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WHAT'S NEWS

A review of the latest happenings in electronics.

All-digital HDTV development

Major changes have occurred in the US development of HDTV over the past few years. Where NTSC-compatible systems were the early favorites, the FCC has indicated that it will select a simulcast 6-MHz HDTV broadcast standard in 1993—and it is unlikely that the FCC will even consider any analog systems.

After 18 months of cooperative effort, Zenith Electronics Corporation (Glenview, IL), AT&T Bell Laboratories, and AT&T Microelectronics unveiled an all-digital high-definition system that is said to solve many of the problems associated with simulcasting. Zenith handled system definition and transmission technology, AT&T Bell Labs designed and implemented a new video-compression system, and AT&T Microelectronics supplied the necessary semiconductor technology.

Interference now renders unusable many standard 6-MHz channels in the VHF and UHF broadcast spectrum, including those that are targeted to carry HDTV simulcasts. Building upon key elements of Zenith's previously proposed, partially digital "Spectrum Compatible" HDTV, the Zenith/AT&T system uses an advanced digital filtering system that prevents high-powered NTSC signals from interfering with HDTV signals, allowing use of those currently taboo channels. The system, which uses a unique digital filter at the HDTV transmitter and a complementary filter in the HDTV receiver, is said to offer interference- and noise-free signals.

AT&T's research in digital video compression, channel equalization (ghost canceling), and advanced high-speed processors rounded out the system. A critical element is a video-compression algorithm that is used to squeeze the enormous amount of HDTV data into a 6-MHz channel without loss of resolution. The compression technique involves motion compensation, analysis of each frame to prepare it for transmission, and modification of the signal to compensate for the properties of human vision and the idiosyncrasies of the 6-MHz channels. The HDTV system required high-speed digital signal processors (DSP's), developed by AT&T Microelectronics, to perform the filtering, data encoding, and formatting functions.

The result of all that cooperation is an HDTV system that transmits 1575 horizontal picture lines 30 times a second (compared to 1125 or 1050 lines from competing systems). It uses progressive scan with square pixels, making it easier to interface with computer workstations and to eliminate the jagged edges and other artifacts. Zenith says the system provides "movie-theater-quality pictures and four-channel compact-disc quality digital audio."

We'll learn if their system has what it takes when testing of the five systems remaining in the HDTV race (from an original field of more than twenty) begins this fall by the Advanced Television Testing Center, Cable Television Laboratories Inc., and the Canadian Communications Research Center. After testing is completed, the FCC's Advisory Committee on Advanced Television Services is expected to recommend one as the standard in 1992. The FCC is expected to consider their recommendation and select a standard in the second quarter of 1993.

THE EIA'S HEARING-SAFETY CAMPAIGN, launched in January at the Winter Consumer Electronics Show, aims to educate consumers about the dangers of too-high decibel levels.

National hearing-safety campaign

The Electronics Industries Association (EIA), along with electronic-equipment manufacturers and retailers nationwide, launched a year-long public-service program at the 1991 Winter Consumer Electronics Show to help Americans protect their hearing through the safe use of consumer electronics. Experts estimate that 28 million Americans suffer significant hearing problems, and that 10 million of those suffer hearing loss due to excess noise. The EIA's "We Want You Listening For a Lifetime" campaign provides tips on safe equipment use and general information on potential hearing damage caused by playing sound systems at unsafe decibel levels.

High-speed quantum FET

A new device, developed by Valid Logic Systems (San Jose, CA) engineer Gene Cavanaugh, is expected to surpass the 0.2-μm technology that has been considered the practical limit for conventional semiconductor technology. Called the quantum FET, or QFET, the device potentially increases logic speed ten times, and simultaneously reduces power requirements and size by approximately a factor of ten. Cavanaugh has applied for a patent and has approached Texas Instruments, IBM, and Intel concerning possible licensing agreements to provide an opening for actual QFET production.

