneForAll is offered by Home Automation Laboratories (800-935-4425), and a similar IR kit with source code is available from Home Control Concepts (619-693-8887).

My new project is to rework Invisibot as VideoBot for Windows and the Covex Voice Blaster, which adds voice recognition to a variety of PC sound cards. Video for Windows will bring form to VideoBot in the full-motion image of a very proper English butler, and, if I can sell my wife on the idea, a pretty French maid.—Jon Bek

50% DUTY CYCLE 555 CIRCUIT

Seeing all of the recent interest in the venerable old 555 timer circuit, and having been a 555 user since the mid-70's, I felt compelled to write. Now I can safely state that the old 555 has been outdated by its successors: the LTLC555 and the ICL7555, which are the CMOS versions of this extremely useful chip. The new chips are faster, have a wider supply range, use less current, and (probably most important) are more immune to input noise.

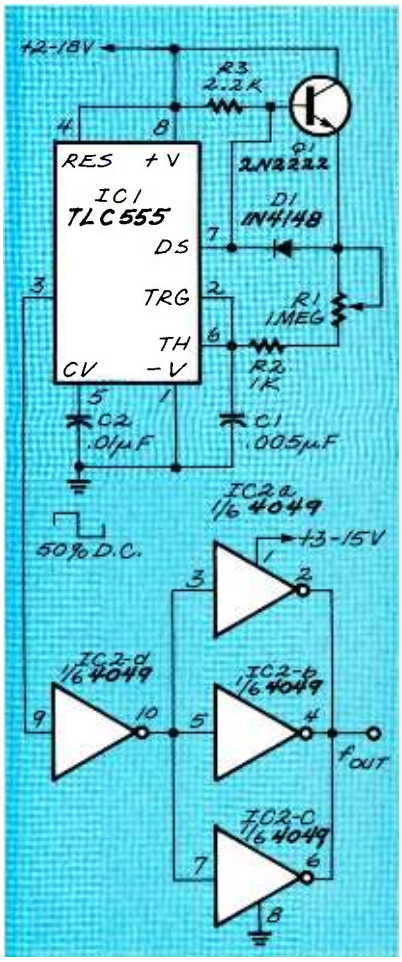

FIG. 1

I've recently seen quite a few versions of 50% duty cycle 555 circuits, all of which suffer from one of two problems: poor symmetry from loading of the output or difficult, if not impossible, variable frequency control. The one design flaw of the chip itself is that a *discharge* transistor is provided on the chip at pin 7, but there is no *charge* transistor! By adding an external charge transistor (2N2222) and one diode (1N4148), you can have 50% duty cycle with no output loading and one control for the frequency.

The simple circuit shown in Fig. 1 uses that technique to provide a continuously variable output of about 100 Hz to 100 kHz at 50%

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uty cycle. When the discharge ansistor is off, the 2N2222 acts as n emitter follower, charging C1 rough R1/R2. When the dis- harge transistor turns on, the N2222 turns off and C1 dis- harges through R1/R2 at the exact ame rate. The 1N4148 adds some emperature compensation.

The one quibble I might have bout using the CMOS 555s could e the lower output current they de- ver. It's very easy to add buffers to heir outputs, as shown in Fig. 1. ach gate of a CD4049/CD4050 an supply at least ±10mA, so you an parallel as many as you need sing one input gate to buffer the 55 output from the parallel input apacitance of the combined gates.

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South Bound Brook, NJ

DISK DENSITY

In reference to "Density Prob- ems" (*Q&A*, **Electronics Now**, August 1993), I have had to deal with that problem in the past. Not having the correct hole puncher (the one I used for my 5¼-inch Apple II disks wouldn't work), I considered drilling a hole, as you mentioned. I discarded that idea, not relishing the idea of plastic chips and dust grind- ing into the media, drive heads, and other moving parts of the drive.

Figuring I had nothing to lose, since I was unable to recover the data from the disk anyway, I heated up the old pencil soldering iron and carefully melted a hole in the appro- priate place. Apparently, it need not be as big as the square hole that the manufacturers put in, as long as it is correctly placed. That method worked like a champ, and I was able to recover my data files.

Although I have used the disks intermittently for several years, I al- ways back up the data on another disk. I am as cheap as the next guy, but first-class, big-name, high-den- sity diskettes can be purchased at department stores or warehouse- type shopping clubs for a song. Why risk losing your data for a 20- or 30-cent savings? I only use the double-density disks for my old Mac Plus, and for backing up something that will fit on a 720K disk.

JACK HARRAH
Sacramento, CA

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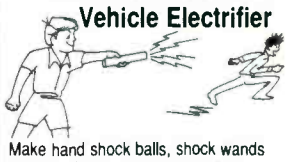

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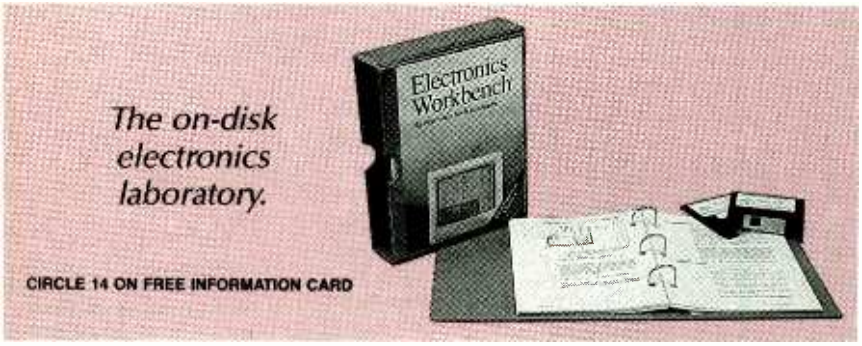
EQUIPMENT REPORTS

Electronics Workbench Circuit Simulator



Electronics is one subject that can't be learned with the help of books alone. Hands-on experience is essential for students who want to gain an understanding how components work and to become familiar with test equipment.

Unfortunately, many students lack the test equipment, power supplies, and components that are required on an electronics learning workbench. That's where the *Electronics Workbench* circuit simulator can be a real help.

Electronics Workbench Version 3.0 is produced by Interactive Image Technologies Ltd. (908 Niagara Falls Blvd., North Tonawanda, NY 14120). It allows users to build and test computer-simulated analog and digital circuits. It runs on IBM-standard PCs with an 80286 or better processor, a hard disk, 512 kilobytes of RAM, a Microsoft compatible mouse, EGA or VGA display capability, and MS-DOS 3.0 or higher. A math coprocessor is supported, but not required. Interactive Image Technologies also produces a monochrome version that will run on an XT with floppy-disk drives, and CGA or Hercules graphics capability. A version for Macintosh computers is also available.

Just as Microsoft Windows presents computer users with a "desktop metaphor," Electronic Workbench presents the user with a workbench metaphor. The main part of the screen is the workspace, which acts as the breadboard for circuit assembly. Along the right edge of the screen is a "parts bin" from which components are selected. Test instruments and program controls are along the top edge.

The program consists of separate analog and digital modules; circuits cannot combine both analog and digital components. Both operate the same way. Parts are selected with a click of the mouse, and dragged from the parts bin to the breadboard. Parts can be connected together by clicking the terminal of one, and dragging a "wire" over to the desired terminal on the other component.

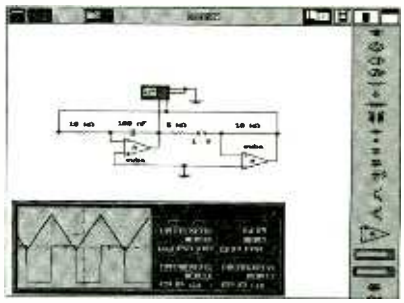
Test equipment can be dragged from the top of the screen to the breadboard and connected to the desired monitoring points in a similar manner. Double clicking on the equipment increases its size so that its front panel can be seen, and so that its controls can be adjusted. The analog module features four tools: a function generator, an oscilloscope, a digital multimeter, and a bode plotter (for frequency-response plots).

The digital module features three tools: a logic analyzer, a logic converter (which converts and simplifies logic), and a word generator (which drives circuits by producing streams of 16 eight-bit words.

The components available in the analog module include resistors, capacitors, coils, diodes, batteries, current sources, Zener diodes, op-amps, bulbs, NPN and PNP transistors, fuses, and transformers. The values of the passive components can be varied through standard ranges. To specify transistors, a number of parameters must be set, including saturation current, forward and reverse current gain, and thermal voltage. Op-amp parameters that can be adjusted include open-loop current gain, input and output resistance, bias current, and offset current. Configured components can be saved for future use.

The analog simulations are performed using SPICE algorithms. The software can be configured to analyze the transient or steady-state response of the circuit.

The digital module contains AND OR, XOR, NAND, NOR, and NOT gates. RS, JK, and D-type flip-flops are



THE ANALOG MODULE of *Electronics Workbench*. Note the parts bin along the right side of the screen and the oscilloscope's front panel near the bottom.

available, as is a half adder, seven-segment display, and an LED probe. To keep things simple, digital circuits are simulated with ideal components. Such real-world problems as fan-out limitations and propagation delays are ignored.

Electronics Workbench is an excellent tool for any student of electronics. It's certainly not a substitute for "getting your hands dirty" with real components. But in some ways, the software provides a better learning experience than a real electronics lab. Circuits can be built far faster than is possible with actual components, and errors become apparent immediately. Ω

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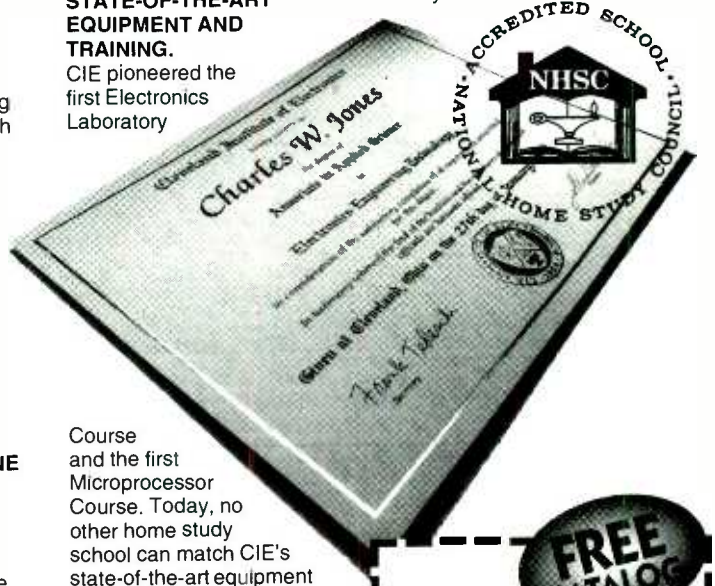

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EDC VS. PARITY CHECKING

On the parity controversy (*Q&A*, **Electronics Now**, July 1993 and *Letters*, October 1993), I have to disagree with James Bigger's letter. Long ago it was decided that parity checking just doesn't cut the mustard on "real" computers.

Error Detection and Correction (EDC) was developed to correct even multi-bit memory errors on the fly, without crashing or halting the computer. A disk log of "Correctable Errors" is normally updated each time a correctable error occurs, which can enable the maintenance personnel to replace defective memory devices later, *after* the computer has been brought to a graceful halt—with no lost data, no screaming users, and absolute data accuracy! Some of the more elaborate mainframes will even automatically re-map the memory (bypassing any memory boards that have logged errors), thus allowing board replacement without shutting the system down!

EDC does take additional memory bits and extra hardware, but with memory prices so cheap (even with the recent summer price spike), I think it is a matter of engineering malpractice that IBM and major clone makers chose not to implement EDC in their top-of-the-line PCs. After all, desktop PCs are taking on roles that would have been given to mainframes just a few years ago.

Tomorrow's denser, faster chips will probably be much more prone to "soft" errors (usually caused by background ionizing radiation). I predict that the next generation of super-fast, memory-bloated PCs will have to implement EDC, or reliability will suffer slightly.

Personally, if I had to work on an assembly line close to a big industrial PC-controlled robot, I would feel a bit safer if the PC had EDC rather than parity checking. On the other hand, the human programmer would be the most likely culprit if the robot should happen to do a Terminator II impersonation, so I would also hope that plant engineers were wise enough to install a mega-dose of watchdog timers, limit switches, safety interlocks, and other failsafe devices on Mr. Terminator.

CHARLES E. BARRETT
Flower Mound, TX

KEYING (AND SEEING) FOREIGN CHARACTERS

To answer P. Durand's question ("Foreign Characters," *Q&A*, **Electronics Now**, August 1993) concerning seeing on screen the foreign characters that he enters in his word processor, there is a simple solution.

He can simply get a hold of a memory-resident program such as Systeme Bilingue from MicoQue Inc. (C.P.40, Postal Box R, Montreal, Quebec, H2S 3K6, Canada; telephone 514-279-1597). This very useful program allows you to type in French and view exactly what you type; there is no need to enter ASCII codes. You can also toggle between the standard (English) keyboard and the French keyboard.

I hope that this is of help to P. Durand and anyone else who has the same problem.

JUSTIN LEGAULT
Sudbury, Ontario, Canada Ω

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Analog Module includes:

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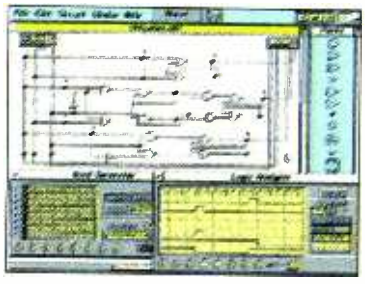
- multimeter
- function generator (1 Hz to 1 GHz)
- dual-trace oscilloscope (1 Hz to 1 GHz)
- Bode plotter (1 mHz to 10 GHz)
- SPICE simulation of transient and steady-state response



Digital Module includes:

- fast simulation of ideal components
- AND, OR, XOR, NOT, NAND and NOR gates
- RS, JK and D flip-flops
- LED probes, half-adders, switches and seven-segment displays
- word generator (16 eight-bit words)
- logic analyzer (eight-channel)
- logic converter (converts among gates, truth table and Boolean representations)

Complement Your Test Bench

Here's why Electronics Workbench belongs on *your* test bench: Wires route themselves. Connections are always perfect. And the simulated components and test instruments work just like the real thing. The instruments are indestructible and the parts bin holds an unlimited supply of each component. The result, thousands of electronics professionals and hobbyists save precious time and money. **Over 90% would recommend it to their friends and colleagues.** Electronics Workbench: the ideal, affordable tool to design and verify your analog and digital circuits before you breadboard.

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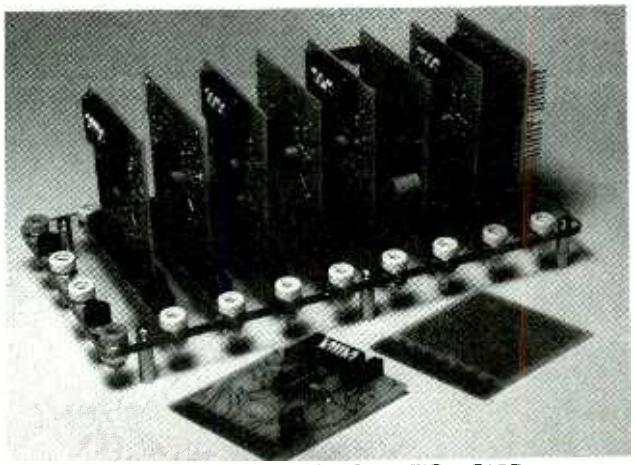
MODULAR PROTOTYPING SYSTEM. Although breadboarding remains a convenient way to check a design idea, it can be the most time-consuming stage of the design process and, if not done properly, can produce unpredictable results. Common problems with breadboarding include improper grounding, lack of flexibility, wrong size, and high cost. *Circuit Tree's Smart Pro* modular prototyping system was designed to solve those problems. The system you to build prototypes the same way as the block diagram. It provides simple analog and digital function modules that can be connected to each other through a motherboard, the same as the blocks of your diagram. With *Smart Pro*, you need only wire-wrap the inputs and outputs of the modules through the motherboard. The 4.5 × 9 × 1.2-inch motherboard is clear to allow you to easily see the connecting wires. Circuits are easy to build and troubleshoot, and they can be reused for other projects.



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Each module is built around one or more integrated circuits and can be configured through switches and/or jumpers to perform several related functions. Each fully tested and calibrated module provides stand-alone functions without the need for external clocks or voltage references. All modules have bypass capacitors for power supplies, sockets for ICs, and eyelets for additional components. The modules are built on 2.5 × 2.8-inch, double-sided PC boards with 30-pin edge connectors.

Available analog function modules include general-purpose op-amps, precision amplifiers, comparators, A/D and D/A converters, 555 timer, RMS/DC converter, function generator, peak detector, stereo amplifier, voltage reference, and data acquisition. Digital function modules include counters, comparators, contact debouncer, digital word generator, line drivers and receivers, flip-flops, multiplexers, and microcontroller. In addition, there are modules that have connectors for interfacing with PCs or microcontrollers, bus-state LED indicators, relays, and power FETs. Blank breadboards also are available for use with the *Smart Pro* system.

The *Smart Pro* mother board costs $89.99, modular function cards range in price from $29.99 to $$69.99, and blank prototyping boards cost $9.99 (one blank board is free with the purchase of five modules).

Circuit Tree
27402 Via Caudaloso
Mission Viejo, CA 92692
Phone: 714-454-2208
Fax: 714-454-1607

WAVE-TABLE SYNTHESIZER CHIPS. Ideal for applications in music keyboards, karaoke equipment, MIDI sound modules, arcade games, and PC sound boards, two wave-table music-synthesizer chips from *Crystal Semiconductor* provide CD-quality music synthesis and are compatible with the Roland General Synthesizer (GS) enhancements to the General MIDI standard. General MIDI specifies a standard set of sounds and performance capabilities that should be implemented in MIDI synthesizers, and the GS enhancements include sound variations, adjustable reverb, and chorus effects. The chips also comply with the Microsoft Windows Multimedia Extensions and are compatible with the MPC Level 2 Extended Multitimbral specification, which defines the capabilities of high-performance synthesizers in the Windows environment.

The *CS8905* is a programmable music processor well suited to cost-sensitive music synthesis and digital effects applications. It can generate up to 188 melodic timbres and variations, 91 drum effects, and 46 special-effect sounds. It can simultaneously generate up to 16 sounds or up to 16 timbres, producing a 16-bit stereo digital audio output up to 44.1 kHz.

CIRCLE 21 ON FREE INFORMATION CARD

The *CD9203* is an advanced music synthesizer that is polyphonic up to 32 simultaneous timbres, producing two 16-bit stereo digital outputs. In combination with associated parameter data, it can generate up to 191 melodic timbres and variations, 118 drum sounds, and 46 special-effect sounds.

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The two chips can be used together to create a powerful synthesizer with digital effects. A full set of development tools and software, including demonstration and evaluation boards and design data packages with complete schematic and circuit-board layout information, is available.

The *CS8905* and *CS9203* music-synthesizer chips, packaged in 68-pin plastic leaded chip carriers (PLCCs), cost $24 and $36.50 each, in quantities of 1000.

Crystal Semiconductor Corp.
P. O. Box 17847,78760
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Phone: 512-445-7222
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TV TRIGGER MATE. Oscilloscopes with built-in TV triggering are expensive and their functions are limited. An alternative for working with composite video is *Ultech's TVT601 TV Trigger Mate*, which provides a stable trigger for oscilloscopes. It can be used for developing and testing multimedia products, TV receivers, VCRs, on-screen display systems, video-editing equipment, closed captioning, cable and satellite TV systems, and video-compression devices. It also can be used to monitor video waveforms at broadcast sites, cable TV head ends, satellite uplink/downlink sites, and video production studios.

CIRCLE 22 ON FREE INFORMATION CARD

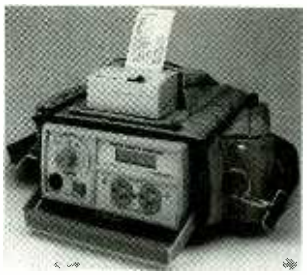
The NTSC/PAL/SECAM-compatible *TV Trigger Mate* can trigger on all fields, odd or even fields, or individual field 1, 2, 3, or 4; it can even trigger on all lines in just one field.It can sync on weak and copy-protected video and is unaffected by VCR head-switch noise. The device's blinking marker signal, available at the video output connector, flashes on a TV or monitor a pixel that corresponds to the trigger point. The marker can provide coordinates of objects on the screen such as text boxes. The *TV Trigger Mate* also provides horizontal, vertical, field, and composite sync from an incoming video signal. Those outputs are available on rear-panel BNC connectors or front-panel probe terminals.

The *TV Trigger Mate* costs $695.

Ultech Corporation
28C Great Hill Road
Seymour, CT 06483
Phone: 203-735-5805
Fax: 203-735-6653

AUTOMATIC SAFETY ANALYZER. The *SA115* universal and automatic safety analyzer from *Bapco* (an affiliate of Sencore) is the first product in a line of safety equipment aimed at the electrical, electronic-manufacturing, electronic-service, and medical markets. The analyzer tests both the power and the product to NEC, NFPA, ANSI, AAMI, CSA, and UL specifications.

The *SA115's* automatic test functions are sequenced and broken into three areas: receptacle testing, grounding-capability testing, and AC-leakage testing to 10 mA. A hot-chassis test checks the product before power is



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turned on to prevent a shock hazard to the tester, the test equipment, or the product under test.

Products can be tested with 120 or 240 VAC to 15 amps from the front panel. Current capabilities can be extended with high-current adapters. Test results are displayed on a four-digit LCD readout, or can be printed on adhesive-backed certification tape. A built-in, preprogrammed RS-232 port allows the *PR116* printer to directly print any reading, or to be interfaced with a PC to become a low-priced management system for medical or production-line tests.

The *SA115* analyzer costs $1295; the *PR116* printer costs $395; and the *CC119* carrying case, which holds the analyzer, printer, and accessory cables, costs $125.

Bapco
100 Industrial Road
Box 536
Viborg, SD 57070
Phone: 800-419-4000
Fax: 605-326-5138

DYNAMIC NOISE REDUCTION (DNR) COMPONENT. *Vista's* universal stereo *Dynamic Noise Reduction (DNR) Component* is non-complimentary and does not require encoded source material to achieve 10 dB of noise reduction from virtually any line-level source material—disc, FM or TV broadcast, and tape.

The device should be installed after any signal preamplifiers and before any volume-control or tone-control circuits. Because the DNR can handle line-level signals from 300 mV rms to 3 V rms, a good location is at the tape-monitor inputs and outputs. It also can be installed at the line output of a stereo TV to hi-fi amplifier to improve the quality of the audio.

CIRCLE 24 ON FREE INFORMATION CARD

Once installed, only one adjustment is required. An LED bargraph display shows instantaneous bandwidth from 1–35 kHz. A front-panel switch allows A/B comparison of the DNR's effectiveness to be made by forcing the bandwidth open to 50 kHz.

The *Dynamic Noise Reduction Component* has a suggested list price of $139. (DNR is a registered trademark of National Semiconductor Corp.)

Vista
Box 1425
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440-MHz HAND-HELD TRANSCEIVER. Designed "by hams for hams," the *Realistic HTX-404* 440-MHz UHF/FM hand-held transceiver is aimed at both the newly licensed Technician-class user and the more experienced ham. The radio offers rugged construction, easy operation, and performance that rivals a full-sized mobile transceiver. A selective 440-MHz-band receiver front end minimizes intermodulation interference, and true FM modulation provides a clearer voice signal and superior packet

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performance. The *HTX-404* features a high-capacity rechargeable battery pack and an AC charger; 5-watt operation when powered by 13.8 VDC power; a high/low RF power switch; and built-in subaudible tone (CTCSS) encoder and decoder and touch-tone (DTMF) encoder and pager. Five 15-number touch-tone sequences and 16 frequencies can be stored in memory. The radio offers multifunction scanning with user-programmable frequency steps.

The *Realistic HTX-404* hand-held transceiver (Cat. No. 19-1202) is available for $299.99 at Radio Shack stores nationwide.

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The device has a maximum measurement range spanning 0 to ±50 g, single +5V operation, and complete self-test on command, including testing of the sensing element. The ADXL50 offers a fully

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scaled, conditioned 19-mV/g analog output. An internal buffer amplifier allows the user to alter sensitivity and set the zero-g level.

Currently available are the *ADXL50JH* (temperature range 0°–+70°C, typical 0-g bias drift ±45 mV) and the *ADXL50AH* (−40°–+85°C, ±60 mV), which cost $39 and $55, respectively. Soon to become available are the *ADXL50KH* (0°–+70°C, ±10 mV) and the *ADXL50BH* (−40°–+85°C, ±25 mV), priced at $70 and $77.

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Electronics Grade Chemicals, Materials & Supplies Catalog. Chemtronics Inc., 8125 Cobb Center Drive, Kennesaw, GA 30144; Phone: 404-424-4888.

Several new specialty products for the electronics industry, including many that are CPC-free or have little or no potential to damage the ozone layer, are featured in Chemtronics' latest catalog. A special section clearly spells out the new "CFC Labeling Rule" (EPA Rule 40 CFR Part 82, requiring labeling of products made with ozone-depleting substances), along with the implications of that rule for electronics manufacturers and servicers. Also new to the catalog is a section on adhesives and sealants that are packaged to provide maximum convenience and flexibility in repair and field-service applications. Color-coded icons clearly identify product categories, and cross-reference information helps users match older products to the new alternatives. The catalog also contains detailed applications and compatibility charts designed to help users more closely match specific needs with the right products as well as complete information on the environmental impact of products.

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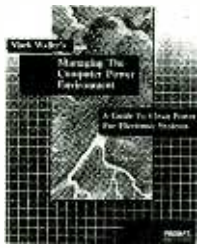
Mark Waller's Managing the Computer Power Environment: A Guide to Clean Power For Electronic Systems; by Mark Waller. Prompt Publications, 2647 Waterfront Parkway, East Drive, Indianapolis, IN 46214-2012; Phone: 800-428-7267 or 317-298-5710; Fax: 317-298-5604; $19.95.



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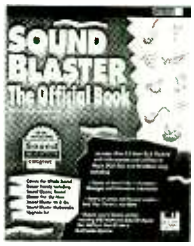
For error-free operation, every computer system requires clean power. Unfortunately, as electricity travels from the utility company to your home or office, noise, surges, static, and a host of other problems that can seriously affect computer performance and data security are introduced. This book, written for data-processing specialists, technicians, field engineers, and computer-network professionals, provides the background in electrical technology that will help you understand and control the quality of the power that drives your computer system. The book covers basic electricity, with an elementary lesson on electrical power and its physics; the difference in quality between what your computer needs and what the power company provides; the effect of buildings on power and your computer, effective solutions to the threats of lightning, static, and noise; practical ways to ensure protection with surge-suppression devices and grounding; and standby power systems. A full glossary and an index are included.

Sound Blaster: The Official Book; by Richard Heimlich with David M. Golden, Ivan Luk, and Peter M. Ridge. Osborne McGraw-Hill, 2600 Tenth Street, Berkeley, CA 94710; Phone: 510-549-6600; Fax; 510-549-6603; $29.95, including 3.5-inch disk.

Covering Creative Lab's entire family of sound cards—including Sound Blaster, Sound Blaster Pro, the new Sound Blaster 16, and the Sound Blaster Multimedia Kit—this book-and-diskette set contains all you need to know to get the most out of your sound card and have fun doing it. The book provides complete instructions for hardware and software installation, as well as troubleshooting tips for solving joystick problems, interrupt conflicts, volume troubles, and the like. There is a thorough discussion of the features and functions of all the software included in the Sound Blaster family. Creative Lab's top technical support staff divulge the answers to most-often-asked user questions, and offer tips and tricks to enhance your recording and playback, including the inside scoop on sampling, microphones, and programming.



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The book also features a survey of, and buying tips for, selected speakers and third-party software for Sound Blaster, as well as coupons for special deals on third-party products. The included diskette contains top-notch utilities such as SPUTMON and BLASTER Master, along with dozens of sound files, songs, and musical jingles.

Your Packet Companion; by Steve Ford, WB8IMY. The American Radio Relay League, 225 Main Street, Newington, CT 06111; Phone: 203-666-1541; Fax: 203-665-7531; $8.

Packet radio, a form of digital communication between one computer system and another, can be an exciting hobby, but beginners are often confused by packet technology and operating styles. Written specifically for Amateur Radio operators who are exploring packet radio for the first time, this book cuts through the jargon with clear, easy-to-understand explanations. The book describes how packet operates and provides details on how to set up a basic packet station, enjoy conversations with other amateurs, and access a variety of information.

The book also shows

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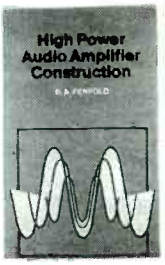

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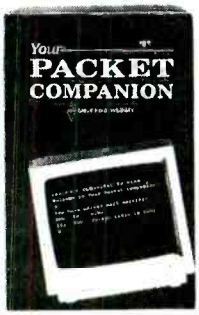

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readers how to use the automated bulletin boards that form the hubs of most packet networks, including how to send and receive mail, send bulletins, and access many other useful features. Specialized networks, such as DX PacketClusters, are discussed in detail.

To tempt readers to explore packet even further, the book offers glimpses of network alternatives such as ROSE, TCP/IP, and TexNET. Readers also are shown how to use the many Amateur Radio packet satellites now in orbit. Informative tables and sidebars appear throughout the book.

1994 Catalog. Radio Shack, 700 One Tandy Center, Fort Worth, TX 76102; $2.95 at local Radio Shack stores nationwide.

This 196-page, full-color catalog contains more than the usual product and pricing information. For the first time in its 44-year history, the catalog includes money-saving coupons on single-item purchases of $3 and $15 and more, 10% off any item marked "new" in the catalog, and 10% off any Tandy Service Plan. In addition, the brochure features easy-to-understand explanations of the features and technologies used in many items, and convenient definitions of "buzzwords" in many product categories. The largest Radio Shack catalog ever printed, the 1994 edition includes quick-index glossaries and color-coded pages to easily identify such product categories as audio, video, telephones, communications, automotive, do-it-yourself, home and family, computers, "just for fun," and calculators. In each category, easy-to-read charts match products feature-by-feature for quick comparison shopping. Close to 500 new products are featured, including the Optimus Professional Series of audio equipment, the country's first digital Compact Cassette (DCC) recorder, a line of Optimus home-theater components, two Tandy multimedia personal computers, and the Tandy Z-PDA Personal Digital Assistant.

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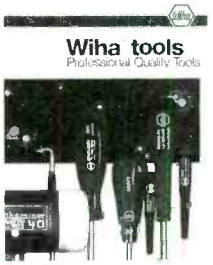
Wiha Professional Quality Tools Catalog. Willi Hahn Corporation, Box 660, 1400 East Broadway, Monticello, MN 55362; Phone: 800-328-8310 or 612-295-5500; Fax: 612-295-4440; free.

This 24-page, full-color catalog details the Wiha line of professional-quality hand tools, including screwdrivers, T-handles, bit selectors, dead-blow hammers, awls, screw-holding screwdrivers, and a magnetizer/demagnetizer. Also included are the complete line of Torx tools. Wiha also offers insulated tools that meet all necessary standards and are certified to 1000VAC/1500VDC. New products include a 6mm reversible blade with either a ratcheting or a power handle. Those blades also are available in slotted, phillips, Supradriv, hex/ball, nutdrivers, Torx, and slotted/phillips.



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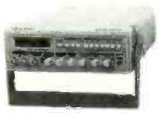

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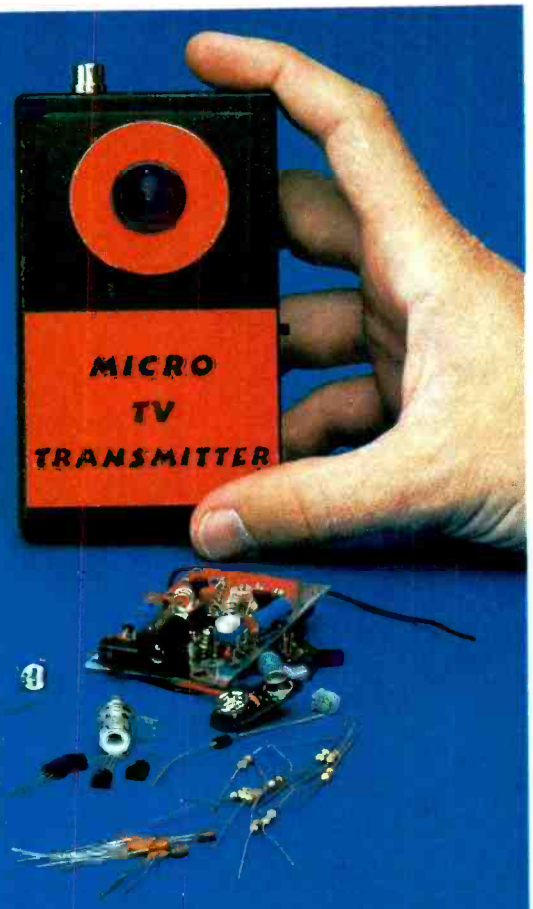

This wireless mini video transmitter sends a picture to your TV set. It's ideal for security monitoring or observing nature.

MARTIN MCKINNEY & GARNET BRACE

THE MINIATURE SINGLE-BOARD VIDeo camera used in this project is an excellent example of how recent advances in integrated circuit and surface-mount technology have led to remarkable advances in video technologies. A complete, reasonably priced solid-state camera will easily fit in the palm of your hand.

This article describes how you can build a simple modulator/transmitter and connect it to a commercially available video camera to obtain a portable, battery-operated camera that can transmit black and white pictures from remote locations back to your TV set. No antenna is needed to transmit to a nearby TV set, but if an external antenna is used, the modulator has enough power to transmit about 100 yards. The RF modulator/transmitter can transmit over standard NTSC channels 7 to 13 or UHF channels 14 to 29.

The mini video camera on which this project is based measures 0.91 × 1.81 × 2.76 inches and it weighs only 1.3 ounces. The camera requires a 6- to 12-volt DC power supply, and draws a current of only 65 milliamperes.

The applications for a battery powered, hand held TV transmitter are limited only by your imagination. Home or business security come most readily to mind. Because cables are unnecessary, there is no danger of an intruder cutting cables and disabling the camera. The camera can be placed in an unobtrusive location protected from the weather.

You can also use this camera transmitter to keep an eye on an infant in a crib or observe a disabled or bedridden person. And you could also put this camera to work as the "eyes" of a robot or for monitoring industrial welding or machining operations that would pose a safety threat to people standing too close.

If you are a farmer, you can monitor the behavior of livestock in a barn, and if you're a nature hobbyist, you can observe wild animals and birds at close range. The ability of the camera to "observe" action in reduced light will be particularly attractive.

The camera/transmitter system can be powered from an AC to DC wall-mounted adapter, or it can be powered from a standard 9-volt battery. The service life of an alkaline-manganese battery is approximately four hours.