The single-junction QFET's take advantage of "quantum tunneling," a physical phenomena that increases speed by eliminating the area of electronic conduction in which carriers slow down by up to 3000 times. A manufacturing process called rapid thermal processing, or RTP, based on ultra-fine layers of material, is used. The device has potential applications in developing design-automation tools that benefit from high speed, low power, and small size. **R-E**

VIDEO NEWS

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

DAVID LACHENBRUCH

• **Low-cost captions.** In a hurry-up effort to implement the recent Congressional mandate to include closed-caption decoders in all TV sets 13 inches and larger (**Radio-Electronics**, October 1990), a special Electronics Industries Association (EIA) task force recommended new parameters that would make decoders inexpensive by building upon the on-screen character-generation systems already used in many sets. The EIA plan, which would decipher existing closed captions for the hearing impaired, formed the basis for an FCC rule-making proposal. Members of the task force said the proposed system might add $2 or $3 to the cost of a TV set.

The EIA plan envisions certain compromises, making some currently mandatory aspects of caption decoding optional. Those include a special full-screen "text" mode that isn't widely used at present, a second data channel, and captions in color. In exchange, the EIA proposes that Field 2 of Line 21 of the vertical blanking interval be opened up for a better—but optional—second channel, and that the captions be capable of location anywhere on the screen to avoid interference with material in the picture.

The proposal was approved by all members of the EIA task force except the National Captioning Institute, which said its own system, currently in use, could also come down to the $2–$3 level when chips are available in large quantities from a variety of sources. The EIA plan possibly can be combined with another EIA project being explored by receiver- and cable-engineering interests. That is a standardized "program identification system," which would make possible on-screen labeling of station call letters and program titles, along with such information as the running time of the program and how much more remains to be shown, at the push of a remote-control button. Ultimately, such information could be combined with automatically recording VCR's, to tape programs of specific interest—for example, all non-scheduled news bulletins, or all operas.

The FCC was ordered by Congress to promulgate final closed-captioning rules by April 12. New TV sets made or imported on July 1, 1993 or later must include caption decoders—but some manufacturers are expected to add the decoders to their sets some time this year if the simplified EIA-proposed rules are adopted.

• **Digital HDTV.** As in audio, "digital" has become the magic word in high-definition TV systems. Most contenders for consideration as the American system now have shifted to digital systems, although detailed engineering plans still are scanty. Major digital systems now include those under development by the ACTV Consortium, consisting of Thomson, Philips, NBC, and the Sarnoff Research Center; the Zenith–AT&T combine; and General Instrument.

In the latest development, the MIT team, which had proposed an analog system, is working with General Instrument on a combined digital technology. There are some dissenting voices in the digital race, however. Dr. William Schreiber, formerly of MIT and a longtime TV authority who in the past has questioned the consumer benefits of HDTV, has decried the "stampede" to digital systems at a time when digital transmission hasn't been proven practical. He warned that if all American proposals are digital and digital transmission proves impractical, the 20-year-old Japanese system could be the winner in the U.S. by default.

• **Interactive video.** The FCC has started a rule-making procedure to set aside frequencies for "interactive video data service" (IVDS), which could be used for pay-per-view systems, home shopping, games, educational programming, and even for programming VCR's. The Commission proposes to allocate 500 kHz in the 218-MHz band to IVDS, and to license two operators in each service area to share in this service from home to TV station or cable system. One interactive proponent said that such a system could probably operate much like cellular phone networks, each cell site connecting up to 10,000 homes by radio and being capable of handling up to 600,000 messages per minute.

• **Multimedia Computing.** What is claimed to be the first mass-market computer with interactive multimedia capability will be manufactured by Emerson Technologies for Trac, Atlanta, and designed to sell for less than $2,000. The price breakthrough, according to Emerson, is the result of the availability of the "PC Video" chip developed by Chips & Technologies Inc., San Jose, CA. That single-chip processor permits PC's to accommodate input from VCR's, camcorders, TV sets, laser discs, and other video sources, for display on the monitor and storage in the PC's program. It will even let computer operators watch and listen to on-screen newscasts while involved in otherwise serious labor. The PC Video chip initially is priced at $55 in volume and is claimed to reduce the cost of adding multimedia to computers by as much as 70%.