Camera modules with several different configurations are available from the source given in the parts list. One is a super wide-angle (110° field-of-view) 3-mm, *f*1.8 lens; the other is a narrower angle (78° field-of-view) 4.3-mm, *f*1.8 lens. A 12-mm, *f*1.8 lens is available for those interested in aerial or nature photography. This camera, when placed behind the viewfinder of a single-lens reflex (SLR) still camera, will accept the full field-of-view of the still camera lens and permit remote

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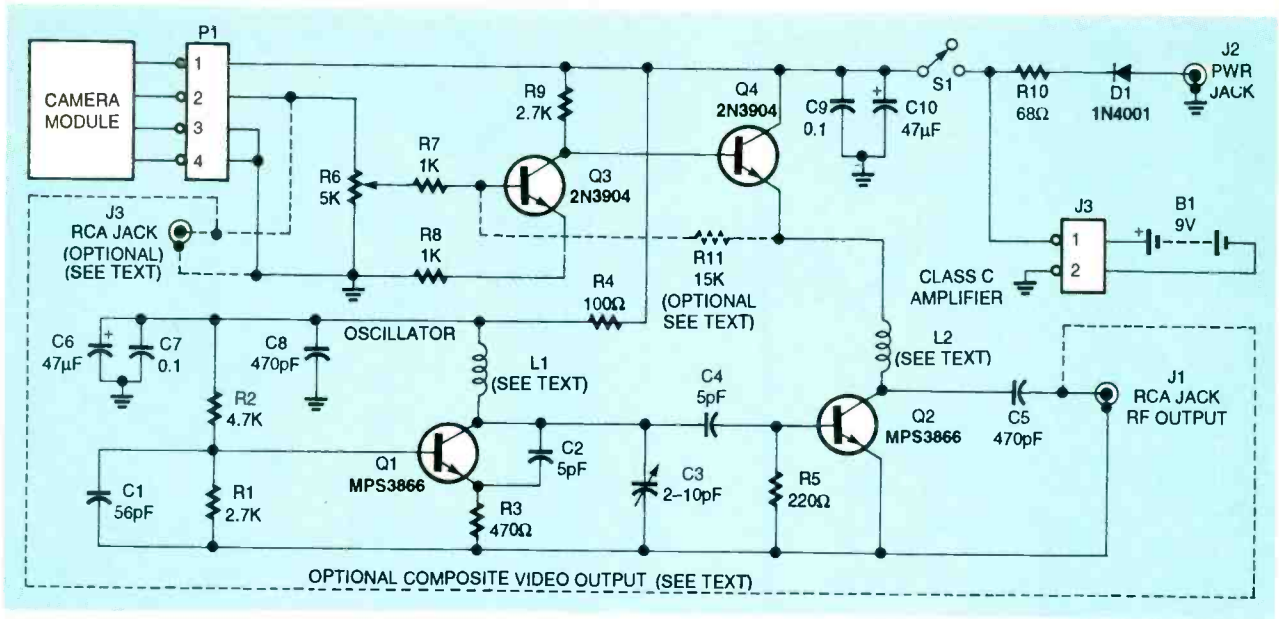


FIG. 1—MODULATOR SCHEMATIC. Coil L1 is the key component that determines the frequency of oscillation.

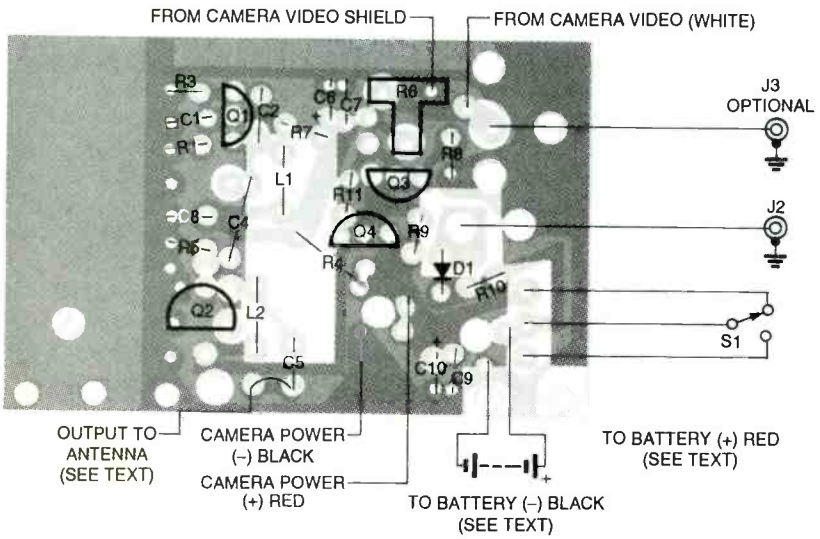
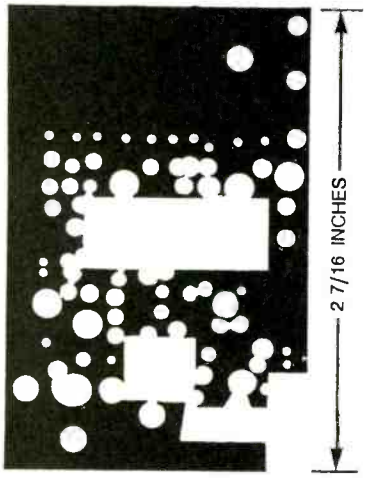
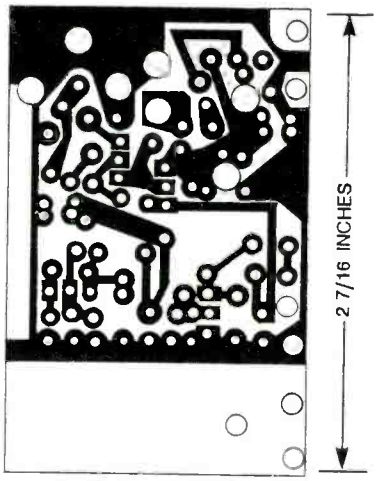


FIG. 2—PARTS-PLACEMENT DIAGRAM. Note that the board can be cut, if needed, to fit in a smaller case.



SOLDER SIDE of the board.



COMPONENT SIDE of the board.

monitoring of the picture to be taken.

The CCD mini camera is also sensitive to infrared (IR) radiation, and when paired with a simple infrared light source, can be used to see in the dark. For robotic or industrial applications, a single infrared-emitting LED emits enough energy to illuminate nearby objects.

The modulator is built on a 2¼ × 1½-inch printed-circuit board, which is mounted on insulating standoffs above the camera module. A wiring harness and plug connect the camera to the modulator.

Modulator operation

The schematic of the transmitter is shown in Fig. 1. The circuit operates as follows: Transistor Q1 is the amplifier in a transistor oscillator that oscillates in the frequency range of VHF channels 7 to 13 (174 to 216 MHz) or slightly above (250 MHz), depending on the desired transmitter frequency. The output from the resonant tank circuit of the oscillator, formed by coil L1 and capacitor C3, is capacitively coupled by C4 to the base of the Class-C amplifier stage that includes Q2.

The combination of L2 and the parasitic capacitance of the PC board broadly tunes the output of Q2 to either the same range of frequencies as the os-

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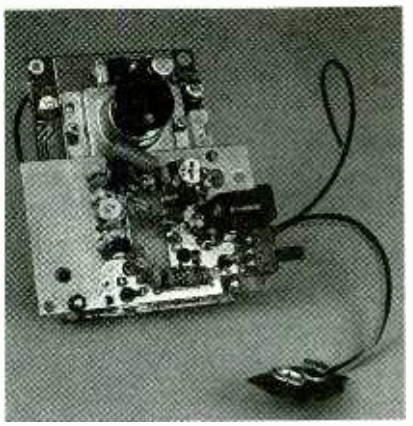
cillator stage, or to a frequency that is twice that of the oscillator stage, which permits the transmitter to cover Channels 14 to 29 (470 to 580 MHz).

The Class C amplifier stage is collector-modulated by a two-transistor modulator that consists of Q3 and Q4. The output from the camera is directly coupled to Q3 through variable resistor R6. The ratio of resistors R9 and R8 in the collector and emitter circuits of Q3 determines the gain of approximately three for this stage. The output of the camera is an NTSC composite video signal of approximately 2 volts peak-to-peak amplitude with a 0.7 volt DC offset. The output of Q3 is directly coupled to emitter follower Q4, which collector-modulates the Class C output stage.



THE MODULATOR BOARD after being mounted on the video camera module.

The modulator has been designed to work primarily with the camera described, but it can also be used as a modulator for any composite video device. This is accomplished by changing the value of R9 from 2700 ohms to 4700 ohms, thus increasing the gain of the input stage and adding 15 K resistor R11, which removes the DC offset from the amplifier stage. Provision has been made on the modulator printed circuit board to add an optional right-angled RCA connector that can provide baseband video output or accept baseband video input when the modulator is used with other devices.

Diode D1 and resistor R10 form a simple battery-charger circuit. Diode D1 also protects the camera from reverse voltage should a charger with the wrong polarity be connected accidentally.

PARTS LIST

All resistors are ¼-watt, 5%, unless otherwise specified.

R1, R9—2700 ohms (see text)
R2—4700 ohms
R3—470 ohms
R4—100 ohms
R5—220 ohms
R6—5000 ohms, potentiometer
R7, R8—1000 ohms
R10—68 ohms
R11—15,000 ohms (see text)

Capacitors

C1—56 pF, ceramic disk
C2, C4—5 pF, ceramic disk
C3—2 to 10 pF trimmer
C5, C8—470 pF, ceramic disk
C6, C10—47 µF, 16 volts, aluminum electrolytic
C7, C9—0.1µF, ceramic disk

Semiconductors

Q1, Q2—MPS3866 NPN transistor
Q3, Q4—2N3904 NPN transistor
D1—1N4001 rectifier diode

Other components

L1—3 turns tinned bus wire wound on a 3/16-inch drill bit for channels 7–13 OR 2 turns tinned bus wire wound on a 3/16-inch drill bit for channels 14–29 (see text)
L2—Same as L1 (see above)
J1—Bulkhead-mounted RCA jack (optional)
J2—2.1 mm DC power jack
J3—right-angle RCA jack (optional)
S1—SPDT miniature switch
Miscellaneous: CCD Camera Module (Chinon CX-102), PC Board, plastic case, 9-volt alkaline battery, hardware, 5/16-inch nylon standoffs, ½-inch No. 2-56 screws and nuts, coaxial cable, wire, solder.

Note: The following items are available from Bayview Hobby Supplies, 14800 Yonge St. #110, Aurora, Ontario, Canada L4G 1N3. Tel: (416) 713-0528. Fax: (416) 841-4436:

- **Camera module including wiring harness—$229.00 (specify Model M100W with wide angle 3 mm lens and 110 degree field of view or Model M100N normal angle 4.3 mm lens and 78 degree field of view)**
- **Modulator PC board (M200)—$12.95**
- **Drilled plastic case (M201)—$14.95**
- **9-volt AC wall adapter (M202)—$14.95**
- **Modulator kit (M300)—$49.95**
- **Completed modulator (M301)—$99.95**
- **Kit including camera module, all parts, hardware, and case (M400)—$299.00**
- **Semi-kit, includes camera module and fully assembled and tested modulator board (M401)—$329.00**
- **Completely assembled and tested camera and modulator mounted in case (M402)—$349.00**

All prices in U.S. funds.

Construction

A complete modulator circuit board can be purchased from the source given in the parts list. However, foil patterns are provided for those who want to make their own. Note that the circuit board stock is 0.031-inch thick glass-epoxy with copper foil on both sides. (Paper-based PC boards should not be used at the high frequencies produced in this circuit).

Certain parts of the ground-plane foil on the component side of the board must be removed to provide insulated surfaces for some components. See the parts-placement diagram in Fig. 2.

Mount all components on the non-solder ground-plane side of the board. Mount all resistors vertically after forming the leads. Mount all disc capacitors as close as possible to the ground plane. Both electrolytic capacitors are mounted horizontally and their axes lie parallel to the surface of the board.

Begin by mounting the shortest components first. Start first with the variable capacitors, variable resistor, and the ceramic disc capacitors. Then add the transistors, resistors, and coils.

Although there are no critical component positioning requirements, take special care when installing the transistors. They look alike, but the circuit will not work if they are acciden-

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tally interchanged. Capacitor C8 is an RF bypass capacitor that forms part of the tank circuit. Its leads should be as short as possible.

Coil L1 is a 2- or 3-turn coil (depending on the output frequency selected) of No. 22 AWG tinned wire wound on an 3/16-inch drill bit. The coil, in conjunction with variable-capacitor C4, determines the oscillator frequency. This frequency is in the range of 174 to 216 MHz for channels 7 to 13, or 235 to 280 MHz for channels 14 to 29. (The oscillator frequency is doubled to 470 to 560 MHz in the Class C stage for the higher channels). Diode D1 should be mounted with its anode closest to power jack J2.

After all components are soldered, install the battery clip, wiring, and plug for the TV camera module. These wires enter from a hole in the bottom of the board to provide strain relief, and they are soldered after insertion into holes in the top of the board. The modulator can be operated without an antenna but, if longer range is desired, an antenna can be connected to output capacitor C5 (see options section).

Alignment

When the board components have been assembled and soldered, check the current drain with the modulator connected to a 9-volt supply. The current drain should be about 25 milliamperes, and should drop to about 10 milliamperes when the main oscillator is inhibited (which is accomplished by touching L1 with a finger.) This simple test indicates that the oscillator is functioning and the Class C stage is amplifying.

After testing, mount the finished modulator board above the camera module with two 5/16-inch long nylon standoffs and two ½-inch long No. 2-56 screws and nuts.

After mounting the modulator board, the camera plug can be connected. At this time, check the current drain again. With the camera connected, the drain from a 9-volt supply should be about 85 milliamps.

With a television receiver tuned to the desired channel near the completed unit and power applied to the camera and modulator, tune C3 until a video image appears on the screen. Turn R6 clockwise to a position that gives a picture with maximum contrast and no "tearing."

If no video image appears on the screen after all other possible sources of assembly error have been eliminated, adjust L1 by separating its turns to raise the output frequency or compress the turns to lower the frequency. When using video sources other than the camera, it will be necessary to change R9 from 2.7K to 4.7K to increase the gain of the modulator. Also add the 15K resistor R11 to eliminate DC offset.

Once these adjustments are made, mount the completed unit in the plastic case and fasten the back in position with four self-tapping screws.

There is no voltage regulation to compensate for battery-voltage variation. The resistor values in the oscillator section have been selected so that the oscillator exhibits a minimum frequency shift over the usable battery range.

Options

Provision has been made in this design to offer the user a number of options to give the camera extra versatility.

- **Frequency.** The modulator is designed to operate either on Channels 7 to 13 or 14 to 29. For Channels 7 to 13, coils L1 and L2 are three turns of No. 22 wire wound on a 3/16-inch form. For Channels 14 to 29, coils L1 and L2 are *two* turns of No. 22 wire wound on a 3/16-inch form.
- **Enclosure**. You might want to mount the unit in its own enclosure such as a picture frame or lamp for surveillance. The modulator board can be mounted to the camera without modification, or it can be cut with shears along line A-A to make it smaller.
- **RCA Input/Output Jack**. Provision has been made on the PC board for a right-angle RCA jack. (Note that the board will not fit in the case pictured if this option is selected.) This option provides composite baseband output from the RCA jack, or composite video can be introduced to the jack from an external source.
- **Wall Adapter**. The camera unit can be powered from any negative ground (positive tip) 9-volt wall adapter. When a wall adapter is used, the battery should be removed. Be sure that the output of the adapter does not exceed 12 volts.
- **Rechargeable Battery**. A rechargeable nickel-cadmium battery can replace the suggested alkaline battery, although battery life will only be about half as long (two hours instead of four hours) before the battery needs a recharge. Resistor R10 has been selected to recharge the battery in approximately four hours. Many rechargeable 9-volt batteries actually have terminal voltages of 7.2 volts and will charge at a higher rate. Most wall-mounted chargers are poorly regulated and their voltage rises dramatically when lightly loaded. Make sure that the battery does not overcharge.
- **RF and Baseband Output**. For short range use (up to 30 feet), no antenna is necessary as long as there is an adequate antenna on the TV receiver. For longer range, a 1 foot length of No. 18 stranded copper hookup wire can be connected to output capacitor C5 and extended through the case. If you want both baseband output and RF output, an optional RCA jack can be mounted on the front panel of the case and the output from C5 can be connected to it by a short length of wire.

A length of coaxial cable from the camera harness can be connected from the jack to the camera output on the modulator board. (The cable effectively blocks RF from getting back into the camera.)

If you want baseband output, an RCA plug and cable inserted into the jack will provide composite video output to a video monitor. If you want RF output, an antenna can be inserted into the RCA jack. Ω

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HIGH TECH XMAS ORNAMENTS

Add an electronics theme to your Christmas decorating with the Visible Components.

RON HOLZWARTH

CHRISTMAS WOULDN'T SEEM COMplete without at least one electronics project to add a little holiday spirit. This year, build the Visible Components, three light-up ornaments that take on the appearance of three common component symbols: a resistor, capacitor, and inductor. The Visible Components, and definitely worth adding to your Christmas ornament collection.

The Visible Components are surefire conversation pieces, and they are a great way to show off your Christmas spirit. After the holidays are over, the ornaments can decorate your workbench, office, or automobile, letting everyone know about your interest in electronics.

Flash patterns

Each visible component has several LEDs that light up in the pattern of the actual component's schematic symbol. But rather than each visible component having a simple flashing, alternating, or light-chasing illumination pattern, each one lights up in a way that mimics that component's operation in an actual circuit. Let's see exactly what that means.

In an actual resistor, current moves at a constant rate through the component. In other words, the component has a linear I-V relationship. That is represented on the visible resistor by having light sweep through the LEDs at a continuous rate for three cycles and then turning off. The cycle then repeats again after a few seconds. The number of cycles during which light sweeps through the LEDs can be varied by changing certain component values.

Resistors do not store energy in an electric field, as do inductors and capacitors. To illustrate that, no LEDs are on during the off state.

A capacitor can store electrical energy while in a static state. This is illustrated on the visible capacitor by having the six LEDs that represent the lower plate of the capacitor remain lit during the off cycle. After a few seconds, the bottom plate dims completely and the top plate then lights. The following clock cycles successively turn off the outer LEDs of the top plate, and the bottom plate begins to light again indicate a buildup of charge.

The visible inductor has two display sections, the coil itself and the leads. An electromagnetic field striking the coils of the inductor is illustrated by sweeping the ten coil LEDs sequentially.

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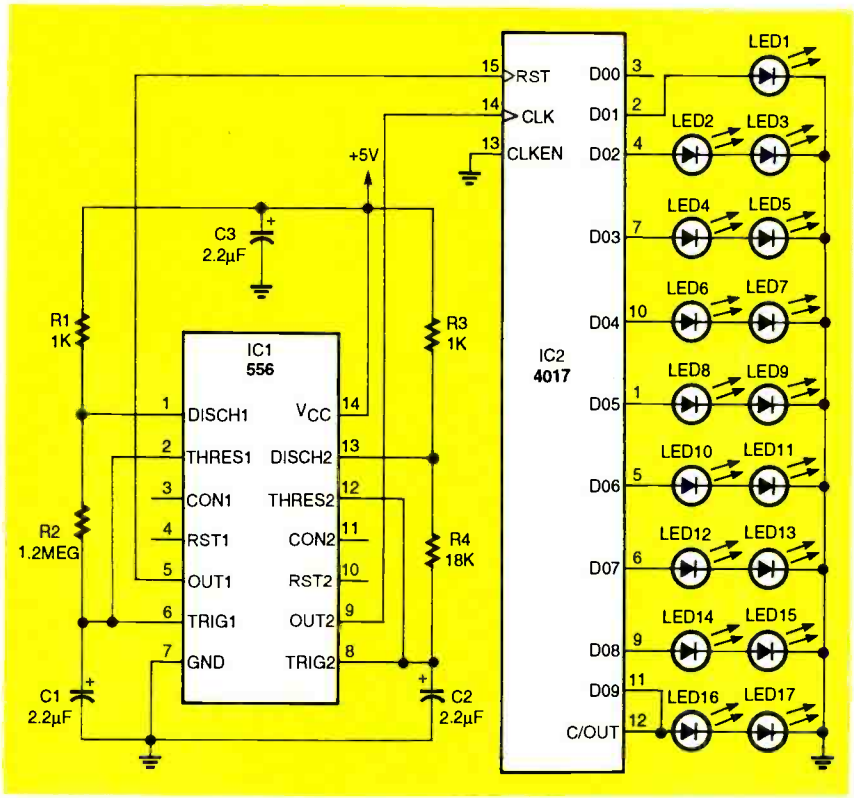

FIG. 1—VISIBLE RESISTOR SCHEMATIC. This circuit drives 17 LEDs in a pattern that represents current flow through a resistor.

Circuitry

All three visible components share some common circuitry. Each is controlled by an LM556 dual timer IC and a CD14017 decade counter. Also, all three can be powered from a single 12-volt DC wall transformer. For the sake of discussion, we'll first examine the visible-resistor circuit shown in Fig. 1.

The reset time is controlled by one timer, IC1-a, whose timing components are C1, R1 and R2. The clock cycle time is set by the other timer, IC1-b, which uses timing components C2, R3, and R4.

The electrical differences between the visible components are the manners in which the decade counter is controlled by reset timer IC1-a.

In the visible resistor, the output at IC1-a pin 5 is connected to the RESET input (pin 15) of the decade counter (IC2). As long as the RESET line is held high, IC2 will not cycle and will keep pin 3 high. Since there is no LED connected to pin 3, no LEDs will be

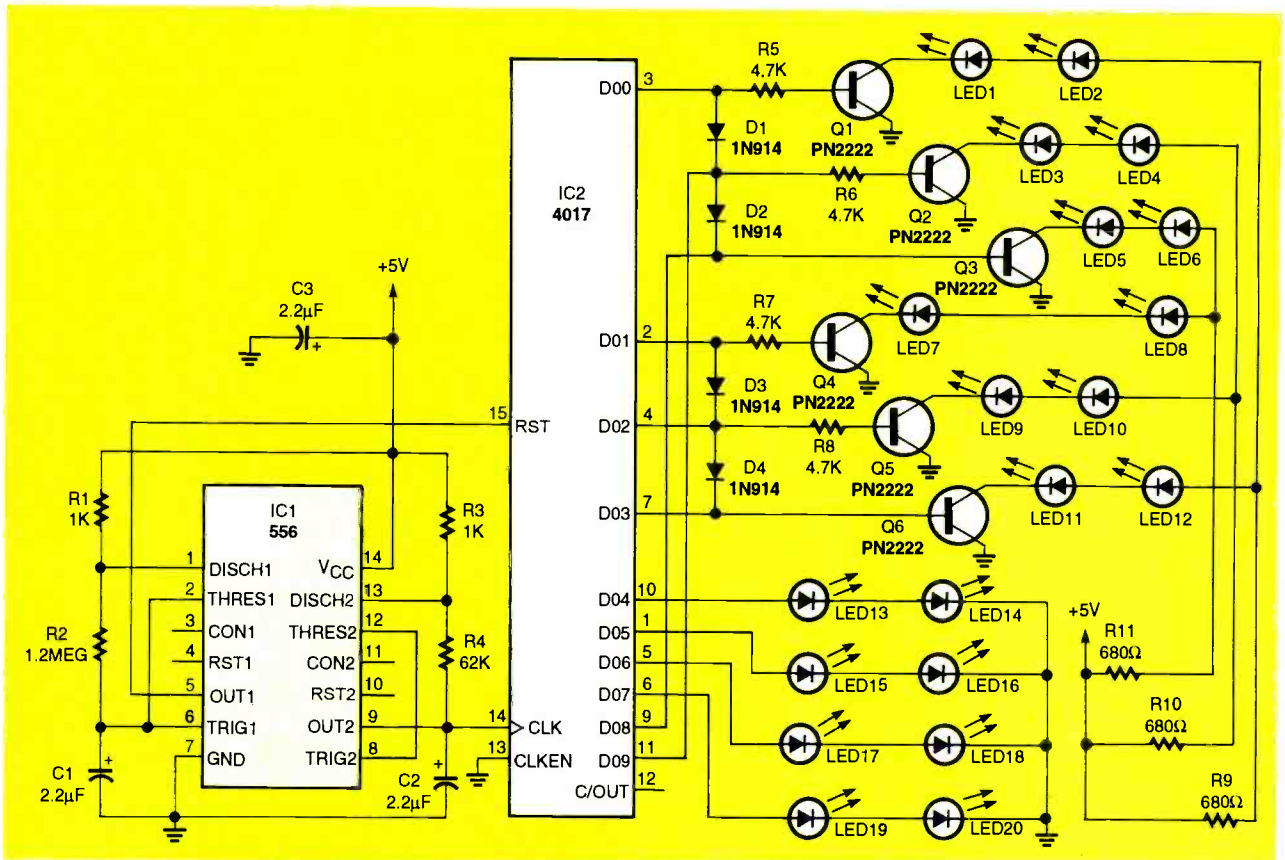

FIG. 2—VISIBLE CAPACITOR SCHEMATIC. This circuit drives 20 LEDs that are laid out in the pattern of a capacitor symbol.

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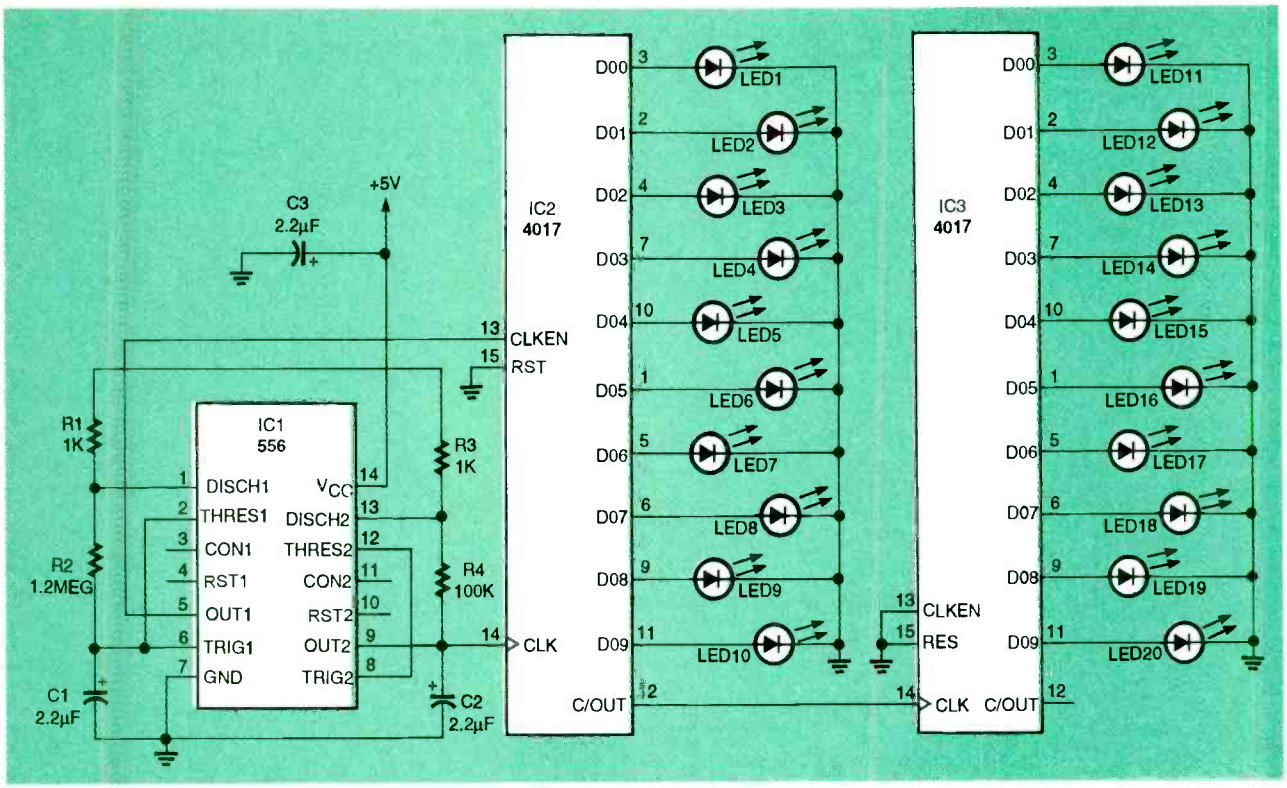

FIG. 3—VISIBLE INDUCTOR SCHEMATIC. The 20 LEDs in this circuit represent the coils of an inductor.

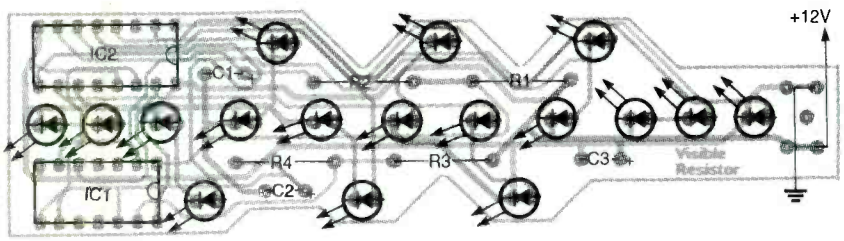

FIG. 4—VISIBLE RESISTOR PARTS PLACEMENT. The LEDs can be mounted on either side of the board as long as the cathode side points toward the power-supply leads.

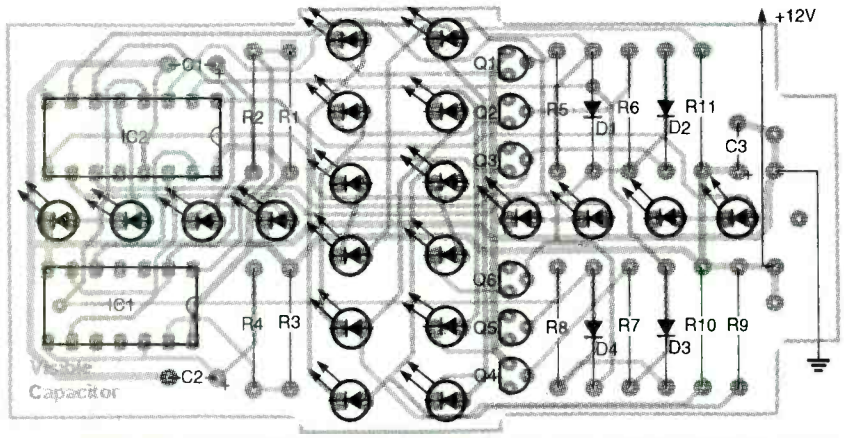

FIG. 5—VISIBLE CAPACITOR PARTS PLACEMENT. You can choose whatever colors you like for the LEDs.

on at this point. When RESET goes low, IC2 will begin its count and repeat until it is again reset.

On the visible capacitor, shown in Fig. 2, pin 3 of IC2 is connected to the base of Q1 (through R5) and also the anode of D1. When pin 3 is high, Q1 will turn on, lighting LED1 and LED2. Each of the current-limiting resistors (R9–R11) are shared by two sets of two LEDs on different sides of the visible-capacitor plate. The ¼-watt resistors are sufficient because they have to supply current to only one set of LEDs at any time.

Steering diode D1 directs current to the base of Q2 and Q3, so that they also light their respective LEDs when one output is high. The diodes prevent illumination of adjacent LEDs, so that the outer LEDs are extinguished as the clock counts continue. The diodes are reversed for the other capacitor plate so that the LEDs illuminate from the center outward.

On the visible inductor, shown in Fig. 3, the IC1-a output (pin 5) controls the CLOCK ENABLE input (pin 13) of IC2. Since IC1-a's RESET line is never pulsed high, the LEDs stay in the state they were in when the CLOCK ENABLE input went high. The CARRY output of IC2 (pin 12) provides the clock signal for IC3. Each complete cycle of IC2 results in the advancement of only one output of IC3, and so 99 steps are required for IC3 to make a complete cycle.

Timing resistors included in

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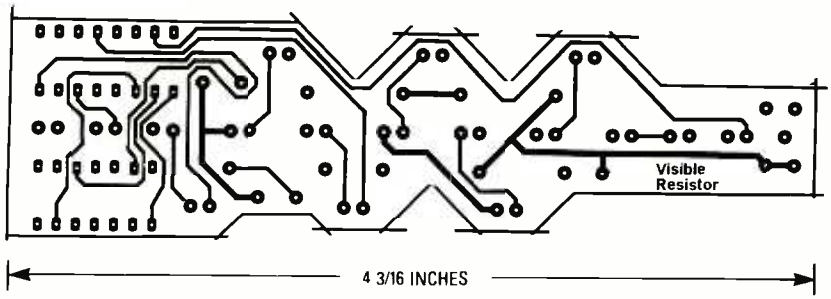
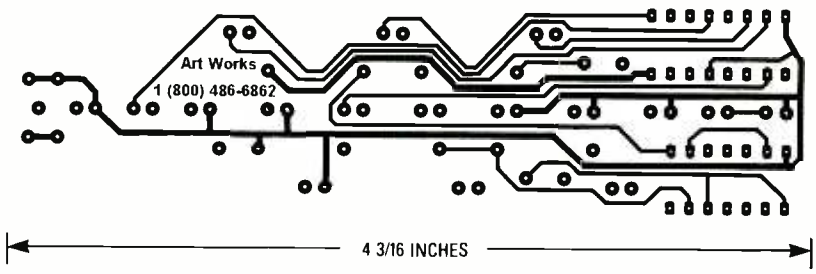
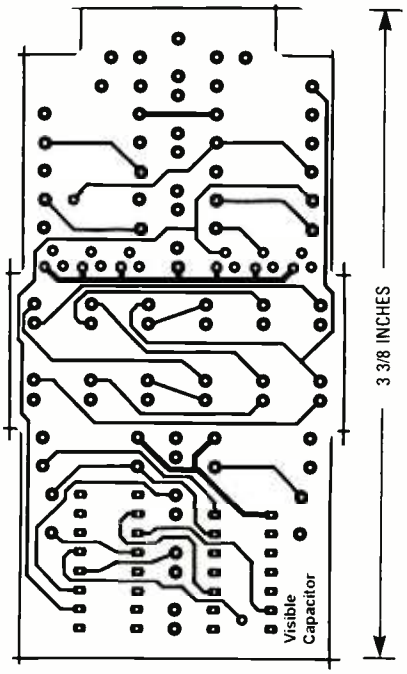


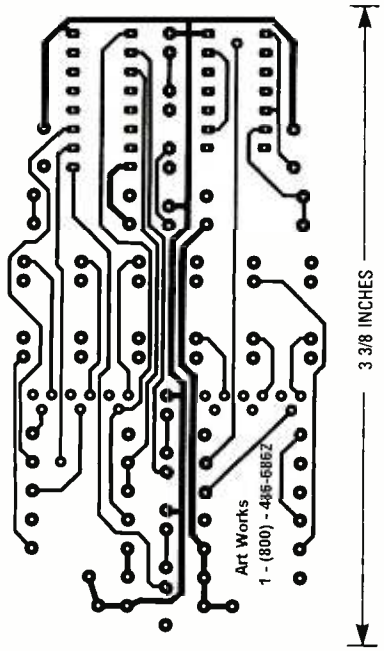
VISIBLE RESISTOR component side.



VISIBLE RESISTOR solder side.



VISIBLE CAPACITOR component side.



VISIBLE CAPACITOR solder side.

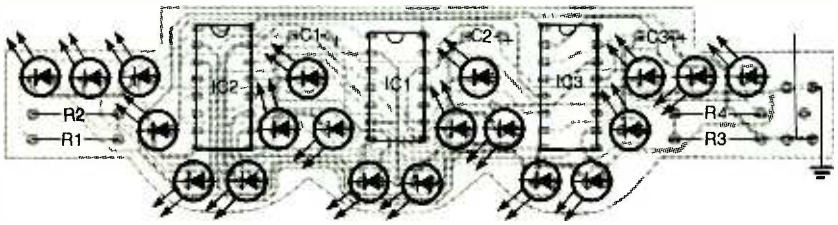


FIG. 6—VISIBLE INDUCTOR PARTS PLACEMENT. Mount the LEDs last, so they're not in your way when installing the other components.

VISIBLE RESISTOR PARTS

R1, R3—1000 ohms, ¼-watt, 5%
R2—1.2 megohms, ¼-watt, 5%
R4—18,000 ohms, ¼-watt, 5%
C1–C3—2.2 µF, 25 volts, tantalum
IC1—LM556 dual timer
IC2—CD14017 decade counter
17 LEDs (any color), 12-volt DC 300-mA wall transformer (one is sufficient to power all three visible components), PC board, wire, solder

VISIBLE CAPACITOR PARTS

R1, R3—1000 ohms, ¼-watt, 5%
R2—1.2 megohms, ¼-watt, 5%
R4—62,000 ohms, ¼-watt, 5%
R5–R8—4700 ohms, ¼-watt, 5%
R9–R11—680 ohms, ¼-watt, 5%
C1–C3—2.2 µF, 25 volts, tantalum
IC1—LM556 dual timer
IC2—CD14017 decade counter
D1–D4—1N914 diode
Q1–Q6—PN2222 NPN transistor
20 LEDs (any color), 12-volt DC 300-mA wall transformer (one is sufficient to power all three visible components), PC board, wire, solder

VISIBLE INDUCTOR PARTS

R1, R3, R4—1000 ohms, ¼-watt, 5%
R2—1.2 megohms, ¼-watt, 5%
C1–C3—2.2 µF, 25 volts, tantalum
IC1—LM556 dual timer
IC2, IC3—CD14017 decade counter
20 LEDs (any color), 12-volt DC 300-mA wall transformer (one is sufficient to power all three visible components), PC board, wire, solder

ORDERING INFORMATION

Note: The following items are available from Art Works, 415 E. Emerson Street, St. Francis, Kansas 67756:

- **PC board for any single visible component (specify choice of resistor, capacitor, or inductor)—$12.00**
- **Set of three visible component PC boards (one of each)—$30.00, or $25 each when buying three or more sets**
- **Complete visible component kit including three PC boards, power supply, and 57 LEDs (specify choice of LED colors; red, green, yellow, or mixed)—$65.00, or $55.00 each when buying three or more kits**
- **Assembled string of three visible components (specify colors desired)—$75.00**

All prices include taxes, shipping, and handling. Visa/Mastercard orders call (800) 486-6862, 24 hours a day. For technical assistance call (913) 332-2726. Foreign orders require a bank check or postal money order in US funds and will be shipped air mail at no extra cost.

the kit available from the source mentioned in the parts list are supplied as fixed units with the values specified in the parts list.