• **Instant Video.** You may not want to see a full-length movie in 15 seconds, but Explore Technology, of Phoenix, AZ., thinks that's all the time that's needed to transmit it. Explore is proposing a pay-per-view system, based on its patent for data compression, which permits transmission of programming in short bursts to a receiver which stores the information briefly in memory, and then plays it back with the proper timing. Explore says the saving in transmission costs will make such programs competitive with video rentals. The system is said to be compatible with any transmission medium, and includes a transmitter and receiver that can be connected by fiber, satellite, broadcast, coaxial cable, or even phone lines. **R-E**

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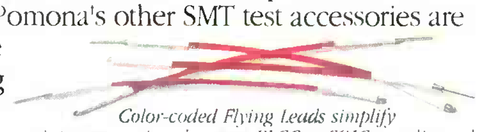

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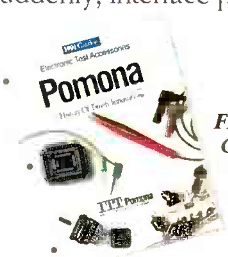

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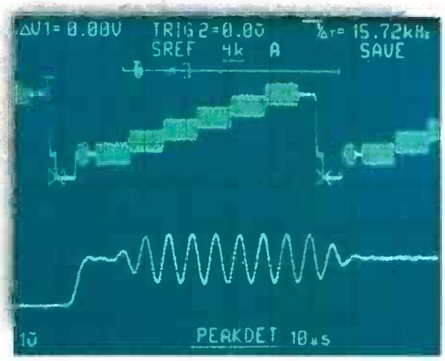
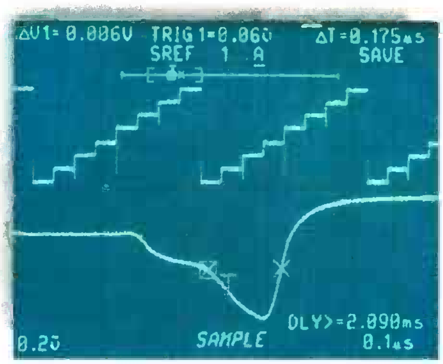
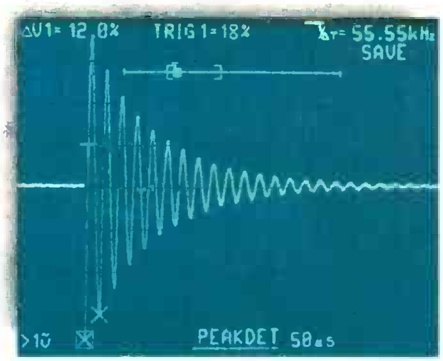


Analyzing TV and complex video signals?

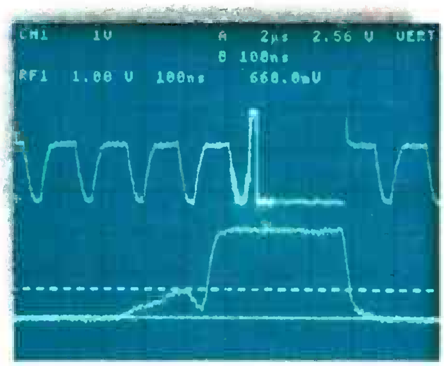


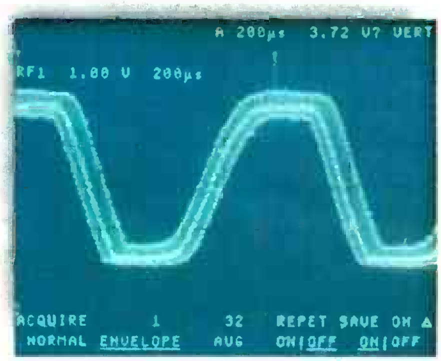
Uncovering elusive glitches?