If you would like to experiment with different timing-resistor values, the kit also includes an adapter board that lets you substitute multiturn potentiometers for fixed resistors. That will be useful if you are not sure what flash rates you want.

Continued on page 47

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AUDIO SCRAMBLING SYSTEM

Prevent eavesdropping by scrambling and descrambling your telephone conversations.

WILLIAM SHEETS AND RUDOLF F. GRAF

THERE ARE MANY INSTANCES where some form of speech encryption is needed for privacy or security. Complex and costly voice-scrambling systems are common in covert military operations, but simpler and less-expensive systems are adequate for discouraging the casual eavesdropper. The voice-encryption system described here inverts the frequency spectrum of the speech about a reference frequency to scramble the audio, and reinverts it to descramble the speech. Although the system is intended primarily to scramble telephone conversations, it is not limited to that. The device can also scramble tape recordings, which will be made intelligible only with the correct descrambler.

This method of speech scrambling is accomplished by mixing the audio input to be scrambled with a carrier tone as shown in Fig. 1. The mixing process is carried out with a balanced modulator, which results in a double-sideband suppressed-carrier signal. The two resulting sidebands are the lower-sideband audio frequencies in the voice range (about 150–3000 Hz) and upper-sideband frequencies (about 3000–7000 Hz).

Since most voice circuits are designed for frequencies in the lower sideband range, the upper sideband is filtered out. The lower sideband contains frequencies that are similar to the original voice frequencies, but it has an inverted spectrum. Assuming a 3000-Hz carrier signal, an input signal of 500 Hz will produce a 2500-Hz output, and a 1-kHz signal will produce a 2-kHz output. The spectral energy of a human voice is more concentrated at the ends of the voice spectrum, mainly the 300–1000 Hz range, and somewhat less in the 2000–2500 Hz range. The resulting output will therefore have a very high-pitched sound, and be unintelligible. It can, however, be carried over normal telephone lines without being understood by eavesdroppers.

A digital voice-scrambling method is used in the circuit because it requires fewer parts than an analog system, needs no adjustment, and requires no switching. Because the descrambling process is the inverse of the scrambling process, the same circuit can be used for both functions. The encryption system has two channels for full-duplex operation, which allows easy two-way communication. Note that two complete systems—one at each end of a phone line—are required for two people to carry on a scrambled conversation.

The system operates as follows: An audio input is first fil-

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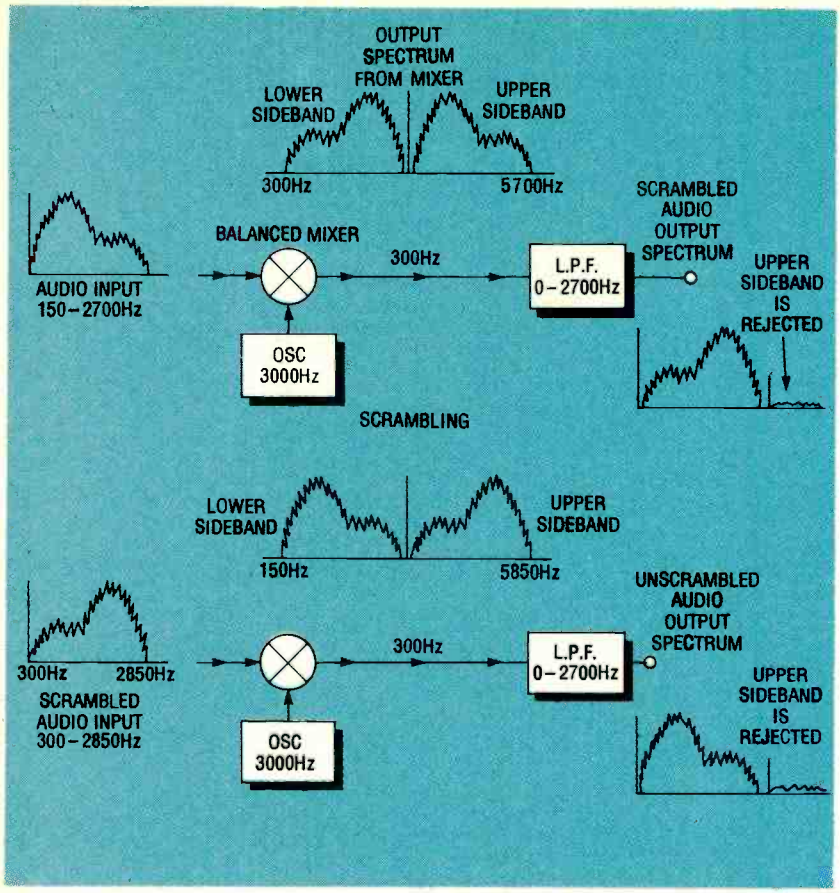

FIG. 1—AUDIO IS SCRAMBLED by mixing the audio input with a carrier tone. The two resulting sidebands are the lower sideband audio frequencies in the voice range (about 150–3000 Hz) and upper sideband frequencies (about 3000–7000 Hz).

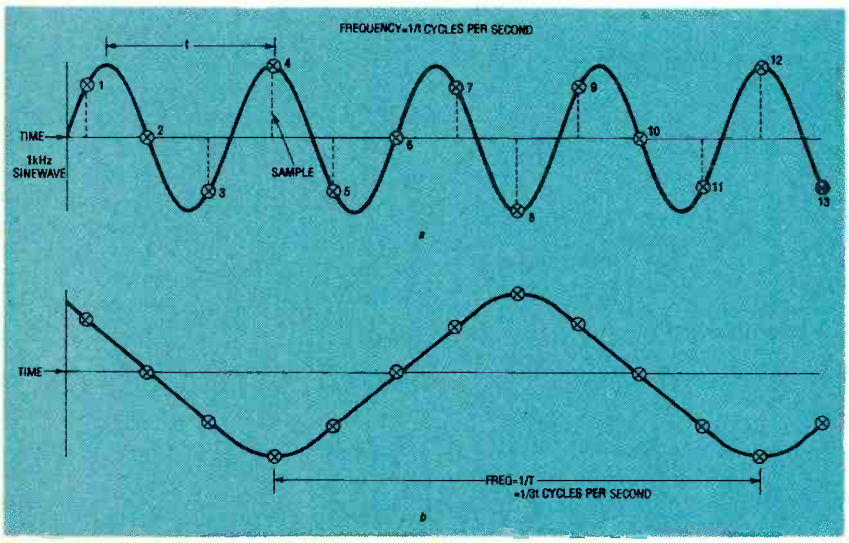

FIG. 2—A 1-KHZ SINEWAVE IS SAMPLED (*a*), and even-numbered samples are inverted, resulting in a lower-frequency sinewave (*b*).

tered with an active switched-capacitor bandpass filter to limit the frequency range to between 150 Hz and 2700 Hz. The signal is then digitized with a sampling rate of 5.86 kHz, which is more than double the highest audio frequency (2700 Hz). Every second eight-bit digitized audio sample has its sign bit inverted while being fed to a digital-to-analog converter. That has the effect of inverting the spectrum of the analog output signal after conversion from the digitized audio. The signal is then fed to a bandpass filter to remove switching components, leaving the final audio signal as one that corresponds to the input signal, except that its spectrum is folded around one-fourth of the sampling frequency, or 1465 Hz.

In Fig. 2-*a* it can be seen that

PARTS LIST

All resistors are ¼-watt, 5%, unless otherwise noted.
R1—2.2 megohms
R2, R3—470 ohms
R4, R5—100 ohms
R6, R7—22,000 ohms
R8, R10, R14, R15, R17—1000 ohms
R9, R11—6800 ohms
R12—8200 ohms
R13—1000 ohms, potentiometer
R16—10,000 ohms, potentiometer
R18–R20—10,000 ohms
R21—33,000 ohms
Capacitors
C1—22 pF, NPO
C2, C3—82 pF, NPO
C4, C5, C11, C14, C16—0.01 μF, disc
C6, C9, C10—1 μF, 35 volts, electrolytic
C7, C8—10 μF, 16 volts, electrolytic
C12—470 pF, disc
C13, C15—470 μF, 16 volts, electrolytic
Semiconductors
IC1—74HC86 quad 2-input exclusive-or gate
IC2, IC7—74HC74 dual D-type flip-flop
IC3, IC4—74HC161 synchronous 4-bit binary counter
IC5, IC6—TP3054N Codec (National Semiconductor)
IC8—LM7905 – 5-volt regulator
IC9—LM7805 5-volt regulator
D1, D2—1N4002 diode
Q1—2N3565 or 2N3904 NPN transistor
Other components
S1, S2—DPDT slide switch
J1, J2—RJ-11 4-conductor modular telephone jack
J3—⅛-inch power connector jack
XTAL1—3 MHz crystal (2.5 to 4 MHz usable)
Miscellaneous: PC board, ⅛-inch rubber grommets, insulated standoffs, case, hardware, 6–14 VAC, 100 mA transformer, IC sockets (optional), wire, solder.

Note: A kit of parts for one voice scrambler (two complete units are necessary) including a PC board and all parts that mount on it (does not include a telephone, case, phone cords, or wall transformer) is available from North Country Radio, P.O. Box 53, Wykagyl Station, New Rochelle, NY 10804 for $59.00 + $3.50 shipping and handling. A wall transformer is available for $9.50. A North Country Radio catalog is $1. New York State residents must add appropriate sales tax.

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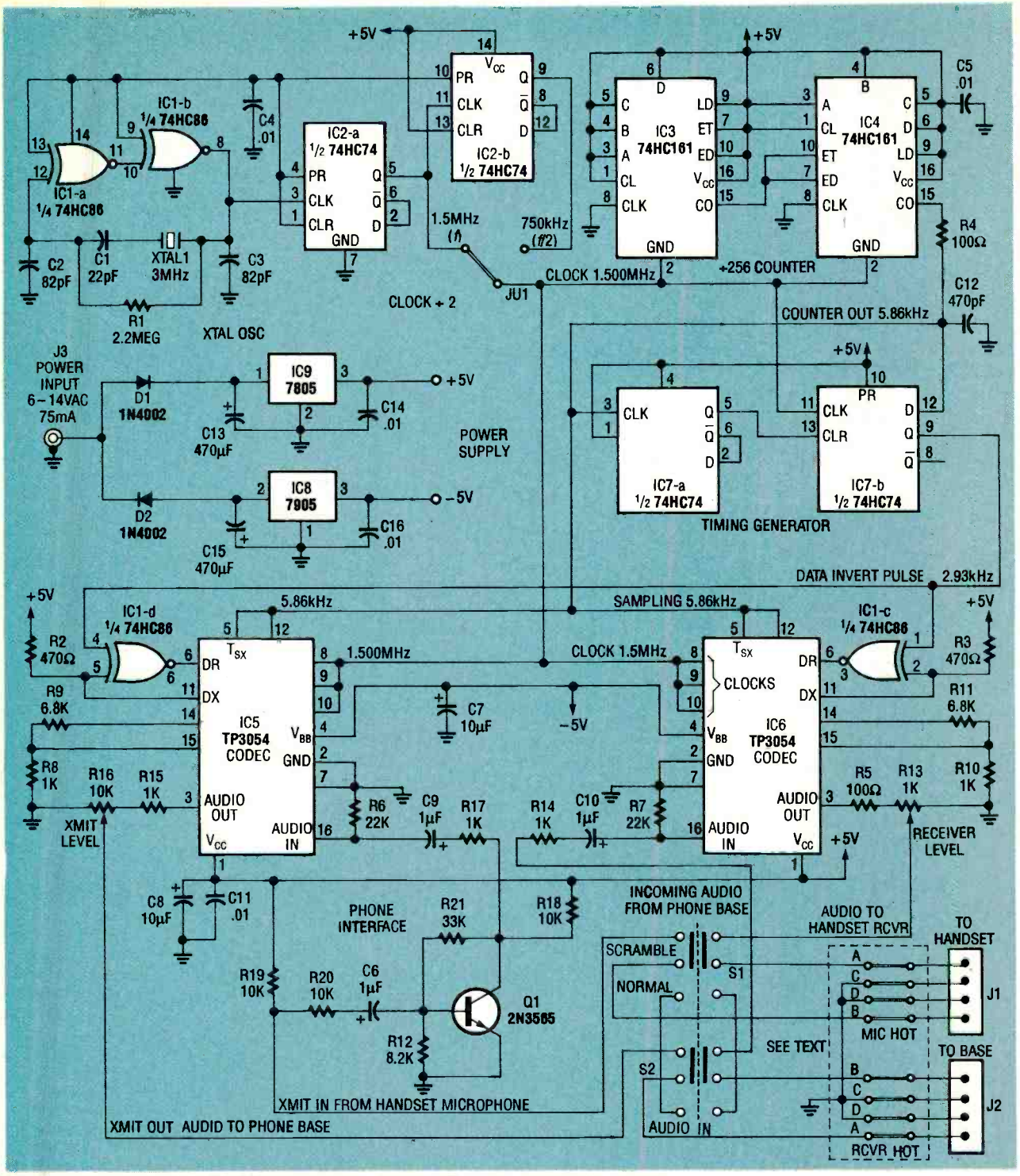

FIG. 3—VOICE SCRAMBLER/DESCRAMBLER SCHEMATIC. The clock and control circuitry supports the two Codecs, IC5 and IC6 (one for each channel).

a 1-kHz sinewave sampled as shown, with even-numbered samples inverted, results in a lower-frequency sinewave (*b*). The process also works in reverse; if the lower-frequency waveform (2-*b*) is sampled at the same points, and alternate samples inverted, the original waveform can be regenerated.

Circuitry

Figure 3 is the schematic of the voice scrambler/descrambler. Two chips—each a National Semiconductor TP3054 coder/decoder, or codec—form the heart of the circuit. The two integrated circuits, IC5 and IC6, contain all of the necessary A/D and D/A converters, switched-capacitor filters, and associated tuning and control circuitry.

The scrambler's "ground" must be isolated with respect to true earth ground. Therefore the PC board of the scrambler should be mounted on insulated standoffs and fed about 75 milliamperes of isolated, low voltage AC from a wall-mounted

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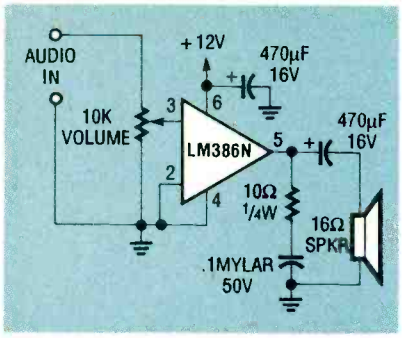

FIG. 4—FOR LOUDSPEAKER APPLICATIONS, a small audio amplifier like this one will generally be needed.

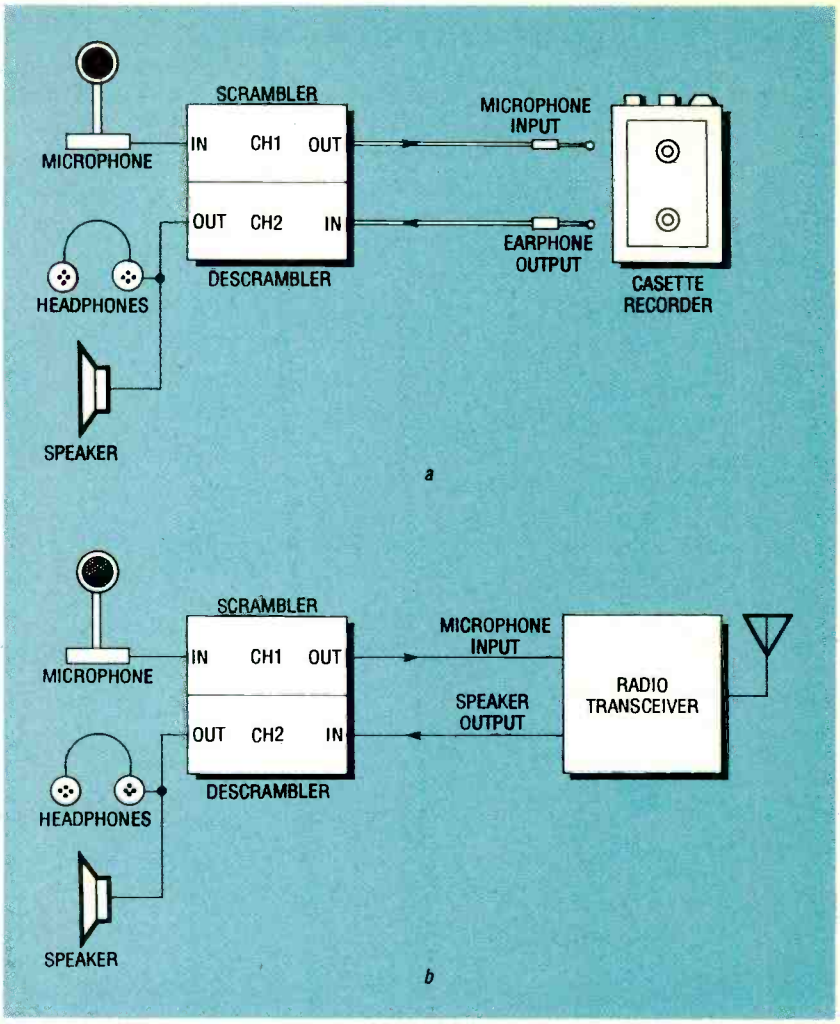

FIG. 5—THE SYSTEM can make scrambled audio recordings (*a*), or it can also be fitted to a radio transceiver (*b*).

transformer. Do not connect the unit to the AC line without such a suitable isolating transformer.

Most of the rest of the circuit is clock and control circuitry that supports the two codecs. The clock signal is generated by an oscillator made up of 3-MHz crystal XTAL1 and IC1-a and -b. The 3-MHz signal is divided in half by IC2-a to produce the main 1.5-MHz clock signal, and IC2-b again divides by 2 to produce an optional clock frequency of 750 kHz. That signal is further divided down by IC3 and IC4 to produce 5.86- and 2.93-kHz signals. D-type flip-flop IC4 produces a 2.93-kHz pulse train that's used for bit-sign inversion.

The 5.86-kHz pulse shifts a serial data stream, eight clock pulses wide, from the codec's A/D converter to the D/A converter. Data from an A/D converter (pin 11 of IC5 or IC6) is fed to IC1-d or -c, respectively. Those EXCLUSIVE OR gates act as inverters if one input is held high, or as straight-through non-inverting buffers if the other input is held low. By applying a 2.93 kHz pulse on one input, alternate data-stream sign bits (which occur at a 5.86-kHz rate) are inverted. Therefore, the data from pin 11 of IC5 (or IC6) that is fed back to the D/A converter section (pin 6) has every other sample reversed in sign. That has the aforementioned effect of inverting the frequency spectrum of the reconstructed analog signal.

The circuitry required to interface the voice-encryption system to a telephone is contained in Fig. 3. Resistor R17 couples audio from amplifier Q1 to IC5. Transistor Q1 provides about a 10 dB voltage gain.

Modular jacks J1 and J2 connect to S1 and S2 via jumpers that are configured for your particular telephone set. Because direct insertion of the device in a telephone line would not be feasible without a lot of switching due to ringing and signaling considerations, it is necessary to install this device in the handset line. This way only the microphone and earphone have to be considered.

The TP3054 can drive a 600-ohm load (the impedance of a telephone line) directly. If telephones are not being used, simply use the input and output pins directly of each codec. To have the chip drive a loudspeaker, a small audio amplifier, such as that shown in Fig. 4 is required. Note that, when using a microphone to input audio to the codec, some microphones have internal audio amplifiers and can produce well over one volt of audio. Those microphone outputs can be input directly to the codec. Low-output microphones require amplification.

A switching network (S1 and S2) is added on the PC board to switch the scrambler in or out of the telephone circuit. Resistor R13 sets the sound level at the telephone receiver, and R16 is set for optimum reception at the other end of the telephone line.

Figure 5 shows two more applications; 5-*a* shows how the system can be used to make scrambled audio recordings, and 5-*b* shows how a radio transceiver can be fitted with this device. (Bear in mind that in services such as amateur ra-

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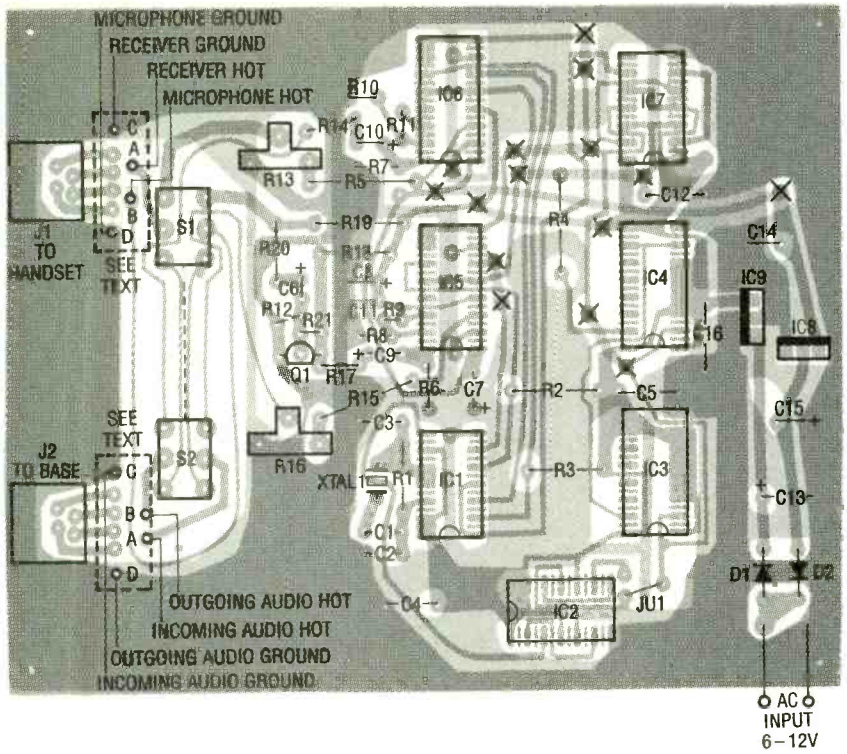
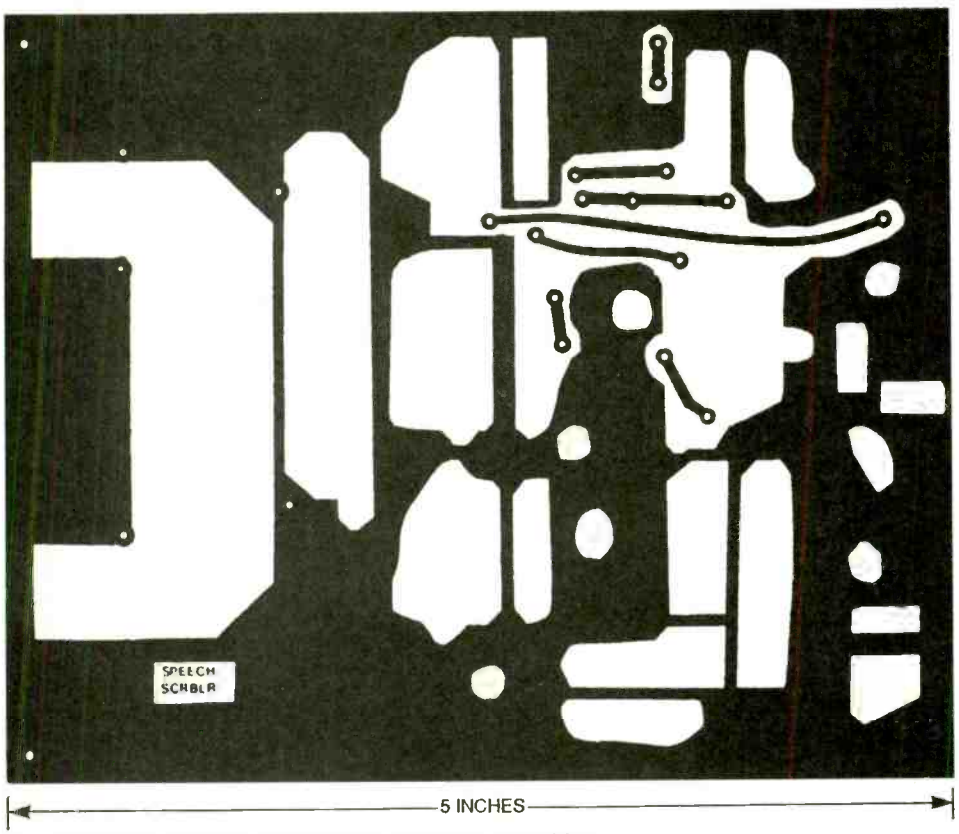


FIG. 6—PARTS-PLACEMENT DIAGRAM. Install through-board jumpers in all locations marked with an "X" and solder them on both sides of the board. All component leads that pass through a hole copper clad on both sides must also be soldered on both sides.



COMPONENT-SIDE FOIL PATTERN for the voice scrambler.

dio, it is illegal to use encryption, so check FCC rules to verify the legality for any intended application.)

Construction

The circuit can be point-to-point wired by hand or made on the double-sided PC board for which foil patterns are provided in this article. Figure 6 is the parts-placement diagram. Because the PC board does not have plated-through holes, first install through-board jumpers in all locations marked with an "X," and solder them on both sides of the board. All component leads that pass through a hole with copper on both sides must also be soldered on both sides.

Install all passive components such as resistors, capacitors, jumpers, and switches on the PC board. Then install voltage regulators IC8 and IC9. Also install the sockets for the rest of the ICs, if you are using them (they are recommended). Before the ICs are inserted in their sockets, apply 6 to 12 volts AC to the junction of D1 and D2 and ground. Check for 5 volts at pin 4 of IC5 and IC6, and pin 16 of IC2, IC3, and IC4, and pin 14 of IC1. Next, verify −5 volts at pin 1 of IC5 and IC6. If these voltages check out, insert the ICs in their sockets. Figure 7 shows how to gang switches S1 and S2 together mechanically, and Fig. 8 shows the finished board, with the ganged switches, mounted in a case.

Testing

Verify that a 5-volt peak-to-peak, 1.5-MHz signal exists at pin 2 of IC3. Check for a 5.86-kHz pulse train at pin 15 of IC4, pins 5 and 12 of IC5, and IC6. Check for 2.93-kHz pulse train at pin 1 of IC1-c and pin 4 of IC1-d. Due to the short pulse width (250 nanoseconds), it might be difficult to see these pulses with an economy model oscilloscope.

If all checks out, apply a 0.5-volt peak-to-peak, 1-kHz tone to the junction of R17 and C9; a 2-kHz tone should be pro-

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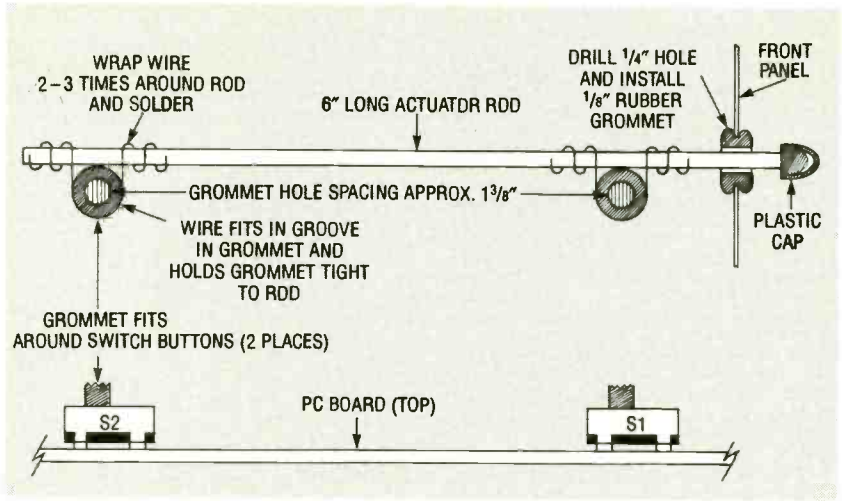


FIG. 7—SWITCHES S1 AND S2 must work in conjunction with one another, so they must be ganged together as shown here.

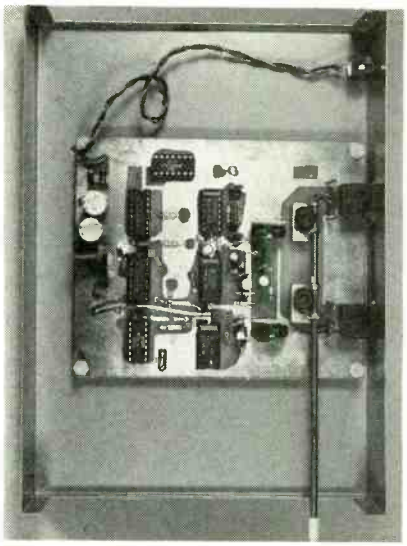


FIG. 8—HERE'S WHAT THE FINISHED board looks like mounted in the case. Notice how S1 and S2 are ganged together.

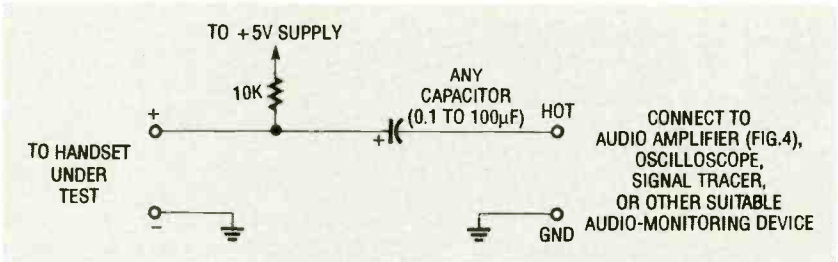


FIG. 9—TO DETERMINE THE POLARITY of the microphone leads, connect the microphone pair to this test circuit and see if the microphone works; if not, reverse the connections.

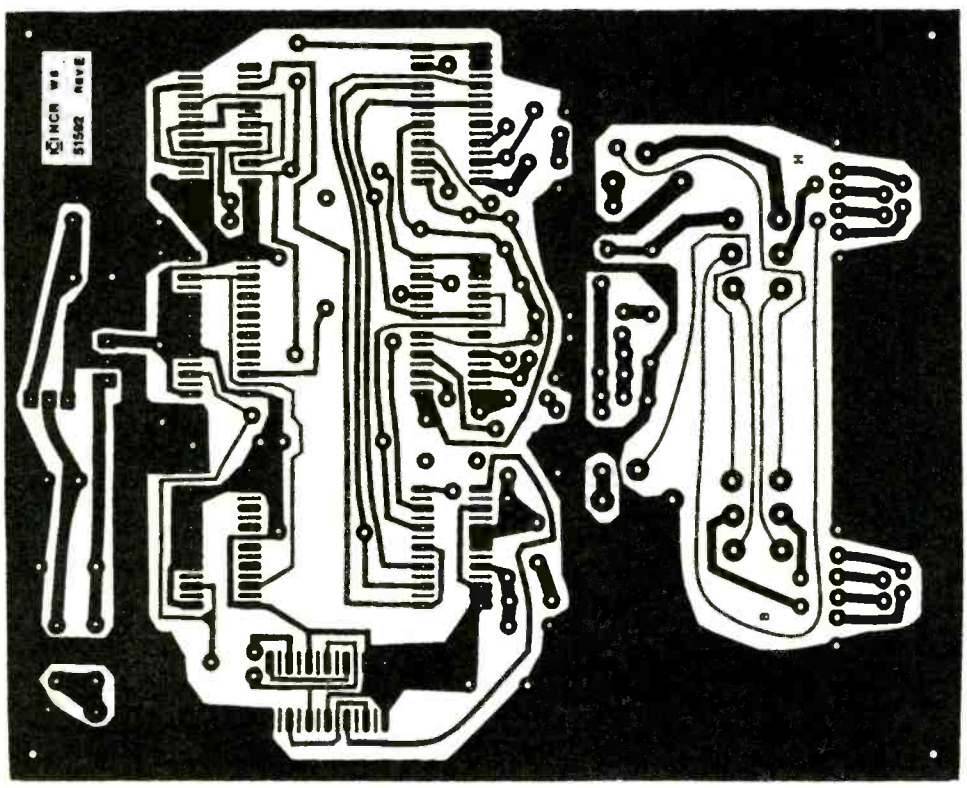
duced by IC5. Now temporarily connect pin 3 of IC5 to the junction of C10 and R14 using a 100K resistor. Pin 3 of IC6 should produce the original 1-kHz tone.

Next, apply an audio signal (from a tape deck or radio) with about 2 volts peak-to-peak to the junction of R17 and C9. Listen to the output at pin 3 of IC5; it should sound "scrambled." Now listen to the output of channel 2. It should be normal, but note that the high and low frequencies might sound somewhat attenuated due to the narrow bandwidth of the system.

Adapting a phone

Note that this unit cannot be connected directly to the phone lines. It will handle speech audio only, and will not pass ringing signals or rotary dialing pulses. It will also distort dialing tones. You must use only a phone whose handset has accessible microphone and receiver connections. You cannot use a unified telephone (where the dial or pad is built into

Continued on page 46



SOLDER-SIDE FOIL PATTERN for the voice scrambler.

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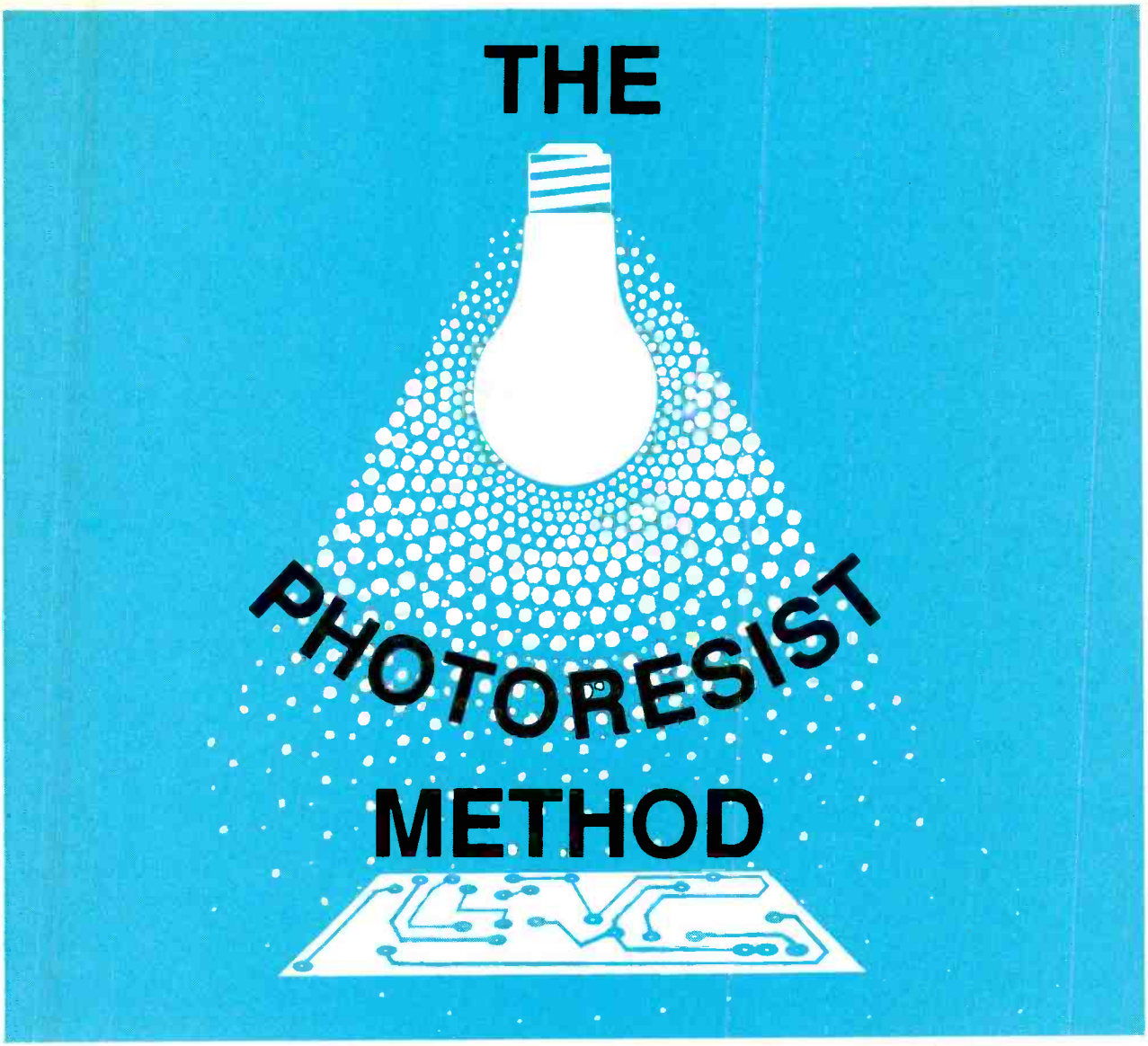
THE PHOTORESIST METHOD



Learn how to use the photo-resist method for making your own PC boards.

JOHN BERCIK

ANYONE CAN MAKE PROFESSIONAL single- and double-sided prototype circuit boards using just a few basic materials and techniques. The techniques shown in this article will allow you to produce a PC board for your prototype in a matter of hours. Board houses can often take weeks to produce a board. Once you are familiar with the techniques described in this article, you will expose, develop, and etch boards in about 40 minutes, at an average cost of about $25 each.

Boards produced with the photoresist method can have traces as thin as 15 mils (a mil is 1/1000 of an inch) with 10-mil isolations. Pads of 65 mils and drill holes of around 30 mils can also be produced. Once you get the hang of the procedure, you can make many copies of the same board with a sucess rate of around 95%; the 5% of the boards that are unusable usually result from reusing etchant and developer too much.

Many of the things you'll need to make PC boards using this technique can be found right in your kitchen, so you don't have to break the bank to try it out. Table 1 shows a list of the necessary equipment, and Figure 1 shows some of those materials.

Artwork

There are many sources for the artwork for your board layout. For you own designs, if you have access to a CAD program and a laser printer, you can get a clear plot from the program onto paper. If the circuit is small you should plot the artwork at double the actual size (a 2:1 scale). If you can't use a computer for your board design, you will have to produce your PC

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TABLE 1—NEEDED MATERIALS

- Artwork (from a printer, preferably a laser printer)
- Sunlamp (not an infrared heat lamp)
- Darkroom safe light
- Kitchen timer
- A piece of plate glass larger than the desired board size (you can use the glass from a cheap picture frame)
- Hot plate
- Glass brownie pan
- Candy thermometer
- Plastic tray
- Bucket
- 1 pint of etchant
- 1 pint of developer
- Light sensitized PC-board material (single- or double-sided)
- Rubber gloves resistant to chemicals (available at hardware stores)
- Drill press and small bits (around .030- or .045-inch)

FIG. 1—HERE ARE SOME OF THE MATERIALS you need to make your own PC boards.

pattern on clear acetate film with black tape and donuts. Taping is recommended only for small boards. If CAD software is available don't use tape at all unless you are experienced in laying out boards by hand.

Next, you might need to have a film, or transparency, made of the artwork. (It is not necessary if your artwork is on acetate and at a 1:1 scale.) Printing shops charge about $15 a sheet. Two sheets are required for double-sided boards unless the patterns are small enough that they will both fit on one sheet (see Fig. 2). Try to keep a 1- to 2-inch border around each piece of artwork.

Determine which side of the transparency you want the emulsion (the image) on, so that when the film is laid on top of the PC-board blank, the pattern is touching the board and not on the side of the film facing away from the board. That prevents light from going under the artwork and causing traces to be etched away.

You must also specify if the film is to be scaled from the paper. If your paper plot is twice normal size, you'll have to get a 50% reduction to get the proper size. Finally, specify if you want a positive or negative. If your film is positive, use positive-sensitized boards and positive developer. With negative film, use negative-sensitized boards and negative developer.

Making a board

The following procedures are necessary to make double-sided boards; some of them are not necessary for single-sided boards. Once you have the film ready, cut a 2-inch border around the solder-side film and a 1-inch border around the component-side film.

Place the component-side film on top of the solder-side film with the correct orientation to simulate a finished board. Line up the patterns and tape the component-side film to the solder-side film along the top and side edges. Don't cover any of the artwork with tape. Insert a 1-inch wide scrap piece of PC-board material along the bottom edge to act as a spacer between the two films. Position the scrap material ¼-inch away from the edge of the artwork on the film. Then tape the material in place on both sides making sure that the through holes on the film still line up. Remove the tape from the sides and top of the film leaving only the scrap stock connecting the films.

You will need light-sensitized board material, developer, and etchant to complete the board. You can use positive or negative techniques as long as your film matches, although the positive technique is described here. Handle the sensitized boards by the edges so that the coating remains intact.

Place the sun lamp 10 inches

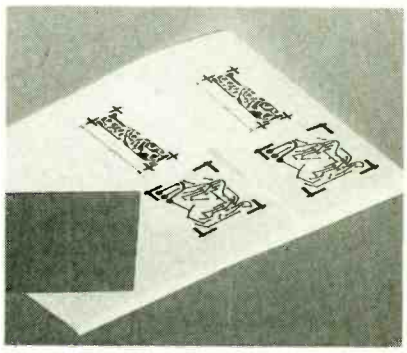

FIG. 2—PUT ALL PATTERNS on a single sheet of film, if possible, to save money on having the film made.

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FIG. 3—ETCHANT IS AVAILABLE from many different suppliers, and in many different forms.

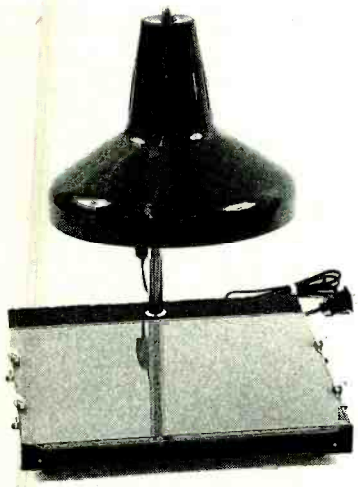

FIG. 4—A SUNLAMP IS MOUNTED to a base that makes exposing the blanks relatively easy. The base holds the glass securely in place.

above the surface to be exposed. Set up the hot plate with the glass brownie pan on it. Mount the candy thermometer to the side of the brownie pan. (The author softened a piece of scrap plastic into the shape of a clip and drilled a hole in it to hold the thermometer firmly).

The etching solution should be prepared before exposing your board, so that it's ready when you are. Ferric chloride can be used to etch the boards, although environmentally safer sodium persulfate etchant can also be used. Figure 3 shows different kinds of etchants. Remember, when working with caustic chemicals, make sure there's good ventilation, wear old clothes because the etchant stains don't wash out, and wear rubber gloves.

Place the glass pan on the hot plate and pour the etchant about 1½ inches deep into the pan. Turn on the heat and get the etchant stabilized to between 125 and 135 degrees Fahrenheit—do not let the etchant get over 140 degrees.

Fill the bucket with cold water. Get a clean glass bottle and mix the developer with the correct ratio of hot water (according to the manufacturer's directions—it might not be necessary at all), and pour it into the plastic developing tray.

Place your film, the large piece of glass, some tape, the sensitized board in its sealed, light-tight plastic bag, and a knife in front of you on a clean surface. Turn on the red safety light and turn off the other lights. Make sure the etchant is up to temperature. Open the sensitized board in the red light and, holding it by the edges, place it between the two films. Flatten the film out beneath a piece of paper (so you don't touch the board) and tape the film firmly to the board on both sides making sure not to upset the alignment. You can cut the corners off the film to make room for the tape.

Place the board and film under the sun lamp with the glass on top to keep the film pressed flat against the board (see Fig. 4). Set the timer for 6½ minutes and turn on the sun lamp being careful not to look directly at the bulb. After the board has been exposed for 6½ minutes, turn it over very quickly and reset the timer for another 6½ minutes. Finally, turn the sun lamp off. Wearing a rubber glove, remove the film and dip the board into the warm developer. Use a stick to move the board around in the developer. Lift it up and down from the edge to get a wave action going. Also flip it over a couple of times. A faint image will appear after a minute or two.

After about 3 or 4 minutes, take the board out and plunge it into the bucket of cold water. That stops the development process and hardens the etch resist.

This is a good stopping point if you plan to make multiple copies of the same board. as you can set the developed board aside, expose more of them, and then etch them all at once. If you are making only one board, you can turn on the lights at this time. After the board has been in the cold water for about a minute, remove it and then place the board into the etchant. After about 1 or 2 minutes, begin moving it around with a stick continuously to prevent dissolved copper from sticking to the board. Check that your temperature is correct as you continue etching. It should take from 5 to 15 minutes to etch, depending on how fresh the etchant and how big the board is. An etching tank—a tank specially made to etch and agitate PC boards—will speed up the process, and is a worthwhile investment should

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you decide to make boards on a regular basis. You can buy an etching tank from suppliers that carry materials for making PC boards, or even build one (see **Radio-Electronics**, December 1989).

When you can see that the unwanted copper is almost fully etched, take the board out of the etchant and plunge it into the bucket of water to rinse off the etchant. If it is not etched enough, put it back into the etchant. It's better to stop etching too soon and then put it back in again than to etch it too much. When the board is done, rinse it off and towel dry it.

If your board does not etch completely, even with fresh developer and etchant, you must repeat the entire procedure, exposing the board a bit longer to the sun lamp. However, if traces are being etched away along with the unwanted copper, then you must reduce the exposure time. Once you determine the correct exposure time, it will work every time. Call your local city officials to find out how to properly dispose of the used chemicals—don't just pour them down the drain!

With a piece of fine steel wool, polish the board to remove all remaining etch resist. Inspect the board for any broken traces. You are now ready to drill the board. Remember to wear safety goggles. Although a drill press is best for drilling PC boards, a hand drill and a steady hand will also work.

When double-sided PC boards are professionally made, holes are plated through the board to connect traces from top to bottom. With our technique there is no plating through of the holes. We simulate the through-holes by inserting short lengths of wire through the holes and soldering them on both sides. In through-holes where component leads pass through, the leads are simply soldered on both sides. Because some components have leads that are difficult to solder on the component side, it is good practice to place as many traces as possible on the solder side when laying out the board.

When your board is complete, you can assemble your prototype. If everything checks out, you are ready to send the information to your PC board manufacturer and have them make as many boards as you need, with the assurance that they will work properly. Ω

SOURCES

Everything you need to make your own PC boards can be obtained from the following suppliers:

- Kepro Circuit Systems, 630 Axminister Drive, Fenton, MO 63026-2992 (800) 325-3878, (314) 343-1630
- Datak Corporation, 3117 Paterson Plank Road, North Bergen, NJ 07047 (201) 863-7667.
- A list of circuit-board houses who provide prototyping and full production services for boards up to 16 layers can be obtained free of charge from Skychaser, 980 Sherwood Place, Eugene, OR 97401 (503) 345-4609.

AUDIO SCRAMBLING

continued from page 42

the handset). The handset should preferably have an electret microphone. However, carbon microphones (found in older phones) can be used, if necessary, but R19 should be changed to about 1K, and R20 might have to be increased if excessive audio from a carbon microphone overdrives Q1, causing distortion.

Depending on the phone you have, you must make the proper jumper connections on the PC board near J1 and J2. A Radio Shack telephone model No. ET-171 (cat No. 43-374) was used in the author's prototype.

You must identify the following things on your phone(s):

1. The handset microphone and earpiece connections
2. The type of microphone (electret, dynamic, or carbon)
3. Microphone polarity (if it's the electret type)
4. The base connections

There are usually four wires that connect a telephone handset to its base. If you can't visually identify the wires after disassembling the handset, try connecting a 1.5-volt battery to alternate pairs of wires on the handset until you hear a click in the earpiece. Mark these as the receiver leads; there should be between 50 and 1000 ohms between them. The other two leads are for the microphone.

Check for short circuits between both of the receiver leads and the microphone leads with an ohmmeter on a high resistance range. A low resistance or a short between any two leads indicates that they are the ground leads for the microphone and receiver. If you find no continuity between the two sets of leads, connect the microphone pair to the test circuit shown in Fig. 9, and see if the microphone works; if not, reverse the connections. This will identify the microphone's hot and ground leads. Once you've identified all of the handset leads, note their positions on the modular connector. The telephone base connections can now be determined from the positions of the handset leads at the modular connector.

When you have all of the telephone connections identified, install the jumpers on the PC board near jacks J1 and J2. In Fig. 6 there are four jumper pads labeled A–D near each modular jack; the pads are also labeled by function. Once you know the signal positions at jacks J1 and J2 for your phone, install four jumpers per jack to properly route the signals.

The finished board can be mounted in a case like the one pictured in Fig. 8, or in any other suitable case. The case pictured allows the telephone to be placed on top of the scrambler without taking up any extra space.

With a pair of scrambler phones in hand, you're ready to start talking. All you need now is someone to talk to and a confidential topic to discuss. Ω

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VISIBLE COMPONENTS

continued from page 36

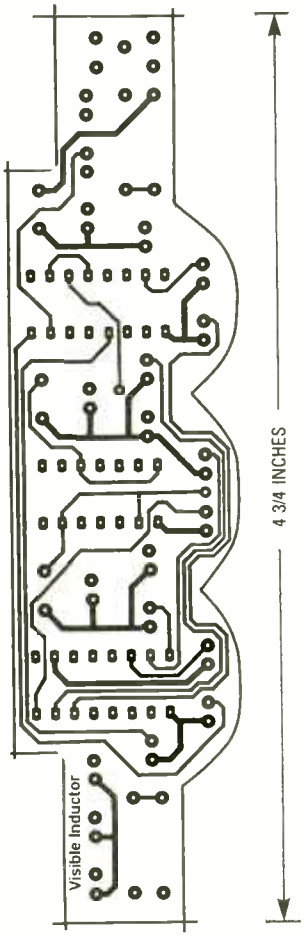
Construction

Assembly of the visible components is not difficult. Although you can build the circuits on perforated construction board, PC boards will provide a better appearance. Perfectly shaped component outlines are difficult to achieve when laying out the parts by hand. Parts-placement diagrams for the visible resistor, capacitor, and inductor are shown in Figs. 4–6.

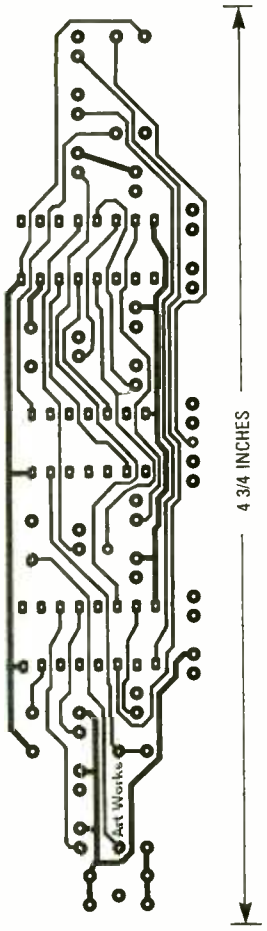
A solder mask on the commercially available boards covers all runs and feedthroughs on both sides of the board, so that solder shorts are easily avoided. The solder mask gives the PC boards their color; the component sides of the boards are blue, and the solder sides are green.

Install the LEDs on each board last, as it will be more difficult to solder the other components in if you have to work around the LEDs. The LEDs are installed on all three boards with the cathode lead (the flat side) pointing away from the power-lead connections. The LEDs can be installed on either side of the board depending on whether you want your completed visible component to have a blue or green background. The LEDs can be any color available. You can specify LED colors when ordering.

Once the LEDs are in place, solder the +12-volt and ground wires to the appropriate points as labeled on the PC board. Two sets of power pads are included on each board, and either set of holes can be used. The extra pair of holes are for stringing all three (or more or less) visible components together so that they can be draped around a tree or along a wall. After you're done soldering, check for correct component placement and good solder connections. Ω



VISIBLE INDUCTOR component side.



VISIBLE INDUCTOR solder side.

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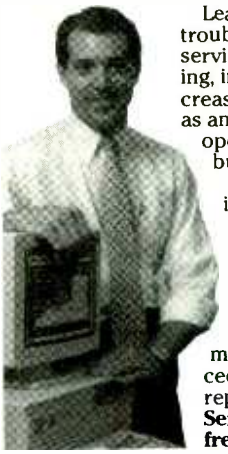

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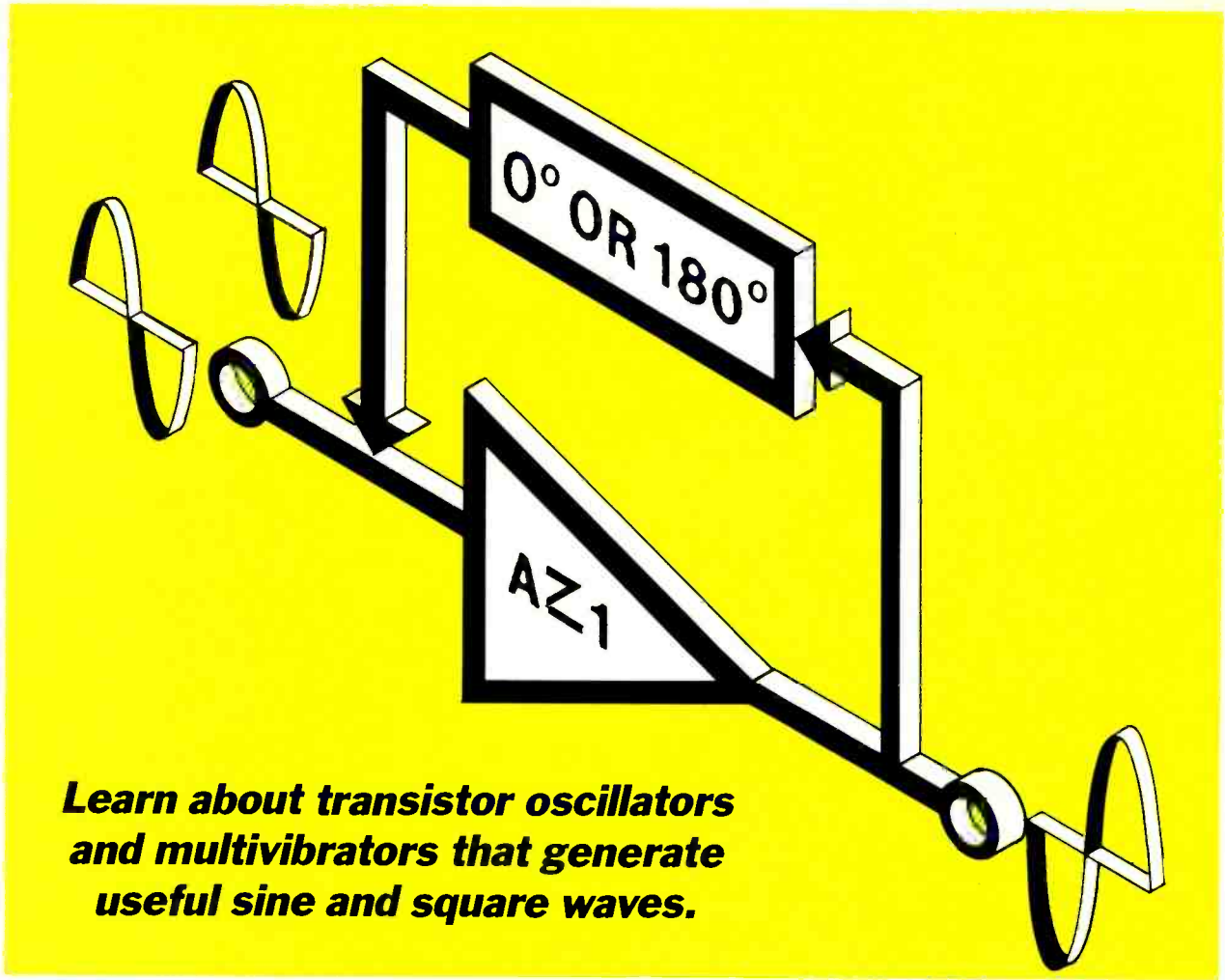

Learn about transistor oscillators and multivibrators that generate useful sine and square waves.

OSCILLATORS

RAY MARSTON

OSCILLATORS BASED ON THE BIpolar junction transistor (BJT) are the subjects of this article. Previous subjects in this series have included an article on the characteristics of the bipolar junction transistor, one on the common-collector amplifier, a third on the common-emitter and common-base voltage amplifiers (September, October, and November).

Oscillator fundamentals

An oscillator is a circuit that is capable of a sustained AC output signal obtained by converting input energy. Oscillators can be designed to generate a variety of signal waveforms, and they are convenient sources of sinusoidal AC signals for testing, control, and frequency conversion. Oscillators can also generate square waves, ramps, or pulses for switching, signaling, and control.

Simple oscillators produce sinewaves, but another form, the multivibrator, produces square or sawtooth waves. These circuits were developed with vacuum-tubes, but have since been converted to transistor oscillators. Figure 1 is a simple block diagram showing an amplifier and a block representing the many oscillator phase-shift methods.

Regardless of its amplifier, an oscillator must meet the two *Barkhausen conditions* for oscillation: 1. The loop gain must be slightly greater than unity. 2. The loop phase shift must be 0° or 360°.

To meet these conditions the oscillator circuit must include some form of amplifier, and a portion of its output must be fed back regeneratively to the input. In other words, the feedback voltage must be positive so it is in phase with the original excitation voltage at the input. Moreover, the feedback must be sufficient to overcome the losses in the input circuit (gain equal to or greater than unity).

If the gain of the amplifier is less than unity, the circuit will not oscillate, and if it is significantly greater than unity, the circuit will be over-driven and produce distorted (non-sinusoidal) waveforms.

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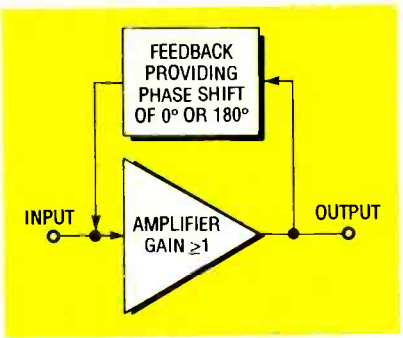

FIG. 1—OSCILLATION CONDITIONS of a sinewave generator. Loop phase shift must be 360°, and there must be adequate loop gain.

As you will learn, the typical amplifier—vacuum tube, bipolar junction transistor, or field-effect transistor—imparts a 180° phase shift in the input signal, and the resistive-capacitive (RC) feedback loop imparts the additional 180° so that the signal is returned in phase. Energy coupled back to the input by inductive methods can, however, be returned with zero phase shift with respect to the input.

Specialized oscillators such as the Gunn diodes and klystron tubes oscillate because of negative resistance effects, but the basic oscillator principles apply here as well.

RC oscillators.

Figure 2 is the schematic for a *phase-shift oscillator*, a basic resistive-capacitive oscillator. Transistor Q1 is configured as a common-emitter amplifier, and its output (collector) signal is fed back to its input (base) through a three-stage RC ladder network, which includes R5 and C1, R2 and C2, and R3 and C3.

Each of the three RC stages in this ladder introduces a 60° phase shift between its input and output terminals so the sum of those three phase shifts provides the overall 180° required for oscillation. The phase shift per stage depends on both the frequency of the input signal and the values of the resistors and capacitors in the network.

The values of the three RC ladder network capacitors C1, C2, and C3 are equal as are the values of the three resistors R5, R2, and R3. With the component values shown in Fig. 2, The 180° phase shift occurs at about 1/14 RC or 700 Hz. Because the transistor shifts the phase of the incoming signal 180°, the circuit also oscillates at about 700 Hz.

At the oscillation frequency, the three-stage ladder network has an attenuation factor of about 29. The gain of the transistor can be adjusted with trimmer potentiometer R6 in the emitter circuit to compensate for signal loss and provide the near unity gain required for generating stable sinewaves. To ensure stable oscillation, R6 should be set to obtain a sightly distorted sinewave output.

The amplitude of the output signal can be varied with trimmer potentiometer R4. Although this simple phase-shift oscillator requires only a single transistor, it has several drawbacks: poor gain stability and limited tuning range.

There are ways to overcome the drawbacks of the phase shift-oscillator, and one of them is to include a *Wien-bridge* or network in the oscillator's feedback loop. The concept is illustrated in the Fig. 3 block diagram. A far more versatile RC oscillator than the phase-shift oscillator, its operating frequency can be varied easily.

As shown within the dotted box in Fig. 3, A Wien bridge consists of a series-connected resistor and capacitor, wired to a parallel- connected resistor and capacitor. The component values are "balanced" so that R1 equals R2 and C1 equals C2.

The Wien network is exceptionally sensitive to frequency. That shift is negative (to a maximum of −90°) at low frequencies, and positive (to a maxiumum of +90°) at high frequencies. It is zero a center frequency of 1/6.28RC. At the center frequency, network attenuation is a factor of 3.

As a result, the Wien network will oscillate if a non-inverting, amplifier with a gain of 3 is con-

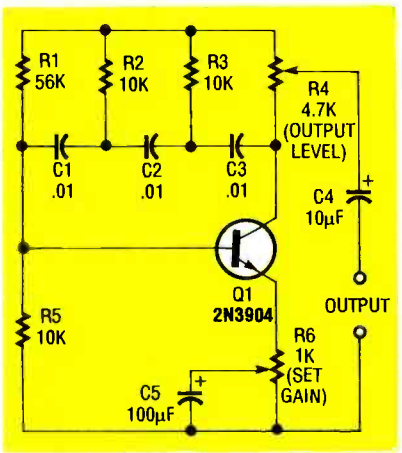

FIG. 2—PHASE-SHIFT OSCILLATOR has a three-stage RC network phase shifter.

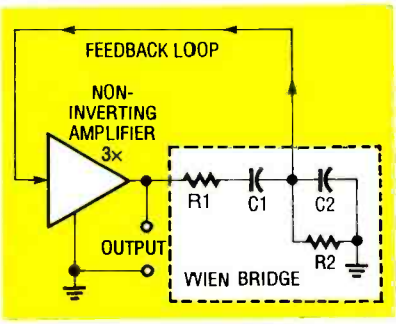

FIG. 3—WIEN BRIDGE will function as a 180° feedback network in an oscillator.

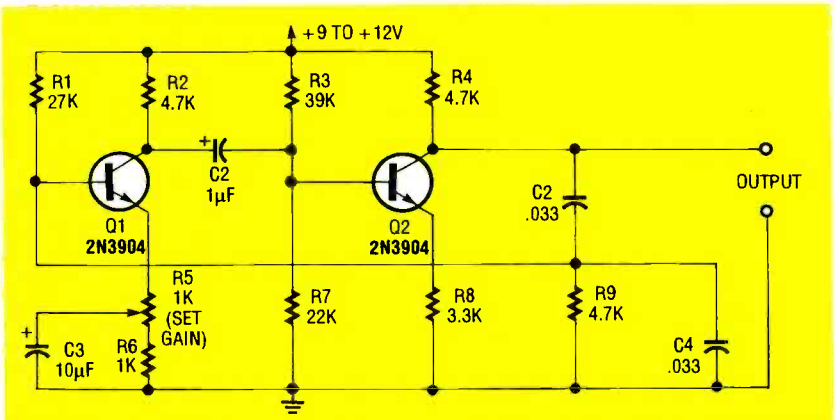

FIG. 4—WIEN-BRIDGE OSCILLATOR has an Wien-bridge network as its phase shifter.

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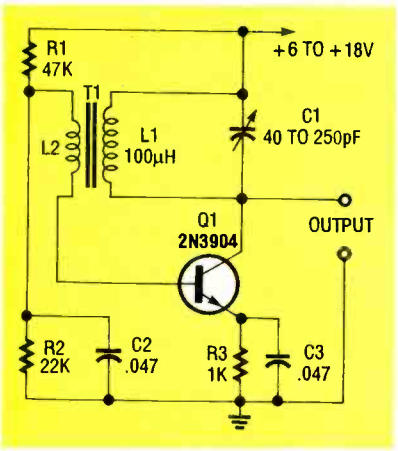

FIG. 5—TUNED-COLLECTOR oscillator has a tuned- transformer resonant tank.

nected as shown between the amplifier's output and input terminals. The output is taken between the output of the amplifier and ground.

A basic two-stage Wien-bridge oscillator schematic is shown in Fig 4. Both transistors Q1 and Q2 are configured as as low-gain common-emitter amplifiers. The voltage gain of Q2 is slightly greater than unity, and it provides the 180° phase shift required for regenerative feedback. The 4.7-kilohm resistor R4, part of the Wien network, functions as the oscillator's collector load.

Transistor Q1 provides the high input impedance for the output of the Wien network. Trimmer potentiometer R5 will set the oscillator's gain over a limited range. With the component values shown, the Wien-bridge oscillator will oscillate at about 1 kHz. Trimmer R5 should be adjusted so that the sinewave output signal is just slightly distorted to achieve its maximum stability.

Many different practical variable-frequency Wien-bridge oscillators can be built with operational amplifier integrated circuits combined with an automatic gain-control feedback systems. No inductors are needed in these circuits.

LC oscillators

Resistive-capacitative sinewave oscillators can generate signals from a few hertz up to several megahertz, but inductive-capacitive (LC) oscillators can generate sinewave outputs from 20 or 30 kHz up to UHF frequencies.

An LC oscillator includes an LC network that provides the frequency-selective feedback between the output of the amplifier and its input terminals.

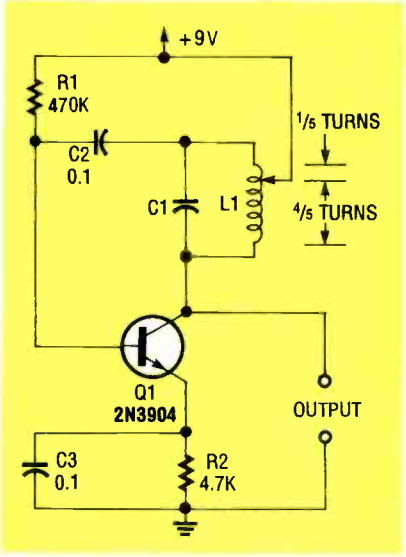

FIG. 6—HARTLEY OSCILLATOR has a tapped tank coil.

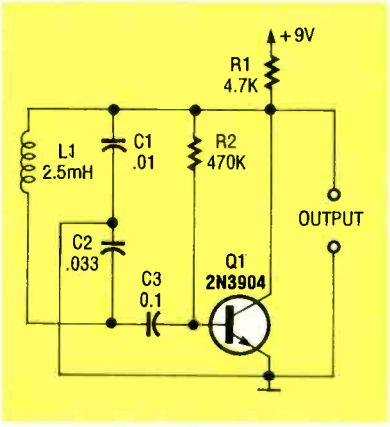

FIG. 7—COLPITTS OSCILLATOR has a dual-capacitor voltage divider.

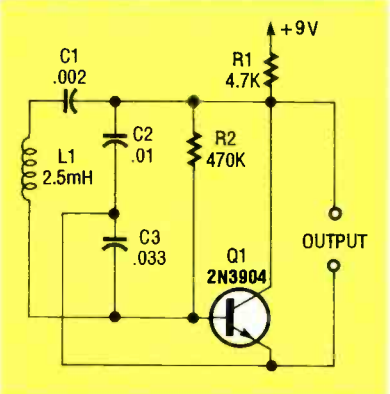

FIG. 8—CLAPP OSCILLATOR is a Colpitts oscillator with improved stability.

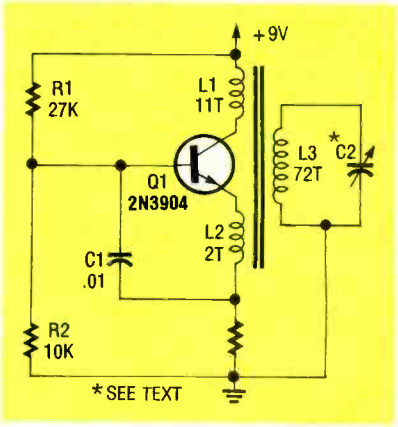

FIG. 9—REINARTZ OSCILLATOR inductively couples emitter and collector signals to its tank circuit.

Because of the inherently high *Q* or *frequency selectivity* of LC networks or resonant tank circuits, LC oscillators produce more precise sinewave outputs—even when the loop gain of the circuit is far greater than unity.

The *tuned-collector oscillator* shown in Fig. 5 is the simplest of many different LC oscillators. Transistor Q1 is configured as a common-emitter amplifier, with its base bias provided by the junction of series resistors R1 and R2. Emitter resistor R3 is decoupled from high-frequency signals by capacitor C3.

The primary turns of transformer T1 (L1) in parallel with trimmer capacitor C1 form a tuned collector resonant tank circuit. Collector-to-base feedback is provided by coil L2 in transformer T1. Coil L2, with a smaller number of turns than L1, is inductively coupled to L1 by transformer action.

The necessary zero phase shift around the feedback loop can be obtained by adjusting trimmer capacitor C1. If loop gain exceeds unity at the tuned frequency, the circuit will oscillate. Loop gain is determined by the turns ratio of L1 with respect to L2 in transformer T1.

The phase relationship between the energizing current of all LC tuned circuits and induced voltage varies over the range of −90° to +90 deg, and it is zero at a *center* frequency given by the formula:

$f = 1/2\pi\sqrt{LC}$.

Because the circuit in Fig. 5

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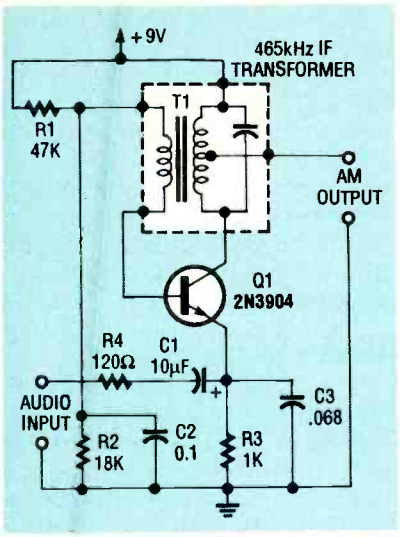

FIG. 10—BEAT-FREQUENCY oscillator that can amplitude modulate audio signals.

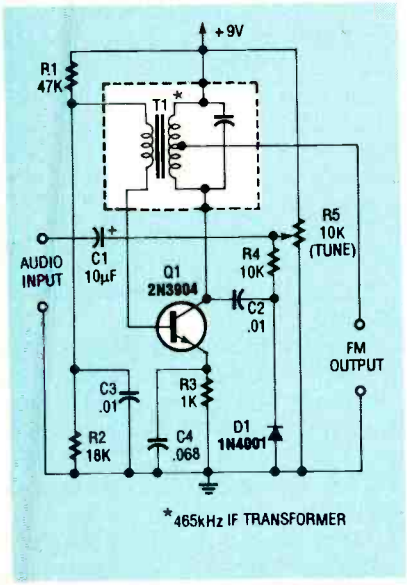

FIG. 11—BEAT-FREQUENCY oscillator with varactor tuning frequency modulates input signals.

provides a 0° overall phase shift, it oscillates at this center frequency. The frequency can be varied by trimmer capacitor C1 from 1 MHz to 2 MHz. The circuit can be enhanced to oscillate at frequencies from less than 100 Hz to UHF frequencies with a laminated iron-core transformer. The same circuit will oscillate satisfactorily in the UHF regions with an air-core transformer.

Classic LC oscillators

Figure 6 illustrates the Hartley oscillator, which is a variation of the tuned-collector oscillator that was shown in Fig. 5. This oscillator is recognizable by the tapped coil in its tuned resonant circuit. Oscillation of the Hartley oscillator circuit depends on phase-splitting autotransformer action of the tapped coil in the tuned resonant circuit.