Capturing single-shot events?

Testing telecommunications signals?


Finding aberrations buried within a signal?



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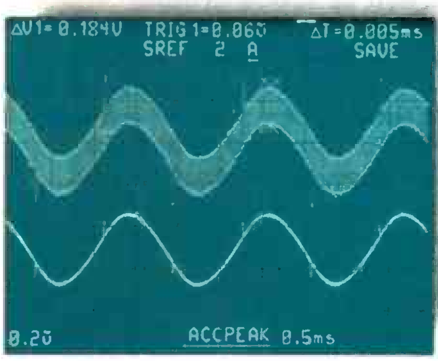
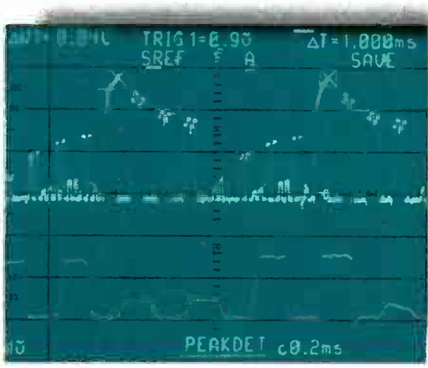
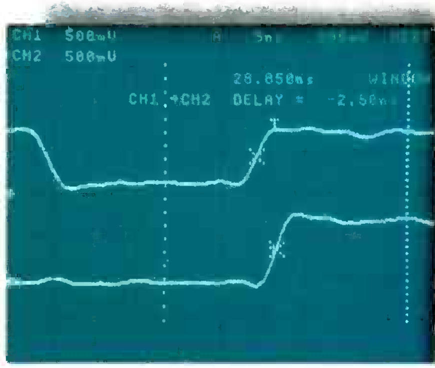


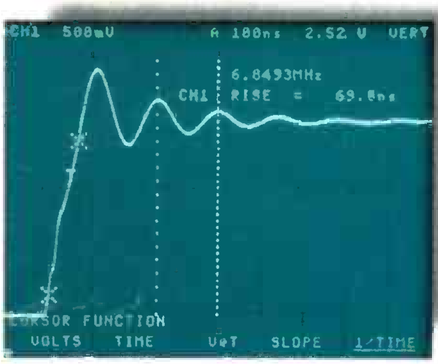
Characterizing signal noise?



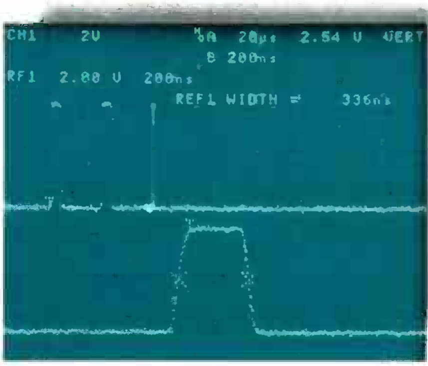
Capturing and analyzing long data streams?



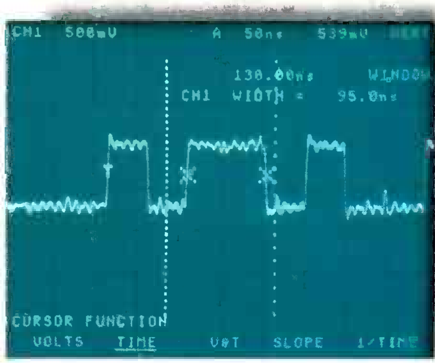
Measuring timing relationship between signals?



Performing complex measurements automatically?



Expanding glitches for close analysis?



Windowing in on signal details?

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PRINT-SCREEN INDICATOR

I'd like to modify my IBM-style keyboard so it has an indicator to show when I'm using the print-screen function. Ideally it should be something similar to the CAPS LOCK, NUM LOCK, and SCROLL LOCK LED's that I currently have. Any ideas?—T. Waller, Yorktown Heights, NY

What you're asking is one of those things that seem simple but is actually quite complex. It's a kind of "Why is the sky blue?" type question.