The tap is located on load inductor L1 about 20% of the way down from its top so that about ⅕ of the turns are above the tap and ⅘ are below. The positive power supply is connected to the tap to obtain the necessary

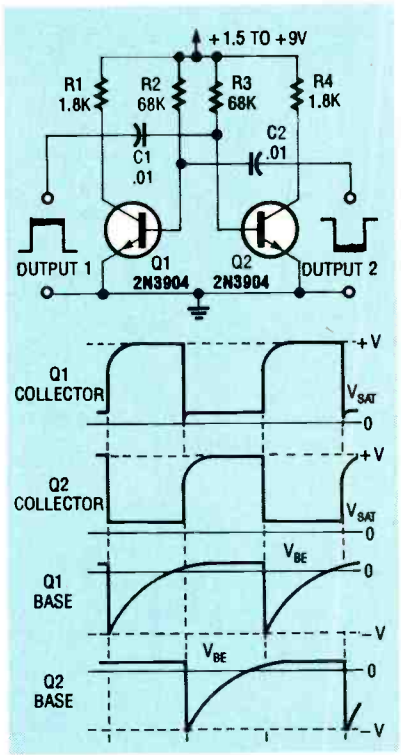

FIG. 12—ASTABLE MULTIVIBRATOR produces 1-kHz square waves (*a*), and waveforms at the collectors and bases of Q1 and Q2 (*b*).

autotransformer action.

the signal voltage across the top of L1 is 180° out-of-phase with the signal voltage across its lower end, which is connected to the collector of Q1. The signal from the top of the coil is coupled to the base (input) of Q1 through isolating capacitor C2. The oscillator will oscillate at a center frequency determined by its LC product.

The Colpitts oscillator shown in Fig. 7 is another classic circuit. It is identified by the voltage divider in its tuned resonant circuit. With the component values shown, this Colpitts circuit will oscillate at about 37 kHz.

Capacitor C1 is in parallel with the output capacitance of Q1, and C2 is in parallel with the input capacitance of Q1. Consequently, changes in Q1's capacitance (due to temperature changes or aging) can shift the oscillator frequency. This shift can be minimized for high frequency stability by selecting values of C1 and C2 that are large relative to the internal capacitances of Q1.

The Clapp oscillator, a modification of the Colpitts oscillator, shown in Fig. 8, offers higher frequency stability than the Colpitts oscillator. This is achieved by adding capacitor C1 in series with the coil in the tuned resonant tank circuit. It is selected to have a value that is small with respect to C2 and C3.

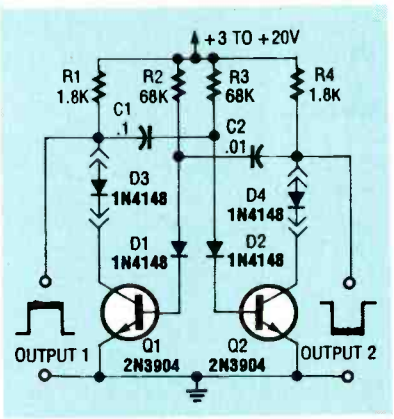

FIG. 13—ASTABLE MULTIVIBRATOR with frequency correction produces 1-kHz square waves.

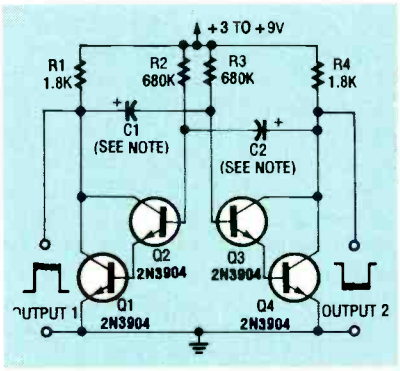

FIG. 14—ASTABLE MULTIVIBRATOR produces long-period square waves.

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As a result of the presence of this capacitor, the resonant frequency of the tank and oscillator will be determined primarily by the values of L1 and C1.

Capacitor C3 essentially eliminates transistor capacitance variations as a factor in determining the Clapp oscillator's resonant frequency. With the component values shown, the Clapp oscillator oscillates at about 80 kHz.

Figure 9 shows the classic *Reinartz oscillator*. In this circuit, tuning coil L1 in the collector circuit and the tuning coil L2 in the emitter circuit are inductively coupled to tuning coil L3 in the resonant tank circuit.

Positive feedback is obtained by coupling the collector and emitter signals of the transistor through windings L1 and L2, and inductively coupling both of these coils to L3. This Reinartz oscillator oscillates at a frequency determined by L3 and trimmer capacitor C2. With the values and turns ratios given in Fig. 9, the circuit will oscillate at a few hundred kHz.

Modulation

The LC oscillator circuits shown in Figs. 5 to 9 can be modified to produce amplitude- or frequency-modulated (AM or FM) rather than continuous-wave (CW) output signals. Figure 10 is the schematic for a beat-frequency oscillator (BFO). It is based on the tuned-collector circuit of Fig. 5, but modified to become a 465-kHz amplitude-modulated (AM) BFO.

A standard 465-kHz IF transformer (T1), intended for transistor circuits, is the LC resonant tank circuit in this oscillator. An audio-frequency AM signal fed to the emitter of Q1 through blocking capacitor C2 will modulate the supply voltage of Q1 and thus amplitude-modulate the circuit's 465-kHz *carrier* signal.

This BFO can provide 40% signal modulation. The value of emitter-decoupling capacitor C1 was selected to present a low impedance to the 465-kHz carrier signal, while also presenting a high impedance to the low-frequency modulation signal.

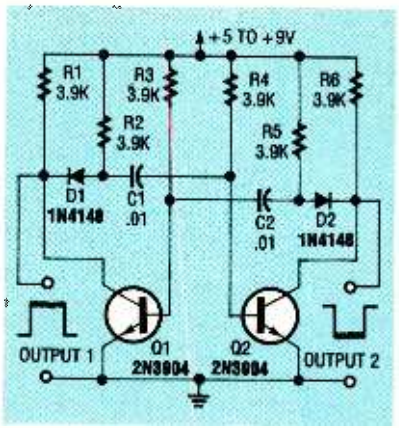

FIG. 15—ASTABLE MULTIVIBRATOR with waveform correction.

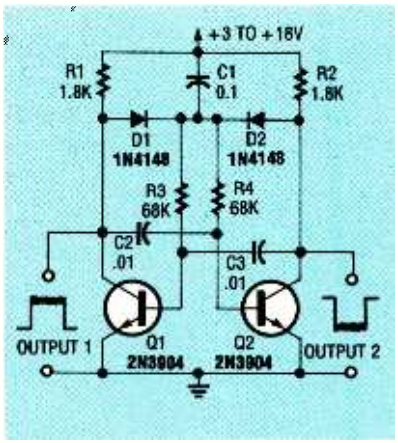

FIG. 16—ASTABLE MULTIVIBRATOR with sure-start capability.

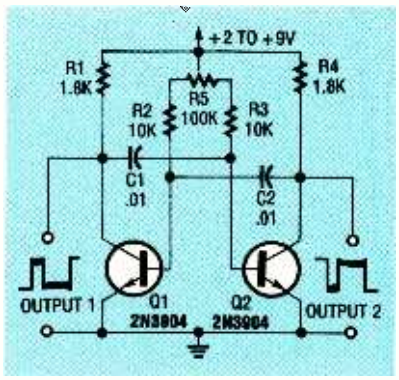

FIG. 17—VARIABLE MARK/SPACE generator runs at 1.1 kHz.

Figure 11 shows how the BFO circuit in Fig. 10 can be modified to become a frequency modulator. Tuning is adjusted by trimmer potentiometer R5. Silicon diode D1 functions as an inexpensive varactor diode. A 1N4001 diode frequency modulates the 465-kHz BFO circuit. Here, C2 and diode "capacitor" D1 are in series.

Consequently, the oscillator's center frequency can be changed by altering the capacitance of D1 with trimmer potentiometer R5, and frequency-modulated signals can be obtained by introducing an audio-frequency modulation signal to D1 through a C1 and R4. Capacitor C2 provides DC isolation between Q1 and D1.

Astable oscillators

Conventional oscillator circuits produce sinewaves, but repetitive square waves are important in electronics. One way to generate them is with the astable multivibrator circuit shown in Fig. 12-*a*.

This multivibrator is a self-oscillating regenerative switch whose on and off periods are controlled by the time constants obtained as the products of R2 and C21, and R3 and C1. If these time constants are equal (because both values of R and C are equal), the circuit becomes a square-wave generator that operates at a frequency of about 1/1.4 RC. The waveforms taken at the collector and base of transistors Q1 and Q2 are shown in Fig. 12-*b*.

The frequency of the astable multivibrator in Fig. 12 can be decreased by increasing the values of C1 and C2 or R2 and R3, or increased by decreasing them. The frequency can be varied with dual-gang variable resistors placed in series with 10-kilohm limiting resistors in place of R2 and R3.

The operating frequency can, if required, be synchronized to that of a higher-frequency signal by coupling part of the external signal into the timing networks of the astable circuit. Outputs can be taken from either collector of the circuit, and the two outputs are in opposite in phase. The multivibrator's operating frequency is essentially independent of power supply voltage between +1.5 and +9 volts.

The upper voltage limit is set by inherent transistor behavior: as the transistors change state at the end of each half-cycle, the base-emitter junction of one transistor is re-

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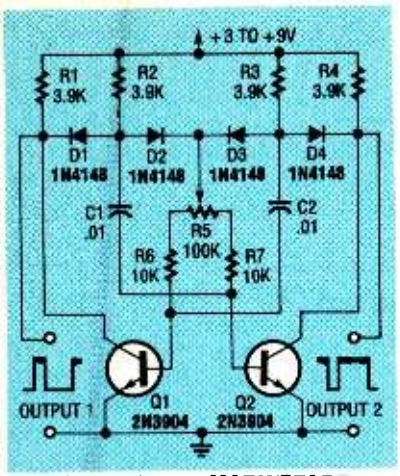

FIG. 18—VARIABLE MARK/SPACE generator features waveform corrrection and sure-start.

verse biased by a voltage that is about equal to the supply voltage. Consequently, if the supply voltage exceeds the reverse base-emitter breakdown voltage of the transistor, circuit timing will be affected.

This characteristic can be overcome with the circuit modifications shown in Fig. 13. A silicon diode is connected in series with the base input terminal of each transistor to raise the effective base-emitter reverse breakdown voltage of each transistor to a value greater than that of the diode.

The protected astable multivibrator will operate with any supply voltage from +3 to +20 volts. Its frequency will vary only about 2% when the supply voltage is varied from +6 to +18 volts. This variation can be further reduced to 0.5% by adding another "compensation" diode in series with the collector of each transistor, as shown in Fig. 13.

Multivibrator variations

The basic astable multivibrator shown in Fig. 12 can be modified in different ways to improve its performance or change the shape of its output waveform. Some modifications are shown in Figs. 14 to 18.

A shortcoming of the multivibrator shown in Fig. 12 is that the leading edge of each of its output waveforms is slightly rounded. The lower the values of timing resistors R2 and R3 with respect to collector load resistors R1 and R4, the more pronounced will be this waveform rounding.

Conversely, the larger the values of R2 and R3 with respect to R3 and R4, the sharper the waveform edge will be. The maximum permissible values of R1 and R2 are, however, limited by the current gains of the transistors. These gains are equal to h_{FE} multiplied either by the value of resistor R1 or R4.

One way to improve the circuit waveform, of course, would be to replace transistors Q1 and Q2 with Darlington transistor pairs and then substitute timing resistance values that are as large as permissible. That is done in the long-period astable multivibrator that is shown in Fig. 14.

Resistors R2 and R3 can have any value between 10 kilohms and 12 megohms, and the multivibrator will run from any supply voltage between +3 and +18 volts. With the R2 and R3 values shown in Fig. 14, the multivibrator's total period or cycle time is about 1 second per microfarad when C1 and C2 have equal values. This multivibrator generates sharp-cornered square waves.

The square waves with the rounded leading edges produced by the multivibrator shown in Fig. 12 are caused by an inherent characteristic of the transistor. As each transistor is switched off, its collector voltage is prevented from switching abruptly to the positive supply value. This is due to the loading between that collector and the base of the adjacent conducting transistor from timing capacitor cross-coupling.

This characteristic can be altered, and sharp square waves can be obtained by effectively disconnecting the timing capacitor from the collector of its transistor as it turns off. That improvement is shown in Fig. 15, a schematic for a 1-kHz astable multivibrator. It includes diodes D1 and D2 that disconnect the timing capacitors at the moment of switching.

The important time constants of the multivibrator in Fig. 15 are also determined by C1 and R4, and C2 and R1. The effective collector loads of Q1 and Q2 are equal to the parallel resistances of R1 and R2, and R5 and R6, respectively.

Basic astable multivibrator operation depends on slight differences in their transistor characteristics. Those differences cause one transistor to turn on faster than the other when power is first applied, thus triggering oscillation.

If the multivibrator's supply voltage is applied slowly by increasing it from zero, however, both transistors could turn on simultaneously. If this happens, the oscillator will be a *nonstarter.*

The possibility of nonstarting can be avoided with the "sure-start" astable multivibrator circuit shown in Fig. 16. There, the timing resistors are connected to the transistor's collectors so that only one transistor can conduct at a time, ensuring that oscillating will always begin.

All the astable multivibrator circuits shown so far are intended to produce symmetrical output waveforms, with a 1 to 1 ratio of square wave to space (1:1 mark/space ratio). Nonsymmetrical waveforms can be obtained by installing one set of RC astable time constant components that is larger than the other.

Figure 17 shows a 1.1 kHz variable mark/space ratio generator. The ratio can be varied over the range 1 to 10 with trimmer potentiometer R5. However, the leading edges of the output waveforms of this circuit could be too round for some applications when mark/space control is set at its extreme position. Also, this generator could be difficult to start if the supply voltage is applied slowly to the circuit.

Both of those drawbacks can be overcome with the modifications shown in the schematic of Fig. 18, another 1.1-kHz variable mark/space ratio generator. The circuit includes both sure-start and waveform-correction diodes. Ω

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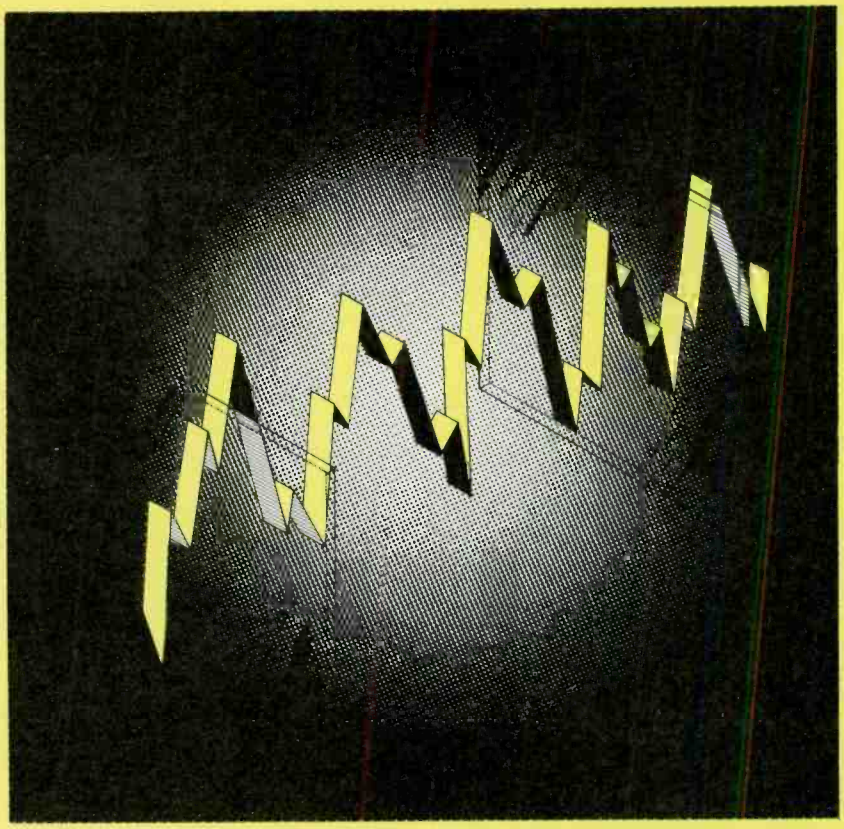

ELECTRONIC NOISE

If you know what causes internal electronic noise you can select components to minimize its effect on your circuit

WE RECOGNIZE TWO KINDS OF ELECtronic noise—external and internal. External noises can be man-made—originating from such sources as motors, relays, and auto ignition—or natural—originating from lightning or aurora. Its effects can usually be eliminated by proper shielding. By contrast, internal noise is generated within your circuit; it can have many different causes and the best way to combat it is to pick your components with care.

Think of internal noise as a limiting factor on the smallest signal that can be amplified by your circuit. We can't eliminate it entirely, but we can minimize its effect. You will not have to worry too much about internal noise in your digital circuits or power amplifiers, but if you're designing or building audio amplifiers or sensitive instruments for scientific experiments, it will be very important to you. As you might expect, internal noise shows up when the input signals are small. It's still there when the input signals get bigger although it's likely to be masked.

It's most important to deal with noise in the first stage. If you deal with it there, you won't have to worry about subsequent stages. Internal noise is completely random; we can't predict what it will do to the output at any given time. Passive components such as resistors usually have a single noise mechanism, but transistors can have three or more sources. Figure 1 shows what random noise might look like on an oscilloscope.

Properties of random noise

Two properties can be determined for random noise: the average energy (or power) produced by the noise, and the average frequency distribution of this energy—commonly called the power spectrum. The average power can be thought of as the net effect of many actions in the random phenomenon. (It's analogous to the square of the rms value of a sine wave, which refers to the sine wave's average effect without considering time.)

It's impossible to predict noise amplitude or phase at any given time. Consequently, it is customary to work with a noise frequency spectrum—the average noise level as a function of frequency. Independent noise voltages do not add linearly. If two sources are independent, the noise power is added, not the voltage. Because of their random phases, the sources can be in phase and add, and they can be out of phase and destructively interfere with each other. The average over phases is calculated by taking the root-mean-square sum of the sources. Average amplitudes are squared and added, and the total noise is the square root of the result. (This is also known as adding in quadrature.) For two equal sources, the sum has an amplitude that is twice that of the individual amplitudes.

Of the many possible power

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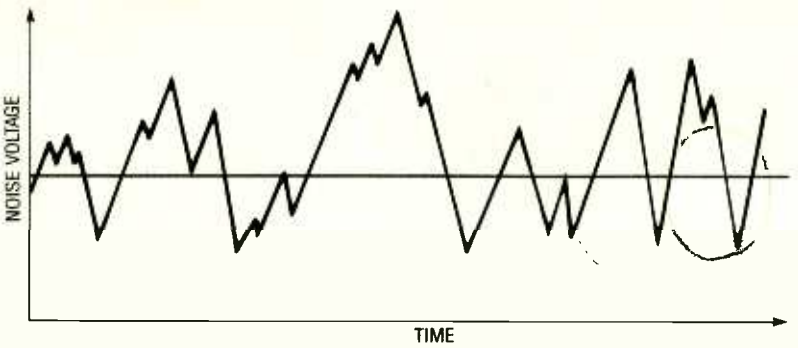

FIG. 1—RANDOM INTERNAL NOISE as viewed on an oscilloscope. The power spectrum of thermal noise is flat. Whenever noise has a flat power spectrum, it can be considered as containing components of all frequencies and is called "white" noise.

spectrums of random waves, we will be concerned with two types: a power spectrum that is "flat," that is, the power density at all frequencies is equal; and a power spectrum that varies with frequency. The most basic type of noise, thermal noise, has a flat frequency spectrum and is called "white" noise. If its spectrum varies with frequency, it's called "pink" noise.

In noise analysis, the important variable is noise power, the square of the noise voltage divided by the characteristic impedance. However, for circuit modeling, it is usually easier to work with the noise voltage, e_n. Noise power is related to the frequency bandwidth, B, so the noise voltage is proportional to the square root of the bandwidth. Noise power is measured in units of microwatts per hertz, so noise voltages are expressed in units such as nanovolts per root hertz, with the square root obtained from the power-to-voltage conversion. Because noise power varies with frequency, noise specifications must include the measurement frequency.

Figure 2 is an equivalent circuit for a signal source-amplifier combination. The signal source could be an antenna, microphone, or a sensor such as a strain gauge, thermocouple, or RTD. The input signal source is shown as a voltage generator, V_s, in series with a source noise voltage, e_{ns}, and a source impedance, Z_s. The amplifier input is modeled as an amplifier noise voltage, e_{na}, amplifier current noise, i_{na}, and amplifier input impedance, Z_a. In a properly designed circuit, only the first stage noise need be considered; the gain of the first stage is high enough so that noise from succeeding stages can be neglected.

In addition to amplifying the signal, the succeeding stages will also act as filters. Because noise is broadband, it is advisable to design for the narrowest possible bandwidth to limit the output noise. It is also important to match the amplifier input impedance with the signal source output impedance to prevent signal loss and a reduction in the signal-to-noise (S/N) ratio. Thus, the input impedance of the signal source determines the choice of amplifier circuit. For example, FET's are selected where high input impedances are required and bipolar transistors are selected where that parameter is not quite as important.

Many different noise sources can be present in a single device so the output spectrum can be complex. Figure 3 maps the regions where the various noise types predominate in the frequency domain. There are many different designations for the same type of internal noise.

Thermal noise

Thermal noise is the most common type of noise in electronic components. (It is also called resistive noise, Johnson noise, and Nyquist noise). Because it is present in every electric conductor (whether or not it is connected), it is present in every electric circuit. Thermal noise is due to the random motion of free electrons within a conductor with resistance. In addition to their forward motion, electrons exhibit random (or Brownian) motion, which introduces current fluctuations. In an ideal resistor, the thermal noise voltage is given by

$$e_n = \sqrt{4kTRB}$$

Where e_n = mean value of noise voltage, k = Boltzmann's constant = 1.38×10^{-23} Joules/Kelvin (absolute), T = temperature of conductor in Kelvins, (Room temperature is approximately 300 K), R = resistance (or real part of a complex impedance) in ohms, B = frequency bandwidth in hertz = $f_2 - f_1$.

kT represents the average available thermal energy. The appearance of the term kT in most noise expressions suggests that cooling might be a suitable noise reduction technique. Unfortunately, cooling individual components is difficult and often impractical. Moreover, as will be noted in the discussion of semiconductors, some noise actually increases with cooling.

Shot noise

Shot noise is present in any electronic device where electrons move across a potential

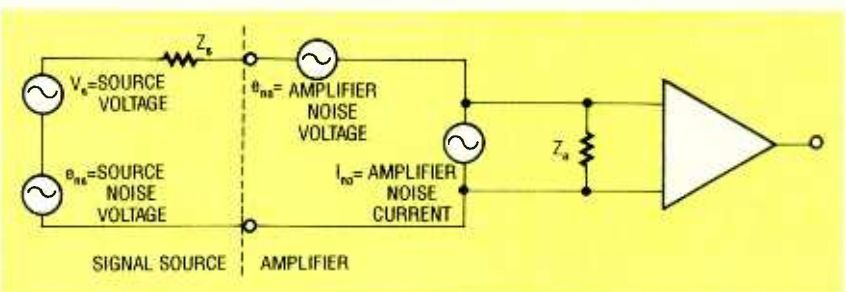

FIG. 2—NOISE EQUIVALENT CIRCUIT for a source-amplifier combination.

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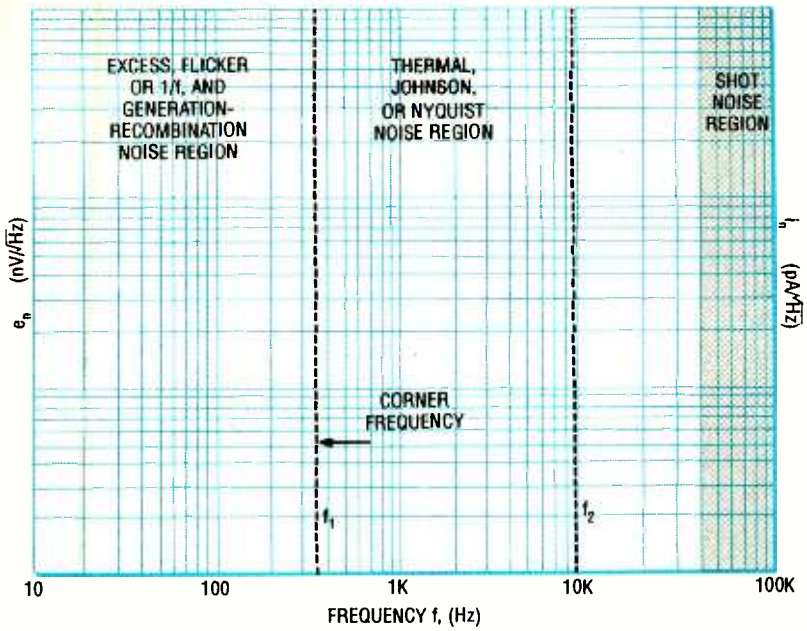

FIG. 3—MAP OF REGIONS OF INTERNAL NOISE in the frequency domain. The variable e_n is the equivalent short-circuit noise voltage and the variable i_n is the equivalent open-circuit noise current.

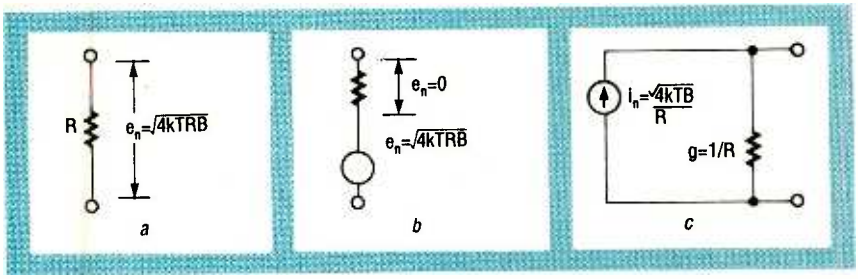

FIG. 4—NOISE VOLTAGE OF A RESISTOR and its equivalent circuit; (*a*) thermal noise across resistor; (*b*) voltage equivalent circuit for a resistor; (*c*) current equivalent circuit.

barrier in a random manner. For example, a noise current flows through a diode as a result of current pulses produced by individual charge carriers.

Excess noise

Another common noise source in electron devices is excess noise. (It is also known as flicker noise, 1/*f* noise, current noise, contact noise, or defect noise.) This noise is inversely related to frequency. A 1/*f* spectrum is one in which noise power amplitude increases linearly with decreasing frequency; the lower the frequency, the higher the noise level. Excess noise occurs because the resistive material is not uniformly distributed in the component. Thus some electrons encounter higher resistance than others. These non-uniform paths lead to current flow variations or noise. Because it is electron-flow dependent, excess noise is proportional to the current through the resistor. In active devices the causes are more complex, but they relate to crystal lattice and surface effects. Excess noise is generally expressed by a noise index in decibels.

Generation-recombination

The doping centers of semiconductors also generate noise. Electron-hole pair generation and recombination at these centers creates generation-recombination (GR) noise. It is frequency-dependent and has a complex spectrum. For a single site, the spectrum is considered to be 1/*f* although this is an approximation. When the noise from a large number of sites of varying activity levels is added, the spectrum becomes more complex and can vary with temperature in very unpredictable ways.

Two other potential noise sources are avalanche noise and crystal defects (popcorn noise). Avalanche noise occurs when a PN junction is reverse biased into breakdown, producing a current avalanche. This event can damage the junction, permanently increasing its noise level. Popcorn noise is caused by a temporary breakdown within the device. It shows up as a current flow with a duration varying from milliseconds to seconds. This noise source is difficult to characterize because it is intermittent. However, it can be observed on an oscilloscope.

Avalanche and popcorn noise will not be covered in greater detail because they can usually be avoided by proper care in device selection and handling. You can avoid this noise by operating semiconductor devices within their rated voltage and current limits.

Noise in resistors

Figure 4 illustrates noise equivalent circuits for a resistor. Figure 4-*a* represents thermal noise across the resistor, Fig. 4-*b* is the voltage equivalent circuit of the resistor shown as a voltage source in series with a noisless resistor. Figure 4-*c* is the shot noise equivalent circuit of a resistor shown as a current generator in parallel with a noisless resistor. Referring to the thermal noise equation, it should be noted that kT is roughly 4×10^{-23} Joules at room temperature, so

$$e_n = \sqrt{(R/64)B}$$

Thus a 64-ohm resistor has a noise of 1 = nV per root hertz. Another useful relationship is that a 1-K resistor has a noise level of about 4 nanovolts per root hertz. Thus a 20K resistor has an average noise level of 2.5 millivolts when measured over a 20-kHz (audio) bandwidth.

Excess noise can also be present in a resistor. It can be reduced by minimizing the voltage drop across the resistor.

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TABLE 1—
RESISTOR EXCESS NOISE

Material	Excess noise (dB)
Metal oxide	−15 to −40
Wirewound	−15 to −40
Carbon-film	−5 to −25
Carbon composition	+10 to −20

Excess noise is related to resistor materials, as shown in Table 1. Proper resistor selection can help to keep it low.

Noise in capacitors

Capacitors introduce two sources of electrical noise: leakage and dielectric loss. Leakage noise occurs because capacitors, like resistors, have finite resistance values. Fortunately, that resistance is effectively in parallel with the capacitor's capacitative impedance, a much smaller value, which effectively shorts the leakage noise.

Dielectric losses occur as a capacitor charges and discharges. In each cycle a small portion of the stored energy is dissipated in the dielectric medium. This dissipation is characterized by a factor called the dielectric loss angle, which generally corresponds to the fraction of energy dissipated. The loss angle is related to the dielectric, ranging from 10^{-2} to 10^{-4}. The noise voltage for capacitors is:

$$e_n = \sqrt{4kTdB/\omega C}$$

where C = capacitance in farads, d = the dielectric loss angle, and $\omega = 2\pi f$.

Noise can be minimized by choosing a capacitor based on its dielectric loss angle. Table 2 lists typical dielectric loss angles for capacitors.

If noise is to be reduced in large-value capacitors, tantalum capacitors are preferred because tantalum oxide has a lower dielectric loss than aluminum oxide. However, loss angle for tantalum capacitors varies with dielectric properties, manufacturing process, and temperature. By contrast, noise output is highest in aluminum electrolytics. It is well known that electrolytic capacitors must be properly polarized at all times. What's not so well known is that in addition to possible damage, accidental polarity reversal can trigger noise bursts that take several hours to subside.

TABLE 2—CAPACITOR DIELECTRIC LOSS ANGLES

Dielectric	Approximate loss angle (d)
Teflon	10^{-4}
Mica	10^{-3}
Paper	10^{-2}

Noise in inductors

Inductor noise is rarely of serious concern in circuit design because of its low level. Inductors generate noise in much the same way as capacitors. When they store energy, some of it is dissipated, creating a noise current, but it is generally at very low levels.

Noise in diodes

Shot noise is the principal source of noise in diodes. Actually two separate currents contribute to noise in a forward-biased diode: thermally generated minority carriers flow across the junction in one direction, and majority carriers diffuse across the barrier in the opposite direction. The size of those currents depends on the voltage. With no applied voltage, the two currents are opposite and equal, and the average net current is zero. However, the two currents are independent, and each contributes noise, even when their sum is zero. In a reverse-biased diode only leakage current is a factor in noise.

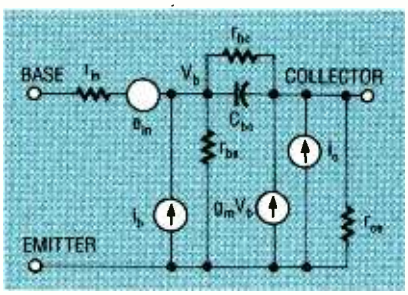

FIG. 5—HYBRID PI EQUIVALENT circuit of a transistor.

The noise current from shot noise in a diode is given by

$$i_n = \sqrt{2qIB}$$

Where q = the charge of the electron = 1.6×10^{-19} coulomb and I = bias point or average value of junction current.

Noise in transistors

Transistors are the sources for at least three types of noise: thermal noise, shot noise and excess noise. Thermal noise occurs in the bulk semiconductor material like thermal noise in resistors. Shot noise occurs at the PN junctions of semiconductor devices because of the flow of discrete electrons across the junction, each carrying one unit of charge.

Shot noise is a major noise source in bipolar transistors, but it is less significant in FET's. Both PN junctions in bipolar transistors conduct significant current, but because FET's do not have current flowing across PN junctions, shot noise can be ignored.

Data sheets for transistors typically specify noise with two curves, one for noise voltage and one for noise currrent, as a function of frequency. At high frequencies, transistor performance falls off, so the signal-to-noise ratio suffers. It is advisable to choose transistor devices that operate in their mid-band range, although for very high frequency circuits this may not be possible.

Bipolar transistors

Figure 5 is a simplified hybrid pi equivalent circuit of a bipolar transistor. The generator $g_m V_b$ produces a current proportional to the voltage across resistor r_{be}. In more familiar terms, $\beta = g_m r_{be}$. For small signals, $g_s m$ can be shown as qI_C/kT.

The resistors represent internal resistances in the transistor. Each has an associated thermal noise generator. Resistor r_{in} represents the base contact resistance, typically a few hundred ohms. Because it occurs at the input, its noise contributes directly to the transistor noise. Resistor r_{bc} is usually very large but, because it is in parallel with capacitor C_{bc}, the noise is shunted, and can be neglected. Similarly, r_{ce} is large

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and in parallel with the output, so its noise can be neglected. The effective base-emitter resistance, r_{be}, is $\beta kT/qI_c$. Because it is not a real resistance, it does not contribute noise.

The total transistor noise can be represented by a voltage generator and two current sources at the transistor input and output. The input voltage generator represents the noise from resistor r_{in}. The input current generator accounts for the shot current across the base-emitter junction as well as the generation-recombination noise. The output current generator accounts for the shot noise across the base-collector junction.

Generation-recombination noise in a transistor is generally represented as a single spectrum source added to the base-collector shot noise. It is given by

$$I_{gr} = \sqrt{(KI_b/f)B}$$

Where K = a constant for the transistor and I_b = the base current.

Generation-recombination activity is proportional to current. Because the recombination sites are dispersed throughout the transistor, rigorous determination of an equivalent voltage can be complicated. The base resistance, r_{in} is often used for this; mismatches are absorbed in the constant K. High 1/*f* noise often indicates faults in the device and is correlated with low transistor reliability.

Typical noise curves for a bipolar transistor are shown in Fig. 6. As the collector current increases, transistor gain rises, so the noise voltage drops. However, the noise current (shot noise) rises with the increased current. The relative sizes of these two sources must be considered in choosing the minimum noise operating point. At low frequencies, 1/*f* or flicker noise dominates. Where graphs are not given, a third parameter, the corner frequency, might be given. This is the frequency at which 1/*f* is equal to the mid-range noise.

Table 3 gives examples of mid-range voltage and current noises for typical bipolar transistor. At a lower collector current, for example 1 microampere, the 2N4250 noise voltage rises to 2.2 nanovolts per root hertz, while the noise current drops to 0.5 picoampere per root hertz. Because the relative contributions to total noise from noise voltage and noise current depend on the input source impedance, the optimal operating current also depends on this impedance.

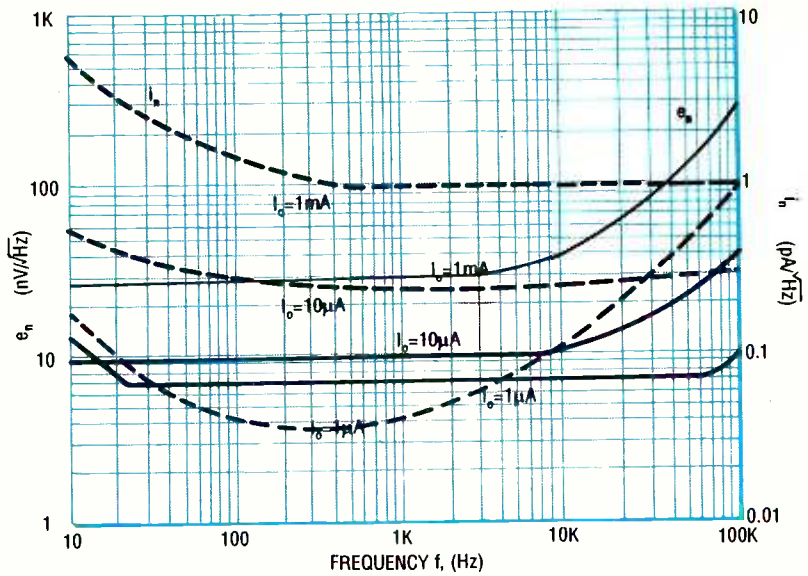

FIG. 6—TYPICAL NOISE CURVES FOR A BIPOLAR TRANSISTOR.