The first thing to understand is that the PC's keyboard is different from the ones used by Apples and a few of the other popular home computers. The first difference is that it's not a simple matrix keyboard in which each keypress connects two or more wires together to generate a series of highs and lows on a multi-pin connector. The PC keyboard is a serial device, and the standard five-pin connector carries the data, power, clock, ground, and reset signals on separate lines.

The second difference becomes evident once you know of the first difference, since you can't generate serial data without a bunch of silicon. As a result, the PC keyboard is really a small computer in itself and, although different keyboard manufacturers use different IC's, most of them base the keyboard circuitry around a microprocessor specifically designed to handle and control I/O. The 803X, 804X, and 805X microprocessor series from Intel is a fairly common choice. Figure 1 shows the inside of such a keyboard.

Knowing those facts, you can see that what you want to do has to involve a lot more than piggybacking an LED onto a couple of switches.

That isn't to say that what you want to do is impossible. It's an involved project and would more than likely require you to design some circuitry of your own. Keep in mind that, if you build something that sits inside your keyboard and monitors anything other than the output, you'll more than likely be able to use the device only on your own particular keyboard. Different keyboards use different circuitry. There's not enough room here to go into the details of building a circuit like this but I can block out the approach that I would follow.

There are two basic approaches to the problem. The first is to monitor the data going from the keyboard to the computer and the other is to capture the particular combination of switch closures in the keyboard before they reach the keyboard's controller. I'm not going to take a guess as to which would be easier but, if I was doing this, I'd choose the first alternative since I wouldn't want to take any chance of damaging the keyboard circuitry.

If you do want to modify the keyboard itself, you could try to identify the combination of highs and lows sent on the keyboard's internal data bus whenever you do a Print Screen. Once you've found those, you could buffer and decode them to drive an indicator such as an LED.

FIG. 1—A PC KEYBOARD is a small computer in itself. This keyboard's circuitry is based on an 8048 microcontroller that's specifically designed to handle and control I/O.

CABLE TRACER

I'd like to trace the path of an underground power cable. One end is above ground and the other end is lost somewhere below ground. Neither end is connected to power. Isn't there some sort of wave generator I could build that would provide a signal I could trace with a receiver and antenna?—D. Andrew, British Columbia, CA

It's really terrific when a simple question like this has a really simple answer. I've faced this problem myself and I'll pass along the method I used.

Most of the commercial equipment that's designed for this purpose works exactly as you described. A signal is sent along the wire and a specially tuned receiver picks it up. Depending on the amount of bells and whistles, that sort of gear can set you back an impressive number of bucks. But there's an alternative.

As long as you're sure that both ends of the cable aren't connected to anything, connect the above-ground end to the 120VAC line (through a fuse and ground-fault protector). Once you've done that, connect the noisiest appliance you have to the line and turn it on. The best ones to use are those with motors that have a set of old brushes in them. You can usually spot that by seeing whether lots of sparks are created where the brushes ride on the motor.

Each one of the sparks is generating a lot of RF noise that's being transmitted down the cable. You can detect the noise with a portable radio since the noise spreads across a wide band of the spectrum. All you have to do is tune the radio between stations (you may find the AM band is better), turn up the volume, and follow the static across the ground. This may seem a primitive method but it's exactly the method used by the "high priced spread."

KEYBOARD UPGRADE

How can I make a 101-key keyboard from an IBM AT operate with an IBM-compatible WYSE PC+ model WY-1400-20? I would be willing to build some simple circuitry if it's necessary.—B. Van de Ayr, Chehalis, WA

While there's probably no reason why you can't do what you want, there are a few problems in getting it done. I'm not familiar with either the Wyse-PC+ or its keyboard but, just because the computers are compatible, there's no guarantee that the keyboards are compatible. (There are different degrees of compatibility.) Not all models of IBM keyboards are interchangeable with each other. The keyboards designed for the XT, for example, will not work with the AT.