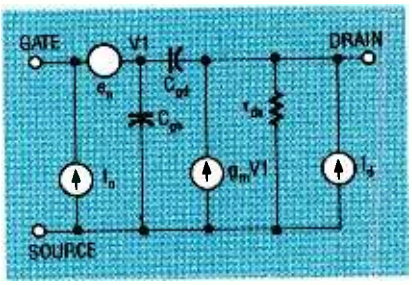

FIG. 7—NOISE EQUIVALENT CIRCUIT for a JFET.

TABLE 3—TYPICAL BIPOLAR TRANSISTOR NOISE VALUES

Transistor	IC	Noise voltage	Noise current
2N404	1 mA	2.0 nV/√Hz	1.8 pA/√Hz
2N4250	1 mA	1.6 nV/√Hz	1.2 pA/√Hz
2N4124	1 mA	1.8 nV/√Hz	1.4 pA/√Hz

Field-effect transistors

Field-effect transistors (FET) have noise sources that are similar to those in bipolar transistors, but they have different levels. Figure 7 is an equivalent circuit of a JFET for noise analysis. The current generator g_mV1 amplifies the signal and produces a current proportional to the voltage V_{gs}. The value r_{ds} represents the channel resistance, C_{gd} and C_{gs} represent the capacitance of the junction, and C_{ds} represents the distributed channel capacitance.

Most of the voltage noise in an FET is caused by the bulk resistance of the channel. Because this channel resistance is distributed over the entire channel, this noise is fed back to the input via the transconductance, g_m, in a complex manner. A detailed analysis leads to the relationship

$$e_n = \sqrt{4kT\,(0.7/g_m)B}$$

Where $0.7/g_m$ is the noise coefficient for a FET.

In most cases, this formula provides satisfactory estimates of the voltage noise. However, at high frequencies, the channel noise is also transmitted through C_{gd}. This shows up as an apparent increase in current noise at high frequencies.

To minimize e_n, you can maximize g_m by choosing a FET with a large g_m and biasing it to

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a maximum. This occurs at the maximum drain current, with V_{gs} close to 0. However, in selecting a FET for maximum gm, an input- capacitance problem is introduced. Voltage noise is reduced with the selection of large FET's because of their higher g_m, or by using multiple FETs in parallel. However, the input capacitance rises in both those options. When the FET capacitance becomes comparable to the source impedance, the signal coupling drops, and the signal-to-noise (S/N) ratio falls. To maximize the S/N ratio, the FET must be matched to the source impedance.

At lower frequencies, noise from generation-recombination centers adds to the noise voltage. As in bipolar transistors, the 1/*f* noise amplitude cannot be calculated so it must be measured. It has a complex temperature dependence because majority and minority carriers have contributions that vary with temperature. Because of the temperature dependence, moderate cooling of an FET can lead to an increase in noise.

The main source of current noise in an FET is the gate leakage current that appears directly at the gate. This is given by the equation:

$$i_n = \sqrt{2qI_gB}$$

As with bipolar transistors, FET noise is specified by graphs of noise current and noise voltage as a function of frequency. A typical characteristic is shown in Fig. 8.

Single numbers can be given for midrange noise voltage and noise current. Because 1/*f* noise is a problem only at low kilohertz frequencies, and reflected noise is generally quite small, these two numbers are usually usable over a wide range of frequencies. Because of their low junction current, JFET's emit much lower noise current than bipolar transistors while JFET noise voltage is typically slightly higher. Table 4 gives some typical noise figures for JFET's.

The noise equivalent circuits for MOSFET's are similar to those for JFET's. However, a MOSFET does not have a PN junction so it does not exhibit leakage current or shot noise. However, MOSFET's have a much larger 1/*f* noise voltage, 10 to 1000 times that of a JFET. For this reason, MOSFET's are used only in applications requiring very high source impedances and frequencies.

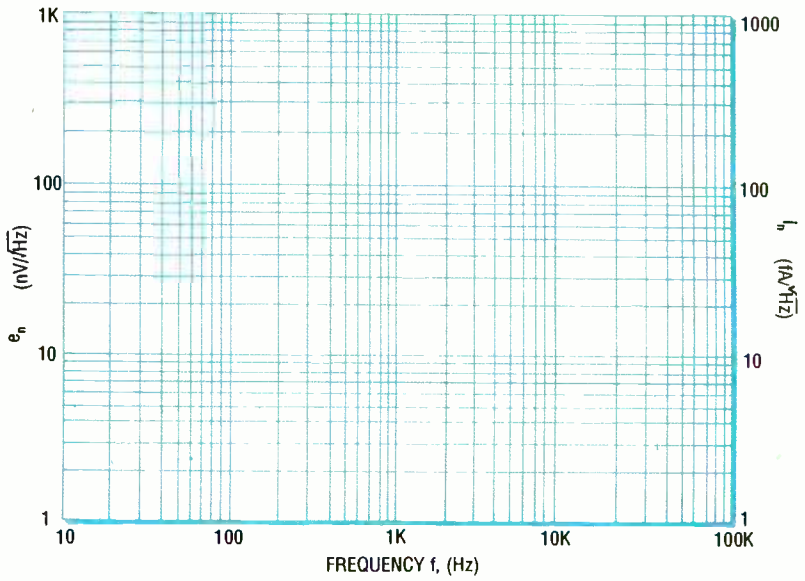

FIG. 8—TYPICAL NOISE CURVES FOR A JFET.

Noise in IC's

Noise equivalent circuits for integrated circuits consist of equivalent circuits for their included components. IC's exhibit slightly higher noise levels than equivalent discrete device circuits because their fabrication requires tradeoffs that err in the direction of higher noise. However, these differences are diminishing because of IC fabrication improvements, and the slight handicap in terms of noise is offset by the IC's benefits such as lower power consumption, higher reliability, and smaller size.

The noise generating elements in IC's are concentrated at the input stage, so noise modelling should focus on the input device, whether it is a JFET or a bipolar transistor. For simplicity, noise specifications of IC's are lumped together as an e_n and i_n referred to the input. The noise current might not be given for a JFET input IC because it is so small. Table 5 gives typical values for some popular IC's. The corner frequency, below which 1/*f* noise is large, is only 2.7 Hz.

TABLE 4—TYPICAL JFET NOISE VALUES

JFET	Noise voltage	Noise current
2N4416	2.0 nV/√Hz	2.0 fA/√Hz
2N4469	2.7 nV/√Hz	7.0 fA/√Hz
2N5266	12 nV/√Hz	5.0 pA/√Hz

TABLE 5—TYPICAL ANALOG IC NOISE VALUES

Device	Noise voltage	Noise current
741 op amp	25 nV/√Hz	0.7 pA/√Hz
OP-37 op amp	3 nV/√Hz	0.4 pA/√Hz
LF357 op amp LFET input	12 nV/√Hz	10 fA/√Hz

Designing for low noise

Ideally, noise should be one of the first considerations in designing a circuit. Many noise-reduction techniques are fundamental to the design process. Most noise sources are wideband so the circuit should have the narrowest possible bandpass. Frequency shifters can reduce the bandwidth. By converting RF to a lower-frequency

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IF, it is easier to select only the desired frequency range. At very low frequencies, where $1/f$ noise is likey to cause problems, it might be desirable to chop or upconvert that low-frequency signal to a higher band, especially if the signal source can be modulated.

A second major consideration is the selection of the first-stage active device, which usually depends on the frequency that the device must operate at and desired input impedance. For simple projects, the obvious choices are bipolar transistors or JFET's. For special projects such laboratory equipment, the designer might wish to use more exotic (and expensive) devices such as Josephson junctions, superconducting quantum interference devices (SQUID's), or tunnel-diode parametric amplifiers, all of which offer very low-noise inputs.

The crucial factor in bipolar transistor or FET selection is input impedance; FET's are inherently high-impedance devices, while bipolar transistors are lower impedance devices. Bipolars are favored for impedances in the 100-ohm to 1 megohm range, JFET's are satisfactory above 1K, while MOSFET's are the best choices for impedances above 1 megohm. If the input conditions are not established or subject to variation, as in an oscilloscope input, a JFET is preferable. JFET's offer much lower noise current than bipolar transistors, but their noise voltage is only slightly lower. Except when they must operate at very high frequencies, MOSFET's are at a disadvantage because of their large $1/f$ noise.

Once a device type is selected, the next step is to choose a specific device. This can be done by looking at the noise specifications on the data sheets. For best noise performance, it is advisable to choose a device that is operating in its midrange. Also, high-gain devices generally exhibit lower noise.

It is important that signal impedance be matched. Compare the source impedance (a function of frequency) vs. the device's noise current and voltage at the operating frequency, input impedance, and operating point. If the source impedance is less than a few hundred ohms, transformer coupling should be considered. Remember that if two FET's are in parallel, the effective input impedance will be halved. This doubles transconductance and noise current noise while halving the noise voltage.

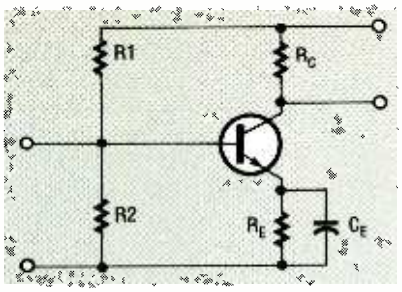

FIG. 9—COMMON-EMITTER AMPLIFIER with traditional biasing.

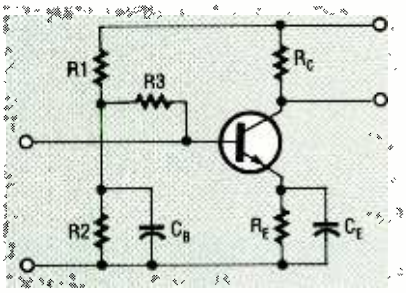

FIG. 10—COMMON-EMITTER amplifier with low-noise biasing. Noise from resistors R1 and R2 is shunted to ground by the capacitor.

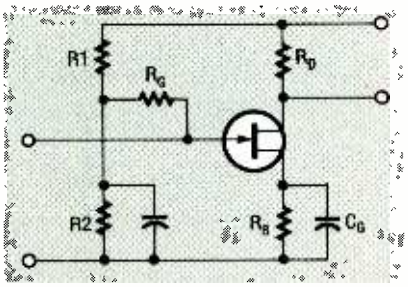

FIG. 11—JFET AMPLIFIER biased for low noise.

Suprisingly, feedback has little effect on noise performance. Except for the possible introduction of noise from the feedback resistors, the addition of feedback does not affect the S/N ratio. Also, the amplifier configuration—common base, common emitter, or common collector—does not significantly affect device performance. This gives you the freedom to choose the amplifier configuration that best matches the signal source impedance.

The next step is biasing. Figure 9 shows a typical common-emitter amplifier stage. For a high-gain stage, R_C is unlikely to contribute noise, and noise produced by R_E is shunted to ground by C_E. Resistors R1 and R2 bias the base. For minimizing amplifier noise, the values fo those resistors should be as small as possible.

Because these resistors have significant voltage across them, resistor excess noise must be considered. A tradeoff might be necessary. If calculations indicate that the excess noise is a problem, the circuit shown in Fig. 10 can be used. Noise from R1 and R2 is shunted by C_B. Only R3 contributes noise, but because the voltage drop across this resistor is low, excess noise does not present a problem. The analysis for a common-collector amplifier stage is similar to the common-emitter except that in this case the emitter resistor should be as large as possible to maximize the gain.

JFET biasing is illustrated in Fig. 11. Because of the low FET leakage current, R_G can be quite large so that it does not contribute much noise. Because a JFET's channel effectively isolates it from the gate, R_S and R_D are decoupled from the input. Therefore, noise from those resistors appears in the second stage, after the input signal has been amplified by the FET.

Once the input stage is designed, be sure that external noise is excluded. This means ensuring that the input signal source and input stage are well shielded and noise from the power supply is filtered out. Low-inductance capacitors can bypass power supply noise effectively. For more demanding applications, it might be necessary to use a separate modular power supply. In extreme cases, the isolation of a battery might be required. **R-E**

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STATIC ROM

Build your own EPROM emulator for less than $60.00!

FRED EADY

THIS ARTICLE IS DEDICATED TO ALL electronics experimenters who have discovered the microcontroller. Developing a new microcontroller-based project is rewarding, but it can be difficult even with the aid of a microcontroller simulator. After all, you can't flash an LED or write to an LCD with a simulator because programs don't energize relays—hardware under program control does. Our inexpensive Static-ROM project is designed to be an alternative to the expensive professional microcontroller emulation systems. The Static-ROM in combination with an assembled 8048 board (discussed in greater detail later on) is the perfect learning tool for the beginner, and the perfect debugging tool for the experienced microcontroller user.

Designing projects that use EPROM (Erasable Programmable Read Only Memory) technology without reliable and helpful hardware tools can be an iterative and painful process. Each time you change the firmware embedded in the EPROM for your project, you must remove, erase, reprogram, and remount the EPROM. Even if you have dozens of EPROM's, and cycle through them as you change your firmware, it is still very time consuming. An alternative to development with EPROM's is the use of battery-backed RAM modules. But they are expensive, require special programming tools and techniques, and you still have to remove and remount them. Wouldn't it be nice to be able to emulate the EPROM in your project and eliminate the vicious erase/program cycle? Wouldn't it be nice to be able to build your own EPROM emulator in an evening for less than $60.00?

Our Static ROM project is named for its ability to emulate ROM (Read-Only Memory) with static RAM (Random-Access Memory). It plugs in directly where the EPROM would go, and eliminates the hassle of EPROM swapping. An average program change and load to Static-ROM takes less than a minute; it takes a minimum of 15 minutes to erase an EPROM!

Static ROM can be made to emulate the EPROM family from 2716 to 27256 simply by switching EPROM emulator cables. In addition, Static-ROM provides an automatic processor-reset pulse (active-high or active-low) after your program download that can be used to restart your target processor.

Operation

The Static-ROM is built around the PIC16C55 CMOS microcontroller (IC3 in Fig. 1). The 28-pin PIC16C55 provides one 4-bit and two 8-bit bi-directional I/O ports, as well as a timer/counter input, clock input, and clear input. The PIC16C55 contains 512 bytes of EPROM and 32 bytes of RAM. That doesn't seem to be much, but good things come in small packages. The EPROM bus is 12 bits wide, while the RAM bus is standard 8 bits wide. The 12-bit EPROM bus allows the use of a simple and powerful instruction set with emphasis on high-speed bit, byte, and register operations. There are only 33 12-bit instructions for the PIC16C55. With a 4-MHz clock, each instruction is executed in 1 microsecond. Its beauty lies in the power and simplicity of the PIC16C55 instruction set, as it takes less than 60 instructions to implement the entire algorithm for Static ROM.

The algorithm programmed into IC3 reads the STROBE line of parallel port 1 or 2, responds on the BUSY line of the respective parallel port, and supplies control line signals and sequential-address information to the 43256 static RAM, IC4. Terminal software controls the selected parallel port, and communicates with the PIC16C55 and the user while routing binary user-written data to IC4. The PIC16C55, as implemented in the Static-ROM, is essentially an intelligent 15-bit up-counter triggered by the parallel port STROBE line and synchronized with the parallel port BUSY and END lines. The END input on the PIC16C55 serves as an end-of-download indicator, and also supplies the reset pulse for the target system's processor. Resistor SIP's R4 and R5 perform the necessary pull-up functions for the PIC16C55 output lines.

Static RAM chip IC4 (a 43256) holds all of the downloaded user-generated binary EPROM image data. If your application does not use raw binary data, Static-ROM does not care—it downloads whatever the terminal program sends. Therefore, special tables and unique characters can also be downloaded and used during emulation. The 43256 has the equivalent storage capacity (32K) of the 27256 EPROM. Only the amount of storage necessary to emulate a particular EPROM is used during actual emulation. In the program-download mode, the address lines of IC4 are controlled by the PIC16C55. In the EPROM-emulation mode, the 43256 is con-

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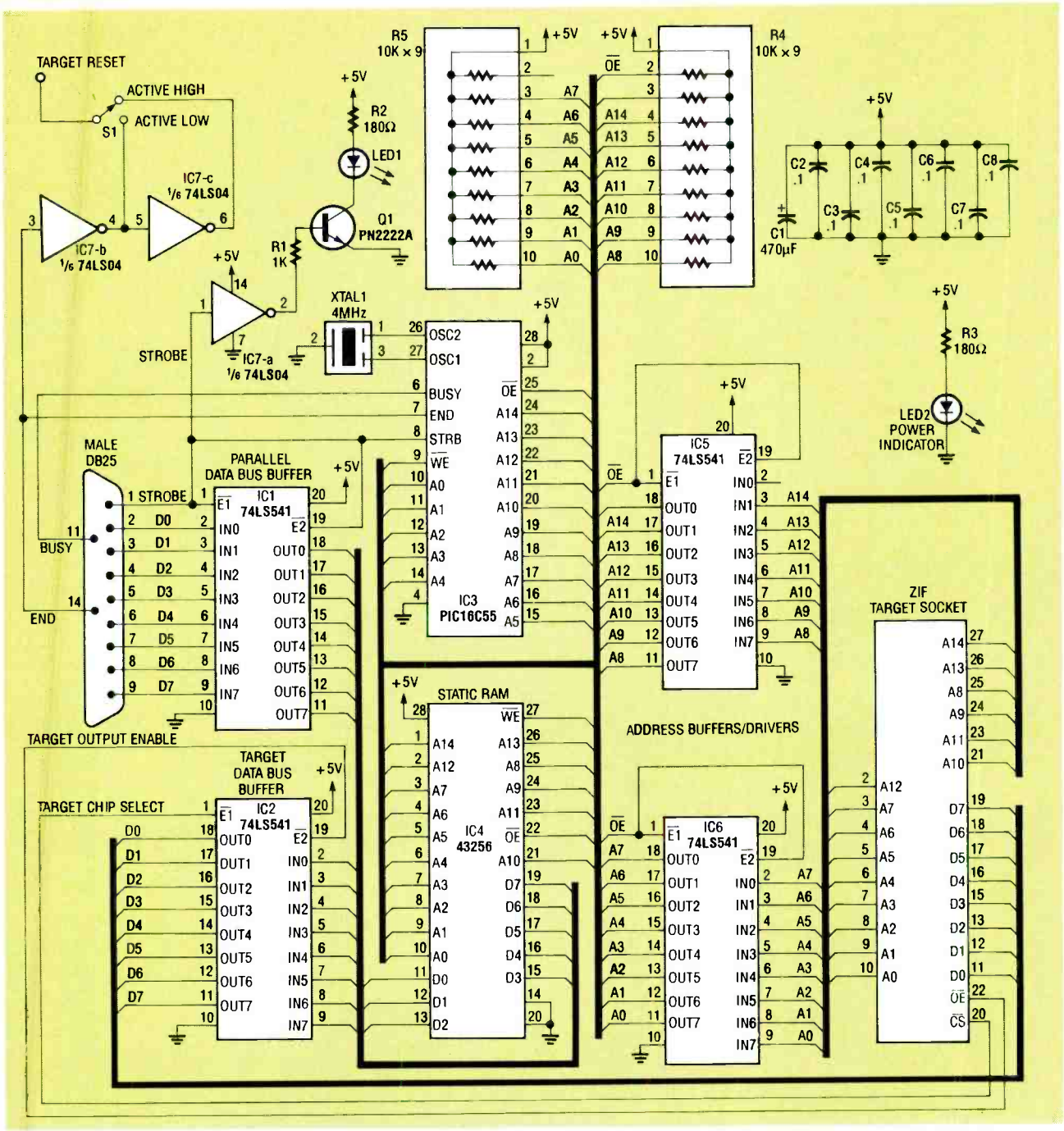

FIG. 1—THE STATIC-ROM is built around IC3, a PIC16C55 CMOS microcontroller that has one 4-bit, and two 8-bit bi-directional I/O ports, 512 bytes of EPROM, and 32 bytes of RAM.

nected via address and data buffers to the target system exactly as an EPROM would be. The target system does not know the difference.

While the PIC16C55 is generating address information for the static RAM, the static RAM address and data lines must be isolated from the target system's address and data lines to eliminate any conflict, and the static RAM data lines must be gated to the data lines of the parallel port. IC1, a 74LS541, provides the gate for incoming data from the parallel port. The chip passes data to the 43256 static RAM when the STROBE line is active (TTL low). When the STROBE line is inactive, IC1 isolates the parallel port data bus from the static RAM data bus.

When in the EPROM-emulation mode, the STROBE line is in the inactive state, which allows the static RAM data bus to be used exclusively by the target system. During the download cycle, the PIC16C55 emits a BUSY signal to the parallel port, and generates the WRITE ENABLE ($\overline{WE}$) signal required to store data in the 43256. During the BUSY time, the PIC16C55 generates the $\overline{WE}$ signal that writes the incoming data to RAM, increments the address counter,

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updates the address lines to RAM, and checks for the END signal. Before dropping the BUSY line, the PIC16C55 also verifies that STROBE has gone from an active to an inactive state. The terminal program senses an active BUSY line and stops data transfer until the BUSY line is made inactive or cleared by the PIC16C55.

Another 74LS541 octal buffer, IC2, has its ENABLE lines tied directly to the target system EPROM CHIP SELECT ($\overline{CS}$) and OUTPUT ENABLE ($\overline{OE}$) lines. When the target system processor is fetching data from the Static-ROM (which it thinks is an EPROM), IC2 gates IC4's data bus to the target processor's data bus. When the target EPROM's select lines are inactive, the outputs of IC2 float, thus isolating the RAM's data bus. That allows the processor data bus to be used by other devices requiring its services.

The incoming address lines are buffered by IC5 and IC6 from the target system. The enable lines for IC5 and IC6 are tied directly to the PIC16C55 OUTPUT ENABLE ($\overline{OE}$) pin. The PIC16C55 disables IC5 and IC6 during program download and enables the line after target processor reset. Those two IC's provide isolation from the target system address lines during program download, and act as target-system address-line drivers during EPROM emulation. That allows the Static-ROM to download a new software image regardless of the state of the target system.

Inverters IC7-b and IC7-c provide an active-high or active-low RESET pulse in synchronization with the END input from the parallel port. Gate IC7-a, driven by the parallel port STROBE signal, drives the base of switching transistor Q1 via R1 to indicate program download activity with LED1 and R2. Upon sensing an active END signal, the PIC16C55 resets its internal address counter to zero, refreshes the address bus to RAM, floats the address lines to RAM, enables the address buffers (IC5 and IC6), and waits for the next active STROBE signal from the parallel port. Upon receiving an active STROBE signal, the PIC16C55 disables IC5 and IC6, which isolates the Static-ROM address bus from the target. The processor then proceeds with loading the incoming data from the parallel port into RAM. Once the download is complete, the cycle repeats.

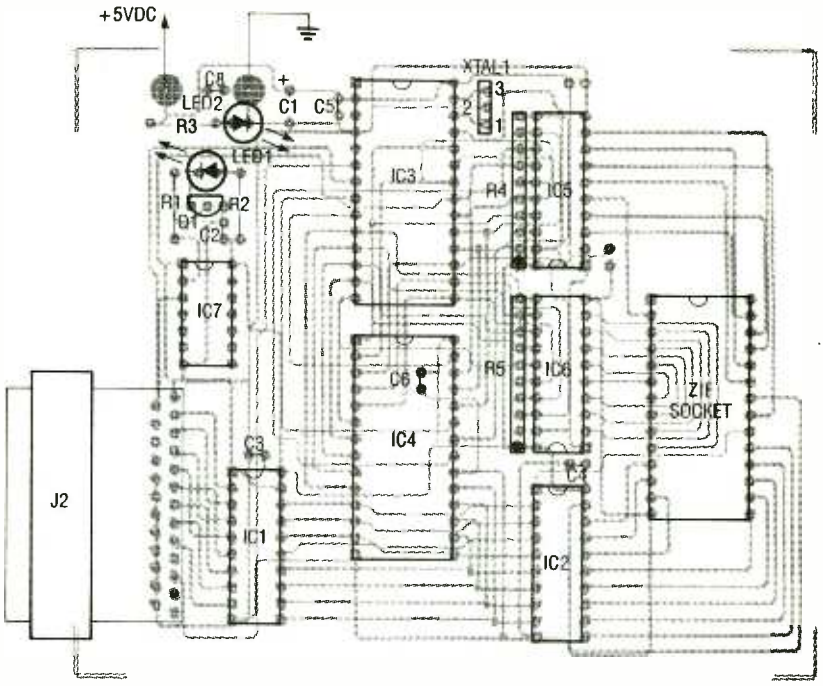

FIG. 2—INSTALL ALL PARTS as shown here. Note that IC5 and IC6 are mounted in a direction opposite that of the other IC's, and that C6 mounts within the confines of IC4's socket.

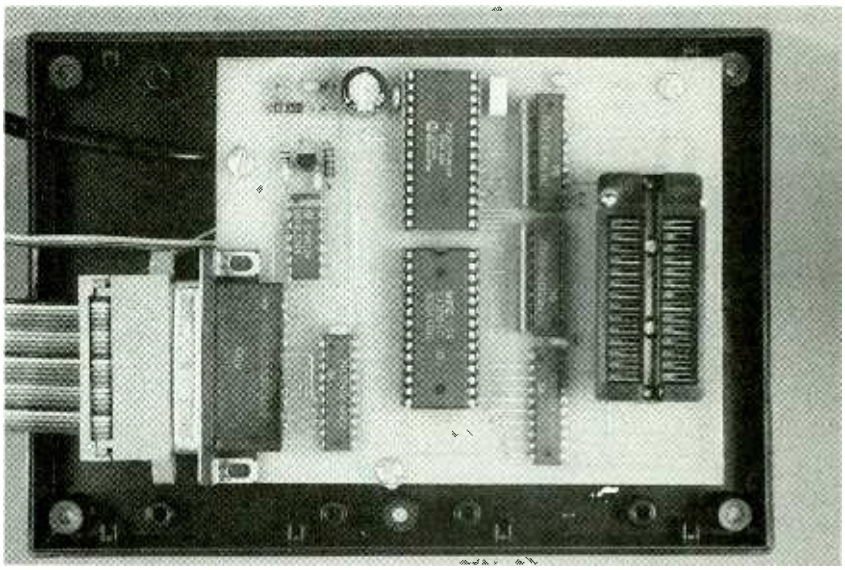

FIG. 3—THE COMPLETED PROTOTYPE. The reset probe plugs into a banana jack, J1, on the outside of the case.

Static-ROM doesn't require personality modules, jumpers, and software to define the EPROM being emulated. Instead, each EPROM has a particular cable wiring scheme that allows the user to switch EPROM's simply by installing the appropriate cable between the Static-ROM target socket and the target system's EPROM socket. An advantage to this scheme is that you need only make the cables you will actually use.

Capacitors C1 through C8 filter and bypass the 5-volt DC power bus. LED2 along with re-

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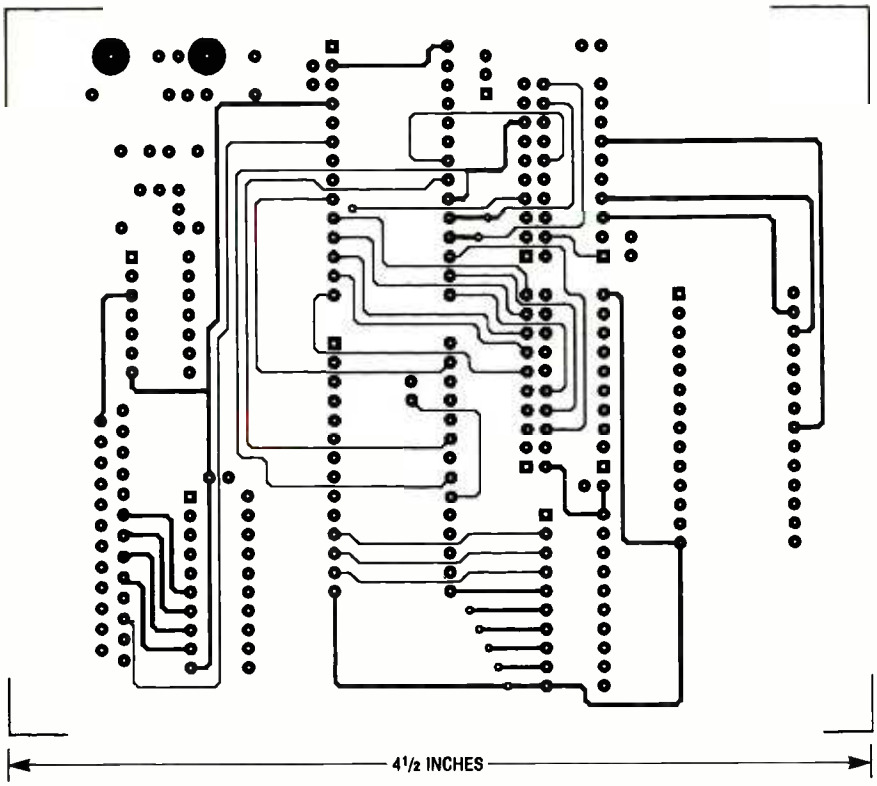

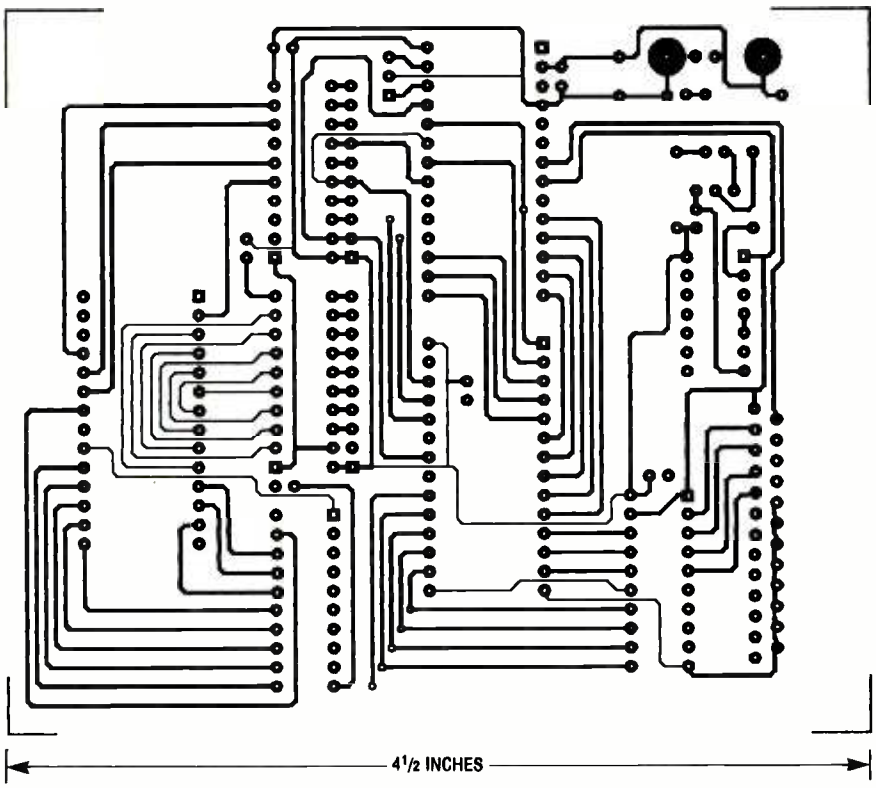

sistor R3 serve as a POWER-ON indicator. An external 5-volt DC regulated power supply is required to power the Static ROM.

The software for the Static-ROM consists of a terminal program that transports user-generated data, and controls the selected parallel port. It has an intelligent address generation algorithm that resides within the PIC16C55. If you own a PIC16C55 programmer, the PIC16C55 source listing is available, so you can program your own. Source listings of the software for both the PIC16C55 and terminal program are available on the RE-BBS or from the address in the Parts List.

Construction

A PC board is recommended, but not necessary. If you choose to make one, use the supplied foil patterns; otherwise you can obtain one from the address in the the Parts List. Placement of the DB25 parallel-port connector is critical, so follow the

PARTS LIST

Resistors
R1—1000 ohms
R2, R3—180 ohms
R4, R5—10,000 ohms × 9, SIP
Capacitors
C1—470 µF, 16 volts, electrolytic
C2–C8—0.1 µF, Mylar
Semiconductors
LED1, LED2—light-emitting diode, any color
Q1—PN2222A NPN transistor
IC1, IC2, IC5, IC6—74LS541 octal buffer/line driver
IC3—PIC16C55 CMOS microcontroller (programmed)
IC4—43256 static RAM
IC7—74LS04 hex inverter
Other components
XTAL1—4-MHz ceramic oscillator
S1—SPDT switch
J1—banana jack
Miscellaneous: 5-volt DC power supply (500 mA), 28-pin ZIF socket (optional, for the target socket), IC sockets, 25-pin right-angle D shell connector, EPROM cables, serial cable, PC board, wire, solder, mounting hardware, etc.

Note: The following items are available from Fred Eady, PO box 541222, Merritt Island, FL 32954:
- **A complete kit of parts including PC board, 25-pin connector, SPDT switch, and IC sockets (not including 8048 target board, power supply, ZIF socket, and cables)—59.95 + 5.00 S&H**
- **Assembled 8048 microcontroller target board and software routines on diskette—$20.00 + 5.00 S&H**
- **Programmed PIC16C55—$25.00 + 5.00 S&H**
- **PC board only—$15.00 + 5.00 S&H**
- **Static-ROM software on diskette—$5.00 postpaid**

Check or money orders only. For technical assistance and inquires call 407-454-9905

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component layout if you choose to handwire the Static-ROM.

It's a good idea to socket all of the IC's. Install all IC sockets as shown in the parts-placement diagram of Fig. 2, paying particular attention to the pin-1 positions of IC5 and IC6, which are mounted in the opposite direction from the other IC's. Capacitor C6 mounts within the confines of the socket for IC4. The dot on SIP resistors R4 and R5 indicates pin 1, as do the square pads on the printed circuit board. The Static-ROM does not require a case, but if you decide to use one, remember to mount the LED's and switches in the appropriate locations.

At this point you should have all of the components except the IC's and the DB25 shell connector mounted on the printed-circuit board. Apply power (the POWER LED should illuminate) and check for power and ground on all of the IC's. If the specified voltages are not present, recheck your work. When you are satisfied with the voltages, install the DB25 connector.

Depending on your choice of target processor, solder a length of wire with a microclip on one end to either pin 5 or pin 6 of IC7 to act as a target-system reset probe. Remember, you will be attaching this lead directly to the pin of the target processor, so be sure to select the appropriate microclip. The prototype was built with SPDT switch S1 supplying either an active-high or active-low reset pulse to a banana jack, J1, on the outside of the case. The prototype's reset probe consists of a multimeter test lead with banana plugs on both ends. That makes connecting the probe to the Static-ROM painless and allows for different types of clips at the opposite end of the reset cable. Incorporating switch S1 not only makes switching between active-high and active-low reset outputs simple, but also provides a way for manually resetting the target processor by simply toggling the switch. Figure 3 shows the completed prototype.

Referring to Table 1 and Fig. 4 as a guide, assemble the EPROM cables of your choice. Use wirewrap wire and insulation-displacement ribbon-cable headers to make the EPROM cables. Use needle-nose pliers to insert the wirewrap wire into the required insulation-displacement header pins, and then insert the ribbon cable on top of the wirewrap jumpers, and then complete the assembly of the header. Maximum EPROM cable length should not exceed 36 inches for reliable operation. The data cable from the parallel port has a 25-pin, pin-to-pin male connector on the parallel-port end and female connector on the Static-ROM end. That cable can have a maximum length of 6 feet. For ease in making the data cable, use insulation-displacement DB25 shell connectors on both ends. When you are satisfied that all connections are correct, install the IC's.

TABLE 1—EPROM CABLE WIRING CHART

EPROM Type	Ground to Pin 14 (Emulator Side)	No Connection (Emulator Side)
2716	2, 23, 26, 27	1, 2, 23, 26, 27, 28
2732	2, 26, 27	1, 2, 26, 27, 28
2764	26, 27	1, 26, 27, 28
27128	27	1, 27, 28
27256	None	1, 28

Notes:
- No connection means that no ribbon cable should be connected to the emulator-side pins listed.
- If you eliminate the connections on the emulator side, you can install the full cable on the target side.
- You can eliminate the ribbon cable for pins 1 and 28 from all EPROM types.
- See text and Fig. 4

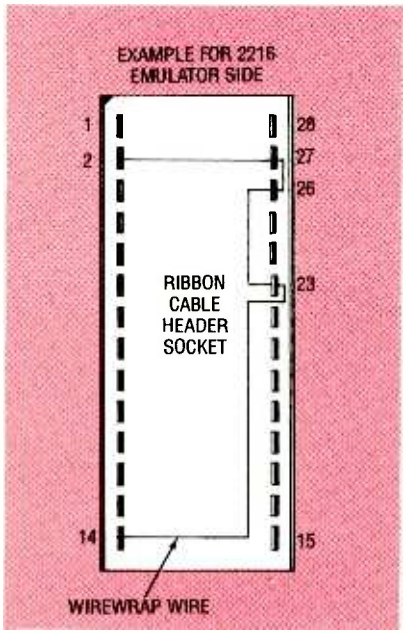

FIG. 4—USE NEEDLE-NOSE PLIERS to insert the wirewrap wire into the insulation-displacement header pins, and then insert the ribbon cable on top of the wirewrap jumpers (see text). Table 1 shows the connections for different EPROM's.

Initial testing and use

The best test for Static-ROM is to write some simple routines for controlling a small microcontroller system and execute them with it. If you do not have an EPROM-based target system, the author will provide an assembled 8048-based microcontroller system that contains a microcontroller, UART (Universal Asynchronous Receiver Transmitter), I/O ports, RAM and EPROM (see Fig. 5). A schematic diagram and software routines to exercise the assembled 8048 board are also included. The author-provided fully commented software routines consisting of an LCD driver, I/O drivers, and a serial I/O routine using the onboard UART. The serial routine is written to talk to an ASCII terminal. A feature of the assembled 8048 board is that you can replace the 8048 and EPROM on the assembled board with a programmed 8748. This feature permits you to eliminate the EPROM if you decide to dedicate

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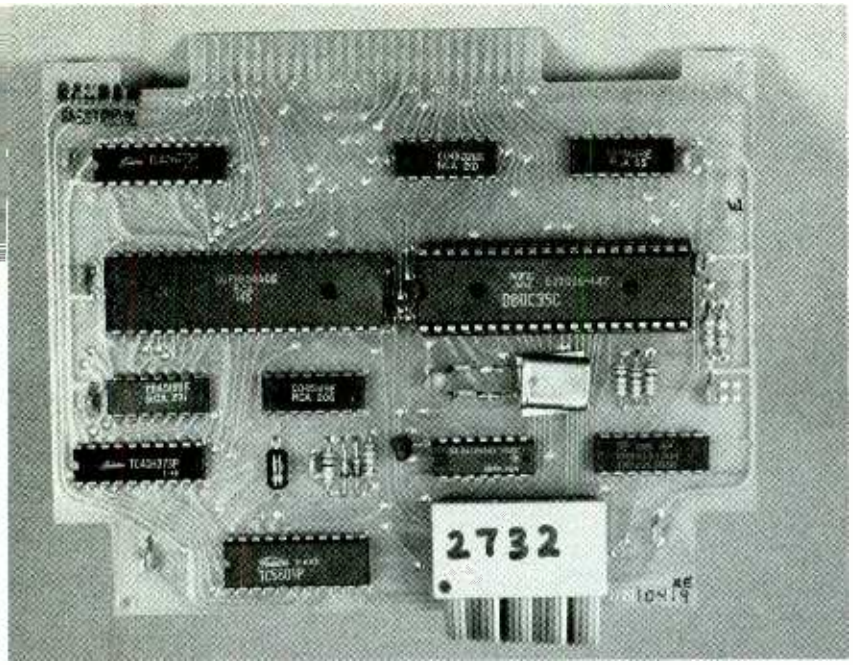

FIG. 5—IF YOU DON'T HAVE AN EPROM-BASED target system, you can buy this assembled 8048-based microcontroller system consisting of a microcontroller, UART, I/O ports, RAM and EPROM (see the Parts List).

the board to a specific application and do not wish to use a separate EPROM. See the parts list for ordering details.

When you have obtained a working target system, connect the 25-pin DB25 male-to-female cable, with the Static-ROM to either parallel port and apply power to the Static-ROM. If the circuit is functioning correctly, the POWER LED should be illuminated, and the LOAD LED can be off or on, depending upon the initial state of the parallel port STROBE line.

Next, connect the EPROM cable to your selected target system. Note that the author-supplied 8048 system uses the 2732 EPROM cable. Select either active-high or active-low reset, depending on your processor. The 8048-based system offered by the author uses active-low reset. Connect the reset probe to the reset pin of your target processor. When you start the Static-ROM terminal program, you will be prompted to select the parallel port that is connected to the Static-ROM. If the LOAD LED was on, it should now be off. Enter the name of the binary object file you want to download to Static-ROM.

After pressing the enter key, you should see the LOAD LED illuminate and a "sending" message with a byte count on the terminal display. The terminal program should indicate that the download has completed, and the target system processor has been reset. You should see immediately the downloaded program running on your target system. Toggle the reset select switch to reset your target system manually or run the Static-ROM terminal program again, and download and run another binary file.

The Static-ROM is designed as a debugging tool, not an EPROM eliminator or substitute. Disconnecting Static-ROM from the parallel port while emulating an EPROM will terminate the emulation if a randomly generated active level is presented to the PIC16C55 STROBE input. Recall that the PIC16C55 always wants to restart on an active STROBE from the parallel port while in EPROM emulation mode and, if an inadvertent strobe is encountered, the algorithm will cease looking for download data that is not forthcoming.

As you can see, you can transfer between your assembler and the terminal program quickly, testing your code until you obtain the desired results. Ω

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HARDWARE HACKER

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DON LANCASTER

Several readers have reported problems when logging on to my *GEnie* PSRT board. The trick is simple: Be sure to enter the HHH *immediately* after your communication software verifies a connection. You will then be prompted to enter an account number, and can proceed from there.

I have looked further at one of our "free energy" resources from a few columns back. *Rexearch* is one well-done labor-of-love operation. What Rex has done is gather together his lifetime collection of weird science, junk science, pseudoscience, and utterly off-the-wall papers, patents, and press coverage. His typical $6 packages might include full copies of several patents and an article or two. There are hundreds of topics. All of them strange and wondrous. A free master list is offered.

Yawn. Stupendous breakthroughs are a thankless task, but somebody has to do them...

Spotless halftones

I've recently been exploring ways to improve the quality of digital photos produced on laser, dot-matrix, or inkjet printers. By going to a new *spotless halftone* technique that does non-obvious stuff in non-obvious ways, print quality can be very much improved.

Most "experts" would agree that the "best" photo halftone you could do at a plain old 300-DPI resolution is something like 19 grays at 70 spots per inch or 15 grays at 85 spots per inch. That, at its very best, is worse than "Sunday funnies" or "auto shopper" tabloid print quality.

Instead, Fig. 1 shows a portion of a stock Lena digital photo, done with a brand new *spotless* 300 DPI halftone. This offers 65 grays, a grain that seems much finer than 106 spots per inch, and full compatibility with traditional ink. I'd dearly love to show you the 600-DPI version, so I'll show you where to get your own copy shortly.

FIG. 1—A SPOTLESS HALFTONE reduced by about 50% from an unenhanced 300 DPI laser printed original. With care, this new technique offers significantly better image quality than traditional methods.

The bottom line: You can now print your own "useful" photos at 300 DPI and "very good" photos at 600 DPI for top-quality book-on-demand publishing. They're often good enough to eliminate the need for high-resolution typesetters.

Traditional photography is an extremely flexible and forgiving process. You can raise or lower brightness by opening up or closing down a stop. Change the contrast by printing one paper grade higher or lower, or custom dodge out all your muddy grays and burn in your harsh highlights. Simple and easy.

Unfortunately, digital halftones lack that flexibility. There is absolutely no room for forgiveness. Let's look at some of the essential tools we now have to improve digital halftones. We'll also summarize them in Fig. 2.

Decent input data—"Garbage in, garbage out" is especially true for digital halftones. Unless you start off with your best possible image data, a disaster is a certainty. Each *pel*, or picture element, in the original should correspond *precisely* to *one* pel in the final image. Those pel values must be *linearly* coded to at least 64—and preferably 256—gray levels.

There's lots of tools available to do the job, such as *Adobe Photoshop*. If you are careful, photo enhancement can be done by using the PostScript in your printer as a general-purpose computing language.

Cropping—This is just throwing away outside areas that do not add to your image content. Always get the key theme or subject as obvious and as dominant as possible. But keep your aspect ratio at something sane, like 1:1 or 4:3 or 1.62:1. Photos at other aspect ratios can be visually jarring.

At any rate, the key point is to start off with the very best image you can. And then enhance it using every trick in the book.

Histogram equalization—Within limits, the more gray levels you can print, the better your results. If you have only a few grays available, you don't want to ignore some of them. That can only make matters worse. Too few grays give you a step effect with annoying visible jumps between the gray levels.

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Decent input data –

The original source material has to be first rate, including sampling of one pixel per pel to 64 or 256 gray levels.

Cropping –

Removes unneeded background info, focusing on the subject matter itself. Makes the subject relatively larger.

Histogram Equalization –

Makes each available gray work equally hard by redistributing the gray values in the image for best spread.

Gamma Correction –

Linearizes the display to eliminate dot gain and similar effects. Matches perceived to actual gray values.

Error Diffusion –

Eliminates or minimizes gray steps by spreading the step error out among several nearby pixels.

Spotless Haftones –

Combines the best features of dithering and halftones by using randomized multiple dots per cell.

FIG. 2—TOOLS AND TECHNIQUES for superb digital halftones.

Histogram equalization can make each possible gray level equally important. To do an equalization, the usage (or popularity) for every gray is plotted into a *histogram plot*. Then the gray levels are reassigned so that each one is used equally often.

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Histogram equalization is *absolutely essential* for all decent digital photos. Sadly, most image users have never even heard of it, or else refuse to spend the few seconds needed to do this incredible improvement. Lots more on this in HACK56.PS and in those *Hardware Hacker* reprints.

Gamma correction—Most printers and some display devices are very nonlinear; they might favor whites or blacks, or extremes over mid range. Every effort must be made to make a printer as linear as possible. Such things as engine technology, toner density settings, and paper choices help a lot here.

The linearity plot is usually called a *gamma curve*. *After* you have done everything else you possibly can to improve your gamma, you may want to selectively "throw away" certain gray levels, so that the remaining grays create the *illusion* of a more linear response. Thus you can trade off the total number of printing grays against the gamma for those grays.

Laser printers are notorious for a *dot gain* effect. A few details appear in Fig. 3. The first goal in laser printing is to produce solid blacks. The black pixels on the page are square, but the laser spot is usually round. If a square hole is going to be covered completely with a round peg, the peg has to be larger. Each of the overlapping segment quadrants causes a net dot gain of 14 percent or more.

The net effect on any "black write" laser printer is to make surrounded black pixels 1.56 times *larger* in area than desired, and any surrounded white pixels 0.44 times *smaller* than usual. What that does is strongly favor blacks and deep grays. For instance, a 50 percent gray that alternates white and black pixels can end up way on down at a mere 22 percent gray. And the "white write" systems will do the exact opposite. Proper gamma correction is super important; so is picking halftoning schemes that avoid alternating pixels.

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Error diffusion—The big problem with a limited number of grays is that steps are created on any gray crossing, rather than a smooth gradient. At the crossing, you have an error whose difference is the gray you want minus the gray you got.

A new technique known as *error diffusion* takes the error and distributes it among several future pixels. On even lines, the current error is zeroed out. Some of the error is added to the next pixel to the right, some to the next below and left, some to the next below, and the rest to next below and right. On odd lines, the error leans to the left rather than to the right.

The net result is that any sharp jumps can be replaced with diffused blends. Instead of steps, a fairly smooth gradient is produced. Diffusion is most effective at higher resolutions.

If the steps are very exact and repeat over and over again vertically, repeating artifacts can result. That can happen if the error diffusion math keeps coming up with identical number sequences. To beat that, noise is *added* to the data so that the numbers do not repeat. On a 256 gray level subject, 15 percent of your gray-56 values might be replaced randomly with a substitute value of 53, 54, 55, 56, or 57.

This is an example of *adding* noise to make something look better! The trick here is that the added noise is random and high in frequency. Thus it can be almost invisible. Purposely adding noise can eliminate any low-frequency artifacts.

Properly done error diffusion can make 600 DPI artwork look like it was done on a premium phototypesetter of higher resolution.

Error diffusion utilities appear on *GEnie* PSRT.

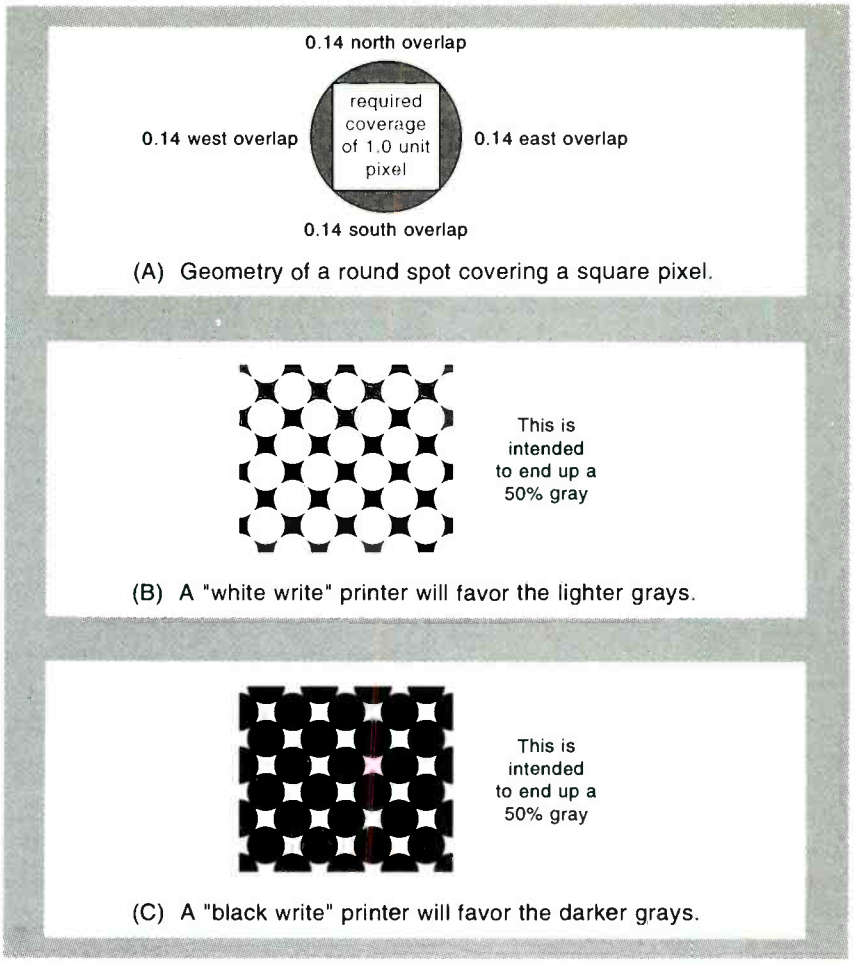

FIG. 3—LASER PRINTER DOT GAIN occurs whenever a round spot tries to cover a square pixel area. Dot gain creates a nonlinear gamma curve.

Spotless halftones—Anything that is done digitally involves some approximations. The sampling process inherently adds noise, which creates *artifacts* of one kind or another. Typically, these artifacts will appear as grainy dots or as distinct gray steps.

O.K. We *must* have noise in any digital system. And we might even want to purposely *add* more noise. As we've just seen, carefully added noise in a digital system can often *raise* your final perceived signal-to-noise ratio! Now the trick here is simple: *Make the unavoidable noise work for you, rather than fight you.*

Certain types of noise look much worse than others. Large repeating spots are bad. Quantized gray levels are bad. Anything that happens over and over again in a row or a column is bad. Thus, we have "good noise" and "bad noise."

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To optimize things, make your "good" noise:

- as random as possible
- as uniform as possible
- as consistent as possible
- as spread out as possible
- as visually diagonal as possible
- as high in frequency as possible

Let's assume you have a square 8 × 8 cell of dots that you can only turn completely on or off. That should give 65 gray levels, including black and white. There are two traditional ways of converting this cell into a "gray" splotch on your page: *halftoning* and *dithering*.

With halftoning, you'll create *one* black area in the middle of your cell and let it "grow" as you go blacker. Just the same as a traditional printer's halftone dot. Your quantizing noise will be low in frequency and repeat regularly. The low frequencies and obvious repetitions are about the *worst* types of noise you can have in your halftone.

In theory, dithering can greatly improve on your noise artifacts. With dithering, you create a pattern of the correct number of dots spread out as uniformly as you can inside your cell. You'll end up with a very high noise frequency and a more or less uniform noise distribution. So, dithering can *theoretically* give us lower noise and pleasing results.

Unfortunately, dithering has a few nasty habits. If you've got dot gain, then the dithered patterns can end up *much* darker than you intended. You may end up with a very bad gamma curve.

Dithering can have annoying and very obviously repeating artifacts, especially in large gray areas. These can look just plain awful. Finally, dithering creates spots that are tiny by traditional printshop standards. A fully dithered halftone can *not* usually be reproduced in ink!

The secret scoop

Spotless halftones take the best features of halftoning, error diffusion, and good gamma correction, and combine them in an optimum way that best obeys all of our "good noise" rules above.

Let's start with all those repeating artifacts common to dithering. To get rid of these, you simply select at random one of *n* possible dither patterns for a given gray. A good choice for *n* is usually eight. You want to make sure all of your selected patterns have their dots as far apart from each other as possible and that each row and each column gets hit *exactly* the same number of times for the entire pattern set.

Next, instead of using the "single dot" of a halftone or those "too many dots" of dithering, you pick only a *few* dots per cell. Use enough dots to raise your grain frequency but not enough to cause excessive dot gain. Eight dots per cell could be a useful compromise. You allow each of these eight dots to grow in the same manner as you would one halftone dot. You randomize "which

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dot grows how" to minimize long-term repeats. Finally, you throw away a few of your available grays to do a gamma correction and balance the brightness.

One possible 600-DPI result is a picture having the same *information content* as a 75-spot-per-inch halftone, 64 uncorrected gray levels, and grain equal to 212 spots per inch—except that randomizing makes the grain even *less* obvious. A 256 × 256 pel image can end up around 3.4 inches square at 600 DPI and a giant 6.8 inches square at 300 DPI.

There are lots of options in this emerging new technology.

For more information

Naturally, PostScript, a general-purpose hacker's computer language, is absolutely ideal for exploring high-quality digital photos. I've posted lots more on spotless halftones to my *GEnie* PSRT. Especially in our files SPOTLESS.PS and RETOUCH.PS. We also have great heaping bunches of files on related imaging topics. SPOTLESS.PS will give you the 600-DPI Lena I mentioned earlier.

Low-level magnetic fields

There has been a lot of helpline interest in measuring weak magnetic fields. Perhaps you need an accurate solid-state digital compass, or want to do some archaeological site mapping. Or perhaps you want to go lava tube cave hunting, or you are concerned about field safety, or you are trying to date an ancient pot, fireplace, or geological formation by using either *archaeomagnetism* or *paleomagnetism* tools.

Magnetic field intensity is a *vector* quantity because it is described by both an intensity and a direction. A field with an intensity of one *Gauss* will be produced if the current and the coil are designed to produce 2.02 ampere turns per inch.

The earth's magnetic field is even weaker. For instance, here in Arizona, the field is 0.26 Gauss or so. It has a 59-degree *inclination* and a 14-degree *declination*.

For openers on all this, there's a classic paper entitled *Earth's Field Magnetometry* by W. F. Stuart in *Reports on Progress in Physics*, 1972, vol. 35, p. 803–881. It's essential reading.

A smaller magnetic measure is a *gamma*. There are 100,000 gammas in a gauss. A one-gamma sensitivity or better is desirable for archaeological mapping. A ten-gamma sensitivity is needed for a decent compass.

At first glance, there seem to be five schemes for measuring weak magnetic fields: the *compass*, the *Hall effect* device, the *proton precession magnetometer*, the *magnetoresistor*, and the *fluxgate*. But the fluxgate is ridiculously better than the others and is the *only* one you should consider.

A compass is basically a magnet on a string. It twists around and points north. Compass problems include mechanical motions, very low sensitivity, and the ability to measure only the direction of the field.

The *Hall effect* is the transverse current produced in certain materials in the presence of a magnetic field. Lower-cost sources for Hall devices include *Allegro*, *Texas Instruments*, and *Micro Switch*. These are great for working with real magnets. But Hall-effect devices lack the required low field sensitivity by a factor of 1000 or more, and are thus *totally useless* for weak field measurement—with two minor exceptions. The *Dinsmore* people have combined a traditional compass with hall sensors for a low-cost device with a 45-degree resolution. Or 22.5 degrees if you stack a pair of them. And the *F. W. Bell* folks now supply a huge and rather expensive Hall-effect sensor assembly that theoretically could be used for a low-resolution compass.

A proton precession magnetometer is just a bottle of distilled water with a coil around it. A strong current is routed through the coil and then suddenly released. The magnetic field shift can cause a wobble in certain hydrogen atoms in a process known as *Larmor precession*. The frequency of this precession is proportional only to the magnetic field strength, but not to its direction. Typically, the frequency is in the 1300-Hertz range and lasts

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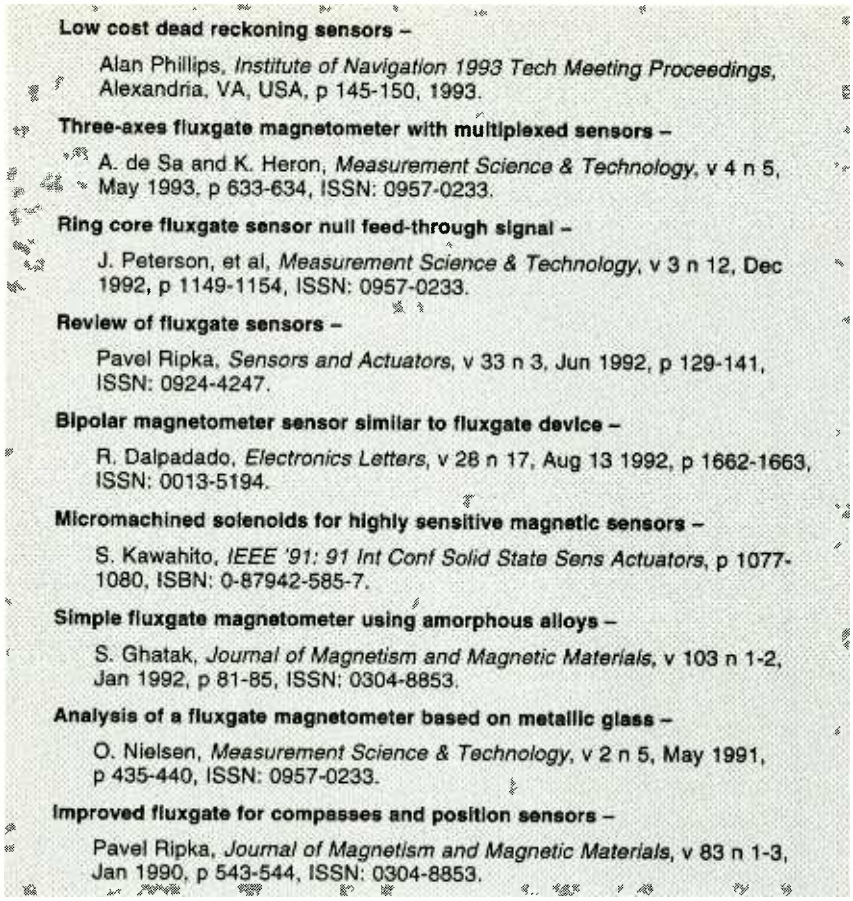

Low cost dead reckoning sensors –

Alan Phillips, *Institute of Navigation 1993 Tech Meeting Proceedings*, Alexandria, VA, USA, p 145-150, 1993.

Three-axes fluxgate magnetometer with multiplexed sensors –

A. de Sa and K. Heron, *Measurement Science & Technology*, v 4 n 5, May 1993, p 633-634, ISSN: 0957-0233.

Ring core fluxgate sensor null feed-through signal –

J. Peterson, et al, *Measurement Science & Technology*, v 3 n 12, Dec 1992, p 1149-1154, ISSN: 0957-0233.

Review of fluxgate sensors –

Pavel Ripka, *Sensors and Actuators*, v 33 n 3, Jun 1992, p 129-141, ISSN: 0924-4247.

Bipolar magnetometer sensor similar to fluxgate device –

R. Dalpadado, *Electronics Letters*, v 28 n 17, Aug 13 1992, p 1662-1663, ISSN: 0013-5194.

Micromachined solenoids for highly sensitive magnetic sensors –

S. Kawahito, *IEEE '91: 91 Int Conf Solid State Sens Actuators*, p 1077-1080, ISBN: 0-87942-585-7.

Simple fluxgate magnetometer using amorphous alloys –

S. Ghatak, *Journal of Magnetism and Magnetic Materials*, v 103 n 1-2, Jan 1992, p 81-85, ISSN: 0304-8853.

Analysis of a fluxgate magnetometer based on metallic glass –

O. Nielsen, *Measurement Science & Technology*, v 2 n 5, May 1991, p 435-440, ISSN: 0957-0233.

Improved fluxgate for compasses and position sensors –

Pavel Ripka, *Journal of Magnetism and Magnetic Materials*, v 83 n 1-3, Jan 1990, p 543-544, ISSN: 0304-8853.

FIG. 4—SOME NEW REFERENCES for fluxgate compasses.

for only a few hundred cycles at a few microvolts maximum. Accurate measurement here is not trivial.

An important proton-magnetometer paper showed up in the August 1956 *Review of Scientific Instruments*. You might also find *IEEE Transactions on Geoscience Electronics*, GE-9 #2, for April 1971, pages 99–103 of value. As well as the *Introduction to Magnetic Resonance* by A. Carrington; and *Nuclear Magnetic Relaxation* by W. Benjaman.

A proton precession magnetometer simply is not worth the hassle these days. Why? Because the upcoming fluxgate is simpler and has better sensitivity.

The *magnetoresistor* is an orphan technology still kicking around for no apparent reason. This is a device whose resistance changes when a magnetic field is applied. Sources include *TDK*, *Murata*, and *Philips*. The sensitivity of magnetoresistors is appallingly low and they have nasty habits of needing exotic external magnetic biasing and then suddenly flipping without warning.

The *fluxgate* is by far the best of the batch. It's a saturable toroid coil with two or three windings. It is simple, cheap, and offers outstanding sensitivity. It's very hacker-friendly to boot. A *control* winding wrapped around the core alternately saturates and unsaturates the core. The *sense* winding goes *across* the core. A second sense winding can be added at a right angle to the first for *sine* and *cosine* channels.

In operation, the core permeability gathers in Earth's field when it is unsaturated and does nothing when saturated. The gathering in and the release of the field induces pulses in the sense windings. The pulses are proportional to the strength and direction of the sensed magnetic field.

Sadly, I know of no cheap source for a hacker fluxgate sensor. *Radio Shack* has apparently dropped their fluxgate car compass. Pricey units are available off the shelf from *KVH* and *Autohelm*. You can make your own fluxgate sensor by starting with a *Magnetics* 50086-2F core and using a control winding of 143 turns of No. 30 wire plus a pair of sine and cosine sense windings of 1000 turns of No. 35 wire. Additional details appear in the *Hardware Hacker II* reprints.

Other sources for fluxgate details include *NASA Tech Brief* LAR13560; a pair of articles in the December 1981 and January 1982 issues of *Sport Aviation*; IEEE transactions MAG-8 No. 1, pages 76–82; and various coverage in *GPS World*, *Journal of Navigation*, and *Speleonics* magazine.

If you know of a good hacker fluxgate source or want to sell them yourself, be sure to let me know. I'll send a free *Incredible Secret Money Machine II* book to you for your trouble.

My story on archaeomagnetism and paleomagnetism appeared in the September 1969 issue of *Electronics World*. Way back when.

Lower-level magnetic-field sensors and various instruments are available through *F. W. Bell* and *Walker Scientific*.

As with any technical subject, you can instantly get up to date anywhere in the world at any time of day by using the *Dialog Information Service*. As we found out last month, Dialog is newly available on a cash-and-carry basis by way of either *CompuServe* or *GEnie* at about thirty cents per title. A quick Dialog dump disclosed the recent fluxgate papers of Fig. 4. I've tried to gather many of these references into this month's resource sidebar.

By the way, if you ever have any ancient "horses mouth" references in any field, all you have to do is use the *Science Citations Index* to pick up any later developments. Unlike most resources, this magic reference lets you work *forward* in time, picking up newer and newer material.

New tech lit

From *Motorola*, there's a *Semiconductor Master Selection Guide*. There's also a new two-inch thick *Linear Circuits Data Book* from *Texas Instruments*—about 1500 pages worth, and a definitive tome for sure. From *Hitachi*, a *Wireless Communication IC Summary*, is available.

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plier that offers a wide variety of name-brand test gear from all of the major suppliers. A free 752-page catalog is available.

There is now a brand new method of using PC parallel ports that is both very high in speed and bidirectional. This major communications improvement is the *Boise* IEEE.P1284 specification. More details on the specification are available from the IEEE, while information on Windows software drivers can be found through *HP Peripherals*.

Trimble Navigation has long offered a great no-charge introduction book titled *GPS: A Guide to the Next Utility*. It has just added a new *Differential GPS Explained* title.

Differential GPS offers navigation and position accuracy to less than one meter, even if your military purposely fouls up the satellite signals. The secret is to have a second nearby receiver in a fixed and known location.

Finding printed-circuit resist ink for plotting pens can be a real hassle. One costly supplier is *Fast Proto*. A free ISMM if you can come up with a more reasonably priced source.

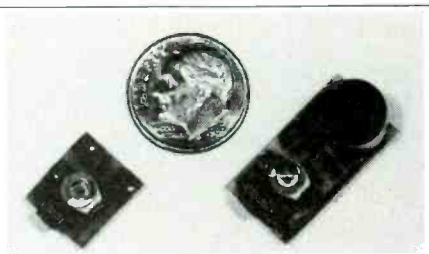
ATV Today is a new newsletter intended for Amateur Television industry insiders.

We have two obscure trade journals this month. One is *Access Control*, all about magnetic stripe readers and such. Then there's *Information Display* for lots of information on LCD, LED, and CRT display technologies.

A reminder that a really great new $19.50 video on how to rewind your own auto alternators for use as CAD/CAM power steppers is obtainable through *John Rees*.

For all the fundamentals of digital integrated circuits, check into my *TTL Cookbook* or *CMOS Cookbook*. They're available separately or as part of my improved *Lancaster Classics Library*. See my nearby *Synergetics* ad for prices. Or send for a free brochure.

As usual, I've gathered most of the items mentioned into the *Names and Numbers* and the *Magnetic Resources* sidebars. Always check these before calling our voice helpline. Ω



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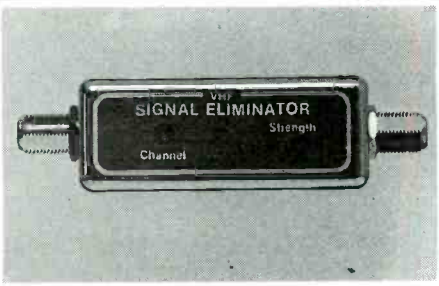

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AUDIO UPDATE

Cable Conflicts: The mysteries of getting wired

LARRY KLEIN

If I had read that Senator Jesse Helms had suddenly become an avid supporter of the Equal Rights Amendment, I could not have been more startled than I was by a speaker-cable article in the July issue of *Audio* magazine.

Originally the organ of the fledgling Audio Engineering Society, *Audio* was for many years the publication in which professional audio engineers discussed their ideas, developments, and breakthroughs. The articles were serious—heavy on math and design theory, light on hype and unsupported claims.

At some point, things changed. As an avid *Audio* reader from the early 1950's, I watched with dismay what I saw to be an intrusion of audio goofiness during the 1970's. The editor's viewpoint as he expressed it to me at the time was that everyone was entitled to his own technical opinion; after all, who was to say what was right? He saw his job as providing an open technical forum for all audio points of view.

In any case, over the years, *Audio* mutated from an authoritative technical journal to a more or less "popular" magazine, attempting to compete with *Stereo Review* and *High Fidelity*. It ultimately found its niche somewhere in the area between the high-end fringe (as represented by *The Absolute Sound*) and the two above-mentioned mainstream publications. Incidentally, for better or worse, the Hachette Filipacchi Magazines company owns all three mainstream titles.

The equipment reviews in *Audio* range from wonderfully authoritative and detailed speaker-system analyses to the frequently off-the-wall meanderings from a few high-end electronics reviewers who are able to detect sonic nuances unheard by ordinary mortals. As I mentioned, the editorial attitude seems to lend equal support to science and silliness, but with a certain special reverence for the overpriced, over-designed, and overhyped components and accessories that make up the High End—which brings me back to July's speaker cable article.

The casual reader might consider further discussion of the pros and cons of esoteric speaker cables as merely beating a dead horse. Not so—the horse is alive and well and galloping through the editorial and advertising pages of the large and small audio magazines. The high-end audio dealers continue to be avid cable pushers because cables represent an excellent opportunity to tack on an additional sale—and at a very good profit margin—after the basic component sale is made.

Good sense, good science

The *Audio* article "Speaker Cables: Testing for Audibility" actually contains few surprises for anyone residing on the rational side of the cable controversy. The author, engineer Fred E. Davis, apparently is not only well versed in consumer-electronics engineering but also seems well equipped with good sense and an understanding of scientific methodology. Early in his article, Davis notes that several manufacturers have published "white papers" (which he lists in a 26-item bibliography) purporting to provide the technical basis for their special designs. Based on the data presented, he concludes that little is sacred to the cable marketeers, including the laws of physics.

Davis goes on to detail the claims of cable manufacturers who variously push high- or low-capacitance and/or low inductance, low resistance, and low skin-effect (involving the signal penetration of the conductor at high and low frequencies). Other phenomena, real and imagined, that are claimed to influence the sound of speaker cables are phase shift, dispersion, transmission-line effects, internal vibration damping, and the use of special insulating material and oxygen-free copper. Davis also mentions the notion that some cables need to be "sexed" (as indicated by directional arrows) because the audio current sound best when the cable is directionally correct.

Given this witches' brew of electrical and physical cable characteristics said to enormously influence the sound reaching the speakers, it's no wonder that many audiophiles act as though they believed that bad sound can only be exorcised by sacrificing cash on the alter of cable correctness. Davis disposes of most of the cable chimera with a few well-chosen citations from past authoritative studies.

The core of Davis's article is the description and measurement of 12 cables ranging in price from 24 cents to over $130 a foot. The cables are analyzed for their electrical parameters, measured as part of a system using two speakers with typical, but dissimilar, impedance characteristics, and two power amplifiers with quite different output impedance characteristics. Each of the twelve cables was tested and measured with every combination of amp and speaker—and Davis's article includes the graphs to prove it. Listening tests backed up all the measurements.

The bottom line

I'm sure that the editors of *Audio* were pleased that Davis found that some cables sounded different under some conditions, thus leaving the door open for continuing the off-the-wall cable claims in full-page ads and advertorials. (See the 6-page insert in the August issue.) I'm also sure that Davis's decision to delete some brand names "in the interest of not adversely affecting the business of any manufacturer"—or *Audio* magazine—made friends in high places.

Continued on page 83

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DRAWING BOARD

We're finally free to play our game without performing the document check!

ROBERT GROSSBLATT

If you've been following this series on software debugging (it's been discussed in the July, September, and November issues of **Electronics Now**), you now know the basic steps to getting rid of a document check. The job involves locating the relevant code and getting rid of it. Although that sounds simple enough, finding the code can be a difficult procedure—especially when there aren't any roadsigns to follow.