If you're dead set on modifying or adapting the Wyse keyboard for use with your AT-compatible computer, you'll need some very specific information before you can get started.

- You need a list of the scan codes produced by the Wyse keyboard and those required by the AT-compatible.
- You need a schematic of the Wyse keyboard that shows, among other things, the pinouts of the output connector and how the data is transmitted to the computer.
- Although not strictly necessary, make sure the scan codes for the extended function keys (F11 and F12) are compatible with the IBM.
- Be certain that both the power and reset requirements of the Wyse keyboard can be supplied by the IBM.

There's one other thing to be aware of since you're trying to use the keyboard with an AT, rather than an XT. In AT-class computers, the data from the keyboard is handled by a preprogrammed microcontroller in the computer itself. There are a few companies (Phoenix, AMI, etc.) that can supply that, but they are not all compatible with each other. That is usually a consideration only for setting the CMOS configuration memory of the computer, but keep in mind.

Adapting the Wyse keyboard may turn out to be something as trivial as changing the connector on the end of the cable but, considering the fact that you can buy a keyboard for about fifty bucks, you have to wonder it's really worth the effort. **R-E**

LETTERS

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MAC PLUS FIX

I would like to thank **Radio-Electronics** for the fine article on building a Mac clone (January 1991). My Mac Plus nuked itself last week. I removed the power board and, upon taking the board to two Apple dealers, I was told that it would cost $300 to fix—and I would have to put the board back in the Mac and then bring them the whole machine. No way! I opened the magazine and called Pre-Owned Electronics. They sent me the board in two days for $119. I want to thank you guys for all the help in locating decent merchants who want to do honest business. Keep up the good work.

RICHARD RUSSO

TABLE THAT TABLE!

I read the article "1 Volt = ?" (**Radio-Electronics**, February 1991) with considerable interest. It was well written and comprehensive. It contained a gratifying amount of basic physics and pulled together a great many ideas that are often hard to find because they are scattered over several different chapters in various textbooks.

Were it not for one fundamental flaw, Table 1 would be an extremely useful reference for students of several academic disciplines. The author used an obsolete and (now) non-standard set of base (or principal) quantities.

Intellectually and philosophically I *like* the author's choice of charge as a base unit and his derivation of dimensional equivalents in terms of coulombs. I also still "like" to use mhos, micro-microfarads, milli-microamps, and kilo-megacycles. Nevertheless, those outdated standards are all contrary to the American National Standards that have been in effect for some time now and really are the ones that should be used.

If the author and your editors would check the IEEE Dictionary for "units and letter symbols," I believe they will find that the electric base quantity (in the SI system) is *current*, not charge. Charge is now properly described as a "derived" quantity that has dimensions of (current × time) or ampere-seconds. Regrettable, that means that in each of the author's "Dimensional Equivalents" in Table 1, the Coulomb (C) term should be replaced with (A × s), and the terms recollected.

I know this all seems perverse to old-timers who learned to start with the charge on the electron and to calculate how many electrons it takes to make a coulomb, but there is a good practical reason for the change. When you use current as the base unit for electrical measurement, you can define the ampere in terms of the force exerted upon two parallel conductors. That is evidently something that is more directly measurable in terms of mass, length, and time—and more up-to-date.

LUCIUS DAY
Lakewood, CO

REMOVING IC'S

Thank you for the years of excellent reading in the extremely diverse field of electronics. I've been reading **Radio-Electronics** on and off for some years, and have enjoyed every issue.

Now for the good news. Over the years I have read letters from readers about the handling of IC's and the questions concerning their abuse. Well, here is some shocking news. When chips (TLL's, CMOS, etc.) are manufactured, they are dipped in a molten material. Notice I said molten, which means that the material is in liquid state. The material used and the temperature of that material must give off heat during the change of state from liquid to solid. Thinking about that concept, I began to work on a way to extract circuit-board components without the use of desoldering tools, and one that would save plenty of time.