The pages and pages of code generated by raw debug dumps is, without question, some of the most stultifying and mind-numbing text you'll ever read. But after a bit of experience, the relevant portions will jump off the screen at you—even though the people who write document-check or copy-protection routines often go out of their way to make it as difficult to find and follow as possible. But more about that later. Let's first get back to finishing off our example.

Recall the steps taken so far. First, a list was made of exactly what happens when the game is played, and the order in which those things happen. We also noted what happens when a document check is answered correctly and what happens when an incorrect answer is given. Then the CALLs that initiated those routines were found and carefully examined for any clues as to the operation of the document check. In our example I've created a JUMP table that ran one part of the game's introduction after another. To refresh your memory, the disassembly listing for the code we're working on is shown in Listing 1. While things probably won't be quite as neat as Listing 1 in an actual program, the basic idea will be the same.

Simply eliminating the document check is usually a bad idea. Putting a bunch of NOPs (no operation) in place of the CALL to the document check will certainly bypass the routine but, as we saw last month, it can also cause the game to crash. That's because when the document check is bypassed, anything that it was supposed to do—such as passing data to the main program—is bypassed as well. If the data is found by the main program, the game gets started. If not, you're out of luck.

Tracing into the document check last month revealed that entering the correct code word caused the routine to set a flag, which allowed the game to continue normally. In the disassembled code shown in Listing 2, the key instruction is the last one before the return. If a 1111h is put in location 1C32h, the game can be started by executing the call that starts the game. What we have to do is figure out how to make that happen automatically.

As with most things, there are lots of ways to do the job. In our example, the most straightforward way to do it is to take the instruction at 554F:62BA and substitute it for the CALL found at 2BC0:190C—the one that calls the document check in the first place. By doing that, the program will set the flag correctly and then go on to execute the game. The only problem with this is that we don't have enough room in the jump table, because the MOV instruction is six bytes long and the CALL is only five bytes.

That's not much of a problem because we actually have a huge area of unnecessary code that we can overwrite—the document-check code itself. Once we finish patching the code so that it will bypass the document check completely, none of the code there will ever be executed. That is, after all, the reason behind this whole exercise. The document check starts at location 554F:5D96 (see the third line in Listing 1). That's the address where the instruction to set the flag and return to the jump table should be patched. The actual code we need

LISTING 1

```
2BC0:1902 9AB3194F55  CALL 554F:19B3    ;Show the company logo
2BC0:1907 9AC6304F55  CALL 554F:30C6    ;Play some music
2BC0:190C 9A965D4F55  CALL 554F:5D96    ;Do a document check
2BC0:1911 9A3ADB4F55  CALL 554F:DB3A    ;Go to the game
```

LISTING 2

```
554F:629C 837EDE00      CMP WORD PTR [BP-22],+00
554F:62A0 7402          JZ 62A4
554F:62A2 EB0C          JMP 62B0
554F:62A4 FF46D6        INC WORD PTR [BP-2A]
554F:62A7 837ED602      CMP WORD PTR [BP-2A],+02
554F:62AB 7D03          JGE 62B0
554F:62AD E937FD        JMP 5FE7
554F:62B0 837EDE00      CMP WORD PTR [BP-22],+00
554F:62B4 7504          JNZ 62BA
554F:62B6 0E            PUSH CS
554F:62B7 E8E8FC        CALL 62A2
554F:62BA C706321C1111  MOV WORD PTR [1C32],1111
554F:62C0 CB            RET
```


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is the last two instructions found at the very end of the document check itself, that is, the last two lines in Listing 2. The program will execute normally, go to the document check, set the flag correctly, and execute the game.

This is easy enough to try while still inside the debugger. All we have to do is edit the instructions at the beginning of the document check and replace whatever we find there with those two instructions. As soon as that's done, the debugger's JUMP command can execute the start of the entire game at the top of the original jump table.

Making this change permanent is a piece of cake. All you need is a hexadecimal editor, a bunch of hex bytes, and a search string. The first is a matter of preference and convenience, the second is the hex equivalent of the last two instructions in the document check, and the third is nothing more than the original hex code found at the beginning of the document check.

Use your hex editor's search command to find the beginning of the document check, patch in the seven replacement bytes, and write the file back to disk with those changes. Once you do that, you should be able to go back to the command prompt, enter the name of the EXE file, and run the game. Everything will be as it was except the document check will be gone.

The example presented here is much easier than what you're likely to encounter in a real program. Since the job of any copy-protection routine is, as the name would imply, to protect against copying, the code that does the work is often hidden and hard to find. You're undoubtedly going to run across techniques such as self-modifying code and hidden checks that can make a complete crack of the program more than you bargained for. In our example, the crack could have been accomplished by something as simple as changing the address in the CALL to the document check. Instead of adding a patch to the beginning of the document check, we could have simply CALLed the end of the check where the flag was set by the original code. In that case, the jump table would have been changed to look like Listing 3, and the result would have been the same as it was when we patched the beginning of the document-check code.

The bottom line in defeating copy-protection schemes is that you have to work under the assumption that nothing should be taken at face value. If you've plodded through the code tracing every CALL and haven't found the one that brings up the document-check screen, there's a good chance that the actual CALL is hidden in some self-modifying code. That can be a real pain in the neck to find because the code being modified can appear to be anything at all. It can look perfectly legitimate and even the most astute crackist can be fooled.

As an example, what's wrong with the code in Listing 4? The answer is that there's nothing wrong with it; it's part of a routine that I wrote some years ago for an EPROM in a microprocessor-controlled lighting system. If you came across this in a game you wouldn't give it a second glance.

Taking this a step further, suppose you ran across code that

LISTING 3

```
2BC0:1902 9AB3194F55   CALL 554F:19B3  ;Show the company logo
2BC0:1907 9AC6304F55   CALL 554F:30C6  ;Play some music
2BC0:190C 9ABA624F55   CALL 554F:62BA  ;Do a document check (HA!)
2BC0:1911 9A3ADB4F55   CALL 554F:DB3A  ;Go to the game
```

LISTING 4

```
1BCE:01D2 8A0E9000      MOV   CL,[0090]
1BCE:01D6 E8BEFF        CALL  0197
1BCE:01D9 380E9000      CMP   [0090],CL
1BCE:01DD 74F3          JZ    01D2
1BCE:01DF A08000        MOV   AL,[0080]
1BCE:01E2 FEC0          INC   AL
1BCE:01E4 3C0A          CMP   AL,0A
1BCE:01E6 7405          JZ    01ED
1BCE:01E8 A28000        MOV   [0080],AL
1BCE:01EB EBE5          JMP   01D2
1BCE:01ED C606800000    MOV   BYTE PTR [0080],00
1BCE:01F2 A08100        MOV   AL,[0081]
1BCE:01F5 FEC0          INC   AL
1BCE:01F7 3C0A          CMP   AL,0A
1BCE:01F9 7405          JZ    0200
1BCE:01FB A28100        MOV   [0081],AL
1BCE:01FE EBD2          JMP   01D2
1BCE:0200 C606810000    MOV   BYTE PTR [0081],00
1BCE:0205 A08200        MOV   AL,[0082]
```

LISTING 5

```
2A23:011F 52            PUSH  DX
2A23:0120 BACE1B        MOV   DX,1BCE
2A23:0122 C706D201B39A  MOV   WORD PTR [01D2],9AB3
2A23:0128 C706D4014F19  MOV   WORD PTR [01D4],194F
2A23:012E C706D6019A55  MOV   WORD PTR [01D6],559A
2A23:0134 C706D80130C6  MOV   WORD PTR [01D8],C630
2A23:013A C706DA01554F  MOV   WORD PTR [01DA],4F55
2A23:0140 C706DC01BA9A  MOV   WORD PTR [01DC],9ABA
2A23:0146 C706DE014F62  MOV   WORD PTR [01DE],624F
2A23:014C C706E0019A55  MOV   WORD PTR [01E0],559A
2A23:0152 C706E201DB3A  MOV   WORD PTR [01E2],3ADB
2A23:0158 C706E401554F  MOV   WORD PTR [01E4],4F55
2A23:015E C706E6010E5A  MOV   WORD PTR [01E6],5AB8
2A23:0164 C706E8010700  MOV   WORD PTR [01E8],0007
2A23:016A B000          MOV   AL,00
```


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LISTING 6

```
1BCE:01D2 9AB3194F55   CALL   554F:19B3   ;Show the company logo
1BCE:01D7 9AC6304F55   CALL   554F:30C6   ;Play some music
1BCE:01DC 9ABA624F55   CALL   554F:62BA   ;Do a document check
1BCE:01E1 9A3ADB4F55   CALL   554F:DB3A   ;Go to the game
1BCE:01E6 5A           POP    DX          ;More code
1BCE:01E7 OE           PUSH   CS          ;And more code
1BCE:01E8 A28000       MOV    [0080],AL
1BCE:01EB EBE5         JMP    01D2
1BCE:01ED C606800000   MOV    BYTE PTR [0080],00
1BCE:01F2 A08100       MOV    AL,[0081]
1BCE:01F5 FEC0         INC    AL
1BCE:01F7 3C0A         CMP    AL,0A
1BCE:01F9 7405         JZ     0200
1BCE:01FB A28100       MOV    [0081],AL
1BCE:01FE EBD2         JMP    01D2
1BCE:0200 C606810000   MOV    BYTE PTR [0081],00
1BCE:0205 A08200       MOV    AL,[0082]
```

looked like Listing 5. That is perfectly normal code as well. If you happened to come across it, especially if it was surrounded by a bunch of other similar MOV instructions, you might assume that something was being set up such as music, sound effects, graphics, or whatever. Actually though, it is some sneaky code whose execution results in overwriting the first piece of innocent code so that it will now look like Listing 6.

Listing 6 is, of course, the jump table we've seen before. It doesn't exist until after the self-modifying code has been executed. A trick that's even more difficult to decipher is using obscure routines to calculate the bytes. Anything can be done by the programmer, whose rule is to make the copy-protection technique as hidden and arcane as possible.

In general, if you can't find the jump table or the CALLs to the major routines in a piece of software, you're probably up against self-modifying code. The best approach is still to find the CALLs that run the routines that you can recognize in the game. Those include such things as playing music and putting messages on the screen.

Once you see a connection between sections of code and different events in the game, you can work backwards to locate other signposts. It's not easy—it's designed to be as difficult as possible. The only piece of encouragement I can offer to you is that the more you do this, the better you'll get.

You won't find any ready-to-use software that can do this job for you, and you won't find a shelf full of books to help you either. You've got to do it on your own and, as an extra side benefit, the better you get at deciphering copy-protection schemes, the better your own programming skills will become.

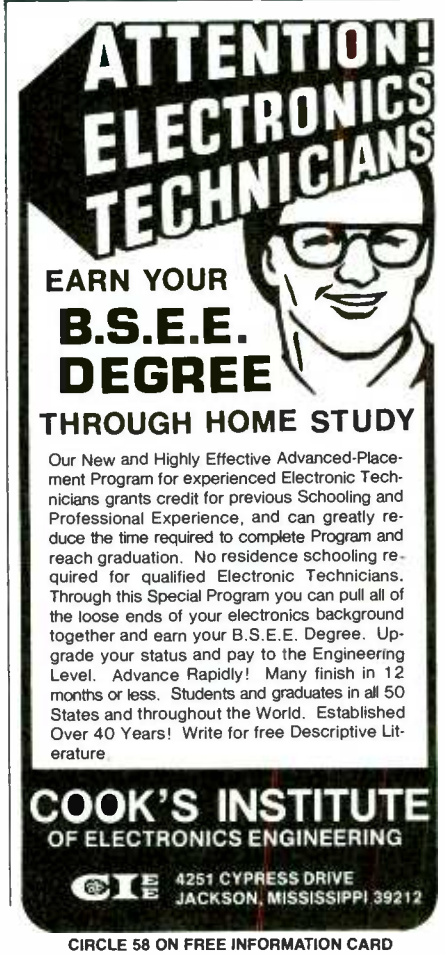
When we get together next time, we'll get back to circuits. Ω

AUDIO UPDATE

continued from page 80

But aside from those cavils, I found Davis's conclusions to be right on target. He found the differences between two-wire cables to be indistinguishable. Comparing two-wire cables with flat ribbon cables revealed a slight difference in the high treble averaging about 0.5 dB at 15 kHz. These differences are at the threshold of audibility and are a far cry from the "quantum leaps" of improvement extolled by the manufacturers and the audiophiles they've entranced.

Davis confirms my view that unless strange amplifier or speaker impedances are involved, 12-gauge "zip cord" will work fine. He concludes that the use of exotic materials for the conductors, or strange cable insulation, or oxygen-free copper multi-strand "hyperlitz" windings will have minimal positive effect on the signal, but maximal negative effect on your wallet. Ω



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COMPUTER CONNECTIONS

The holy grail of the computer industry.

JEFF HOLTZMAN

Layering is a fundamental concept in the computer industry. It is useful because it allows us to compartmentalize portions of problems that would otherwise appear overwhelmingly complex. Compartmentalization is useful for science and engineering. But it is also problematic because, at higher levels, it introduces distinctions that end users of the products of engineering find unnecessary, arbitrary, and confusing.

For example, look at the PC sitting on your desk. It consists of a keyboard, a monitor, and a system unit. The system unit contains a power supply, some disk drives, and a motherboard. The motherboard contains a CPU, memory, and system logic. The system logic consists of logical units that ensure that signals arrive at the right places at the right times. The logical units are implementations of simultaneous and sequential logic equations. These implementations consist of flip-flops, gates, shift registers, adders, and so on, and these in turn are built from transistors, resistors, and diodes. The latter are built from insulating and semiconducting elements and molecules, which consist of subatomic particles, which consist of sub-subatomic particles—and that seems to be the end of the chain for now.

In general, the deeper you penetrate the system of layers, the closer you come to science. As you move up the ladder, you move into systems engineering, application engineering, maintenance, and ultimately, everyday usage.

Most products in everyday use don't require you to penetrate that system of layers very deeply. You don't have to understand resistance heating to use a toaster. You don't have to understand $F = ma$ to realize that crashing a two-ton automobile is destructive and dangerous. You don't have to understand the intricacies of fluid mechanics to flush a toilet.

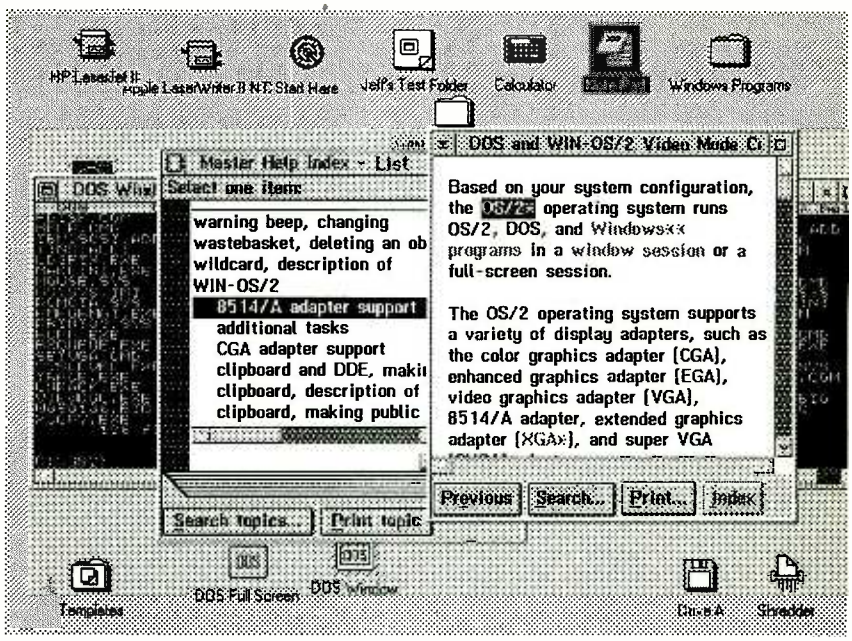

FIG. 1—IBM'S OS/2 2.1 DELIVERS. Seamless support for Windows 3.1 applications, along with extensive video and printer support, now make OS/2 a contender. Take a careful look; you'll find the results interesting.

But to operate a computer at any level of proficiency, you must understand all sorts of technical gobbledygook. Just look at the criteria you must examine when buying a computer: CPU type, speed, and cache; video resolution, speed, color depth, and memory capacity; amount of general-purpose semiconductor memory; number, type, and capacity of removable storage devices (floppy disk, tape, CD-ROM); number, type, and capacity of fixed storage devices; input devices (keyboard, mouse, trackball, digitizing tablet); output devices (monitor, printer, plotter); connectivity devices (modem, network); and the list goes on and on and on.

And then you get to software. As complex as the hardware is, it doesn't touch the software, which can also be difficult to master.

Does it have to be this way? Does anyone benefit from its being this way? Will it remain this way for the foreseeable future? No, yes, and probably.

Complexity where it counts

It doesn't have to be this way. Much of the complexity could be eliminated. Indeed, simple economics is driving the industry in precisely that direction, as computer hardware approaches the commodity status of televisions, VCRs, and stereos.

Those who benefit from the complexity include systems integrators and consultants, and the small clone houses that do essentially no R&D, that assemble systems from components, and that have been disappearing in recent years faster than snowballs from the Sahara. Note that end users aren't on the

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list. That's because end users do not benefit from battling configuration and compatibility problems in buying, expanding, and maintaining their computers.

Quite the opposite. If past history is any indication, computer vendors will simplify their product lines, making available fewer but more clear-cut choices for consumers. We buy automobiles mostly on style, and use just a few technical criteria—number of cylinders, cylinder displacement, transmission style, miles per gallon, passenger seating—to justify our choices. We do so without understanding or caring about all the technical distinctions that go into increasing gas mileage, et al. Soon we'll be buying computers the same way.

However, the complexity of *using* computers is not going to go away. The reason is simple: we ask computers to do lots of things for us, many more so than the average appliance. For example, look at the automobile. A frequently cited goal is that computer software become as easy to use as a car. This is a faulty analogy, and there are several reasons why.

First, the car has only two degrees of freedom: speed and direction. And it has only four controls for manipulating them: brake and accelerator pedals for varying speed, and the steering wheel and transmission for varying direction. The average software package often has dozens of degrees of freedom and hundreds of controls for manipulating them. The real challenge in the software portion of the computer industry is not to design simplistic products with feature sets useful only for beginners, nor to produce massive, all-encompassing products that do everything including taking out the garbage. Nor is it even to come up with some magic product that combines just the right blend of features so that it will appeal to all users from neophytes to hard-core hackers. Such a product simply doesn't exist; it's the holy grail of the computer industry. Application software is complex and must be so because we ask it to do many things. The real challenge is in *managing* complexity through effective user-interface design, or what I call user *interaction* design.

The second reason I don't like the "easy to use as a car" analogy is that it ignores the training we get and the regulation enforced on the use of the automobile. Many people learn to drive in high school under closely supervised circumstances. All drivers must be licensed by the proper authority, and the license must be renewed periodically.

But when it comes to computers, learning is a haphazard affair, and licensing is all but unknown. Most secondary schools still view computers more as a disruption of the status quo than as a new type of tool that is fundamentally altering the very fabric of society. The result is a work force that can barely use the computer to emulate tools of the past (the typewriter, the drawing board, the columnar book), not to mention take advantage of advanced features that are the real pay back.

Grit your teeth. Bite the bullet. Hunker down. It's not going to get any easier. The focus may change—indeed it must. But it's not going to get any easier.

Product watch

I've run across several items of software in the past few months that have proven highly useful. IBM released the retail version of OS/2 2.1, and it's truly an impressive achievement. The operating system now comes on twenty 1.44 MB diskettes (a CD-ROM version is also available), and requires 20–40 MB of disk space. In return you get a system that can run DOS, Windows 3.1, and OS/2 applications with an unprecedented degree of control and stability.

OS/2 has a concept of folders and objects that is extremely powerful. OS/2 uses windows and menus in a manner similar to Microsoft Windows, but in a more conceptually unified manner. The thing you see when you start OS/2 is called the Workplace Shell (WPS); it is also called the Desktop. WPS is a folder that may contain objects (programs and data files) and other folders, which may in turn contain other objects and folders, etc. Program objects can be DOS, Windows, or OS/2 executables. You can copy, move, delete, find, and clone objects. IBM refers to the latter as creating a "shadow," which is a copy of the original object that automatically inherits any changes made to the original. OS/2 now includes a full range of video, printer, and other device drivers; it also includes the latest version of Adobe Type Manager (2.5) for both OS/2 and Windows sessions, detailed on-line documentation, and pretty good paper documentation.

All in all, if IBM had delivered something like this back in April of 1987 when OS/2 1.0 was first released, our operating-system landscape would be totally different today. As it is, OS/2's technical prowess must now be met with applications that provide a compelling reason to switch. I'll be looking forward to seeing these applications when they do arrive. In the meantime, it's worth keeping close tabs on OS/2 2.1.

Artisoft Corporation released version 5.0 of its Lantastic network operating system, long my recommended product for home-office and small-business networks. The new version adds several valuable new features, including file-level security, delayed printing, the ability to

Continued on page 92

RESOURCES

- Adobe Type Manager 2.5, Adobe Systems Corporation, 1585 Charleston Road, P.O. Box 7900, Mountain View, CA 94039-7900. (800) 833-6687, (415) 961-4400.
  CIRCLE 41 ON FREE INFORMATION CARD

- Lantastic 5.0, Artisoft, Inc. 691 East River Road, Tucson, AZ 85704. (800) TINY-RAM. (602) 293-4000
  CIRCLE 42 ON FREE INFORMATION CARD

- Norton Utilities 7.0, Symantec Corporation, 10201 Torre Avenue, Cupertino, CA 95014-2132. (800) 441-7234, (408) 253-9600.
  CIRCLE 43 ON FREE INFORMATION CARD

- OS/2 2.1, IBM Corporation, (800) 3-IBM-OS2.
  CIRCLE 44 ON FREE INFORMATION CARD

- Stacker 3.1, Stac Electronics, 5993 Avenida Encinas, Carlsbad, CA 92008. (619) 431-7474.
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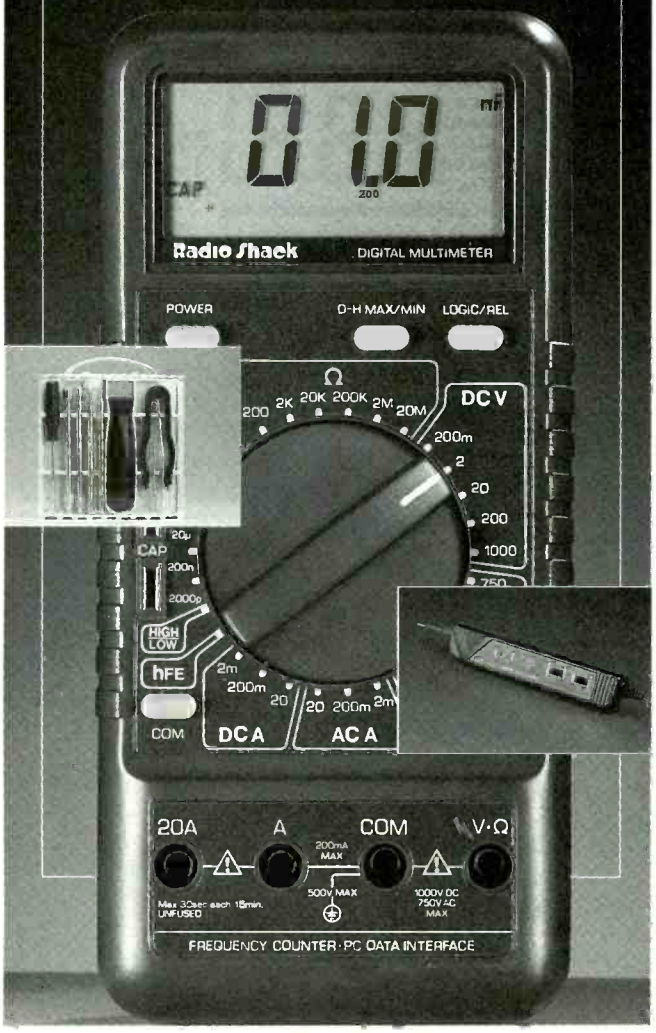

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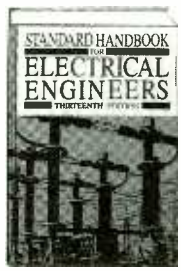

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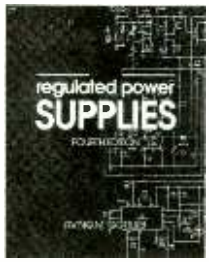

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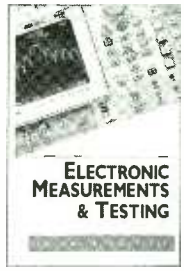

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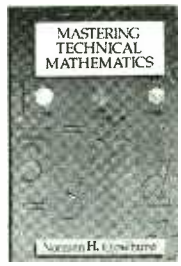

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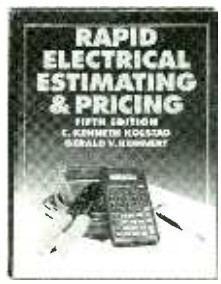

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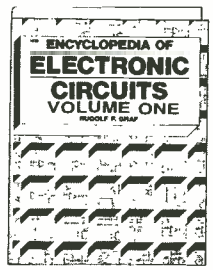

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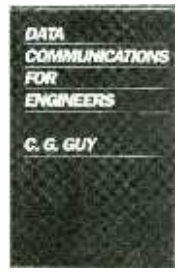

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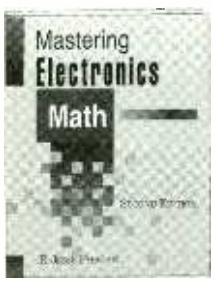

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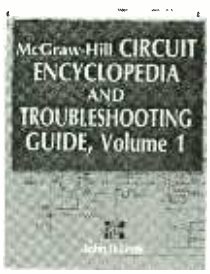

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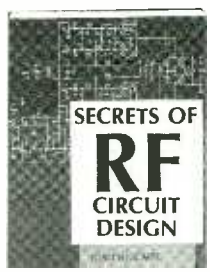

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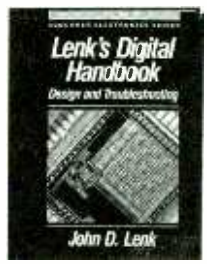

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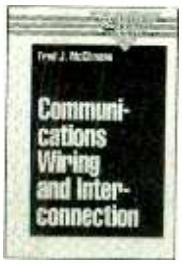

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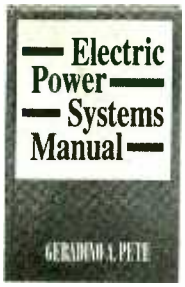

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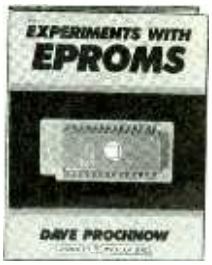

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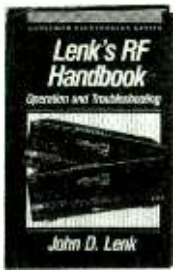

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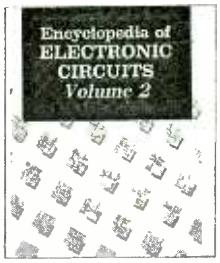

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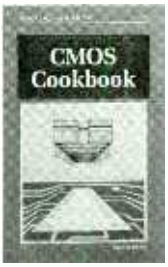

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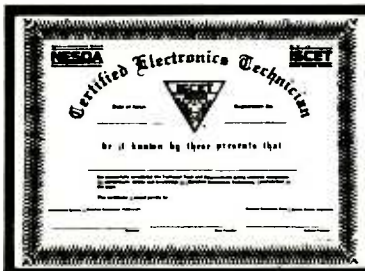

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COMPUTER CONNECTION

continued from page 85

view and operate remote servers from a central location, and the ability to log in to a single server and obtain access to resources (printers, disk drives, CD-ROM drives) on other servers. There's also a Windows-based interface for logging on and off various servers, attaching and removing various remote resources via a point-and-click interface, and a network "clipboard" that multiple users can copy and paste data to and from. Performance is better, RAM usage is about the same (approximately half of what Netware Lite requires), and the documentation and on-line help have improved. Artisoft has been somewhat slow in certifying drivers (e.g., the Katron PE-300B discussed here in the June issue), which lead to a frustrating six or eight weeks in which I was unable to bring up one network node. But once the driver was released, I had no problem using it.

Lantastic 5.0 is more stable than past releases. With some previous versions, I had stability problems when simultaneously using a Windows workstation as a Lantastic server. But the new version appears rock-solid. I tested this capability by running a 486/25 system in Windows enhanced mode with the Lantastic server software running in the background. I logged two other nodes into the 486, and had them perform XCOPYs of several deep directory structures. The 486 slowed down a bit, but didn't crash. Nice.

Symantec has released version 7.0 of the venerable Norton Utilities. This version adds support for MS-DOS 6.0—particularly Double Space and Stacker compressed disk drives. (If you use Stacker 3.1 under DOS 6 make sure you get Symantec's free maintenance update.)

Most of the Norton utilities have been incrementally improved, and several new additions provide enhanced capabilities. The Norton Diagnostics is the major addition. It provides a fairly extensive set of utilities for configuring and diagnosing disk drives, memory, CMOS settings, video, mouse, keyboard, etc. Another new command is Dupdisk, an intelligent version of DOS's Diskcopy command. Dupdisk requires only one floppy swap, and can make multiple copies after reading the source disk. Norton's COMMAND.COM replacement, NDOS, has also been upgraded with many new features. If you spend much time at a DOS command prompt, NDOS alone justifies the price of the package.

Stac Electronics released Stacker 3.1, which can operate more or less transparently under DOS 6, much as Microsoft's own DoubleSpace does. Stacker has several advantages over DoubleSpace: it works with any version of DOS, it can create compressed drives as large as 2 GB (vs. 0.5 GB for DoubleSpace), and it typically has a higher compression ratio and better performance than DoubleSpace. I have no major complaints with the product, although the company's technical support policies and responsiveness have changed detrimentally during the past few months. I hope Stac can keep things together, because I don't like seeing Microsoft swallow up all the good ideas invented by competitors.

Another product that falls in this category is the Adobe Type Manager (ATM), version 2.5, for Windows. What ATM does is provide a systematic means of representing fonts on screen and on paper, regardless of the type of video display or printer. The product was originally developed for the Macintosh, and subsequently ported to Windows 3.0. Then Microsoft introduced the TrueType system for Windows 3.1. TrueType ostensibly obviates the need for ATM. However, it does not work with ATM (PostScript Type 1) fonts; TrueType has its own proprietary format. The popularity of Windows has created a huge market for TrueType fonts, but many of these lack the professionalism of PostScript fonts. ATM and TrueType can run simultaneously, each supporting fonts of its own type. I strongly recommend ATM to anyone producing documents in a professional setting. Ω

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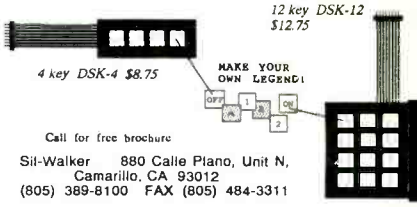

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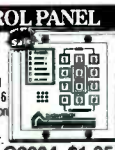

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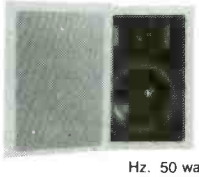

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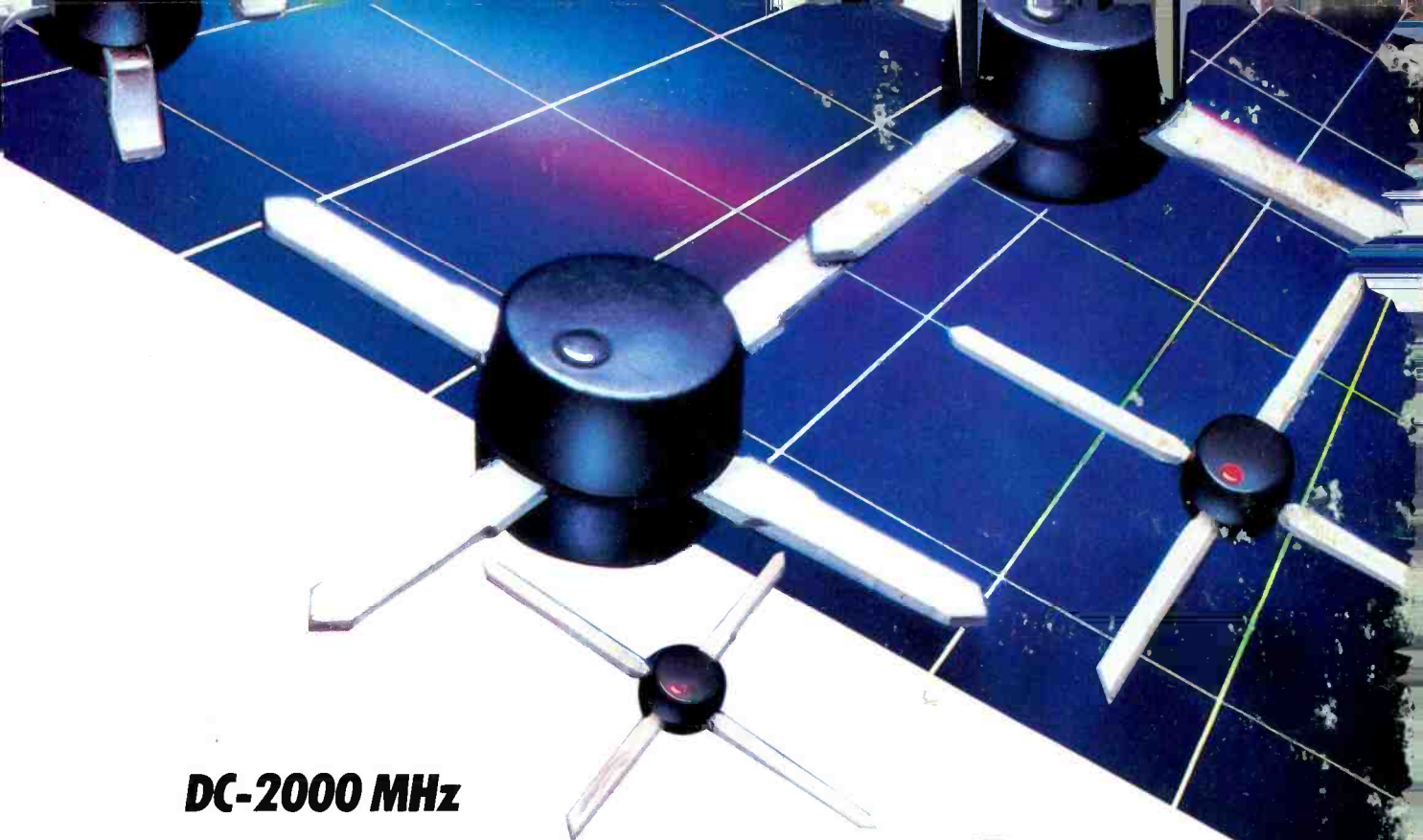

DC-2000 MHz

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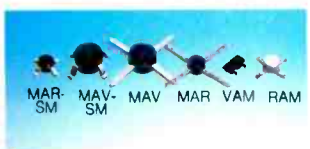

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add suffix SM to model no. (ex. MAR-1SM)	MAR-1 1.04	MAR-2 1.40	MAR-3 1.50	MAR-4 1.60	MAR-6 1.34	MAR-7 1.80	MAR-8 1.75	
	MAV-1 1.15	+MAV-2 1.45	+MAV-3 1.55	MAV-4 1.65				MAV-11 2.15
CERAMIC SURFACE-MOUNT	RAM-1 4.95	RAM-2 4.95	RAM-3 4.95	RAM-4 4.95	RAM-6 4.95	RAM-7 4.95	RAM-8 4.95	
PLASTIC FLAT-PACK	MAV-1 1.10	+MAV-2 1.40	+MAV-3 1.50	+MAV-4 1.60				MAV-11 2.10
	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

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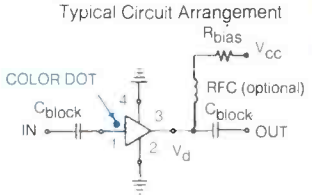

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