Try this out for size: Using a *hot* oil bath as a desoldering fluid and keeping the temperature down to a level that the IC's could handle, I dropped the board in, and within seconds parts began to fall off the board. The temperature of the oil bath should be no lower than 370°F and no hotter than 380°F. That temperature is within an IC's tolerance.

The only exception is electrolytic capacitors, as they will explode and send hot oil all over the place.

Use gloves and eye protection during this process. I have extracted hundreds of useful parts that way and have had an 80% success rate. I said 80% because some plastics cannot withstand that temperature, and the hot oil can break down some plastics altogether.

I hope your readers can use this information—but if you do, be sure to observe safety first. And thanks again for the excellent reading material. Keep up the good work.

MICHAEL BROWN
Stockton, CA

Your method sounds a little dangerous to us, but it does show that where there's a will, there's a way!—Editor.

AM PROBLEMS

Since **Radio-Electronics** printed the article "Whatever Happened to AM Radio" (September 1990), I thought the editors and readers might be interested in the reply I received from my congressman in reply to my suggestion that AM stereo circuitry be mandatory in future AM/FM stereo equipment. Congressman Dale E. Kildee said, in part, "In recent years, new technologies have been employed that have led to a wider use of AM stereo components. At this time, no legislation has been introduced in the House of Representatives that would require stereo manufacturers to place AM stereo components in their equipment."

All three AM-only radio stations in my area were sold at bargain prices last year—one at auction, one in bankruptcy court, and one to a church. Only the latter, a gospel station, emerged with no major changes. The first, which was a leading Top-40 station in the 60's and 70's, became a Christian station whose last Arbitron rating was 0.0. The second, formerly the leading news and information station, switched to a satellite-fed, heavy-metal rock format called "Z-Rock." Despite adding AM stereo equipment, the station was not successful, and went off the air. The owner (who also owns a mobile-home sales lot and added another one on the radio-station grounds) plans to try another format, but as of this writing the station is still off the air.

It would appear that your article is right on the mark concerning AM radio's problems.

GARY FLINN
Flint, MI

WRIST STRAPS

Steve Swenton's statement on using a wrist strap when desoldering static-sensitive devices (*Letters*, **Radio-Electronics**, September 1990), "...always use a ground strap (a metal wrist strap with a detachable ground wire) and connect its wire to ground...," needs further clarification, lest someone fashion a homemade wrist grounding strap from that description.

Commercially available wrist strap/ground wires contain a current-limiting resistor, usually 1 megohm, in order to protect the operator. One should never connect oneself to a hard ground when working around sources of potentially lethal (e.g., household) current.

JOHN L. HORNBY
Madison, CT

XT-TO-AT UPGRADE

Having worked for a company that manufactures floppy disks, I'd like to make several comments concerning the differences between various disk formats.

It's true that 5¼-inch, high-density (1.2 MB) drives have twice as many tracks as the regular 360K drives. That doesn't increase the chance of crosstalk, however, because the track width (the width of the track written or read by the head) is, of course, also half as great.

It isn't a case of the write current being decreased on high-density (HD) drives. Instead, the write *field* is *increased*. That is necessary because there is a fundamental difference between disks designed for HD operation and non-HD operation: The HD disks' coating material needs a *higher* field to reliably saturate (i.e., be fully magnetized one way or the other).

The software on an AT *can* change the write current on an HD drive. There's a pin specifically for that on the drive interface, and the BIOS can flip it when required. Indeed, it *has* to reduce the write current when writing to 360K disks because otherwise the excessive write field would cause each transition, as it was being written, to affect the previously written transition.

The recorded level may seem low when reading on a 360K drive a disk written on a 1.2-MB drive, but that is because only one-half the normal track width has been written, causing a reduced signal output of approximately 70%. I have never had any problems from that, since drives are rated to work with dropouts to 45% remaining signal and below. However, it is true that the loss of signal level does reduce your operating margin against problems like misalignment and drift. Of course, HD drives are rated to work with 360K-formatted disks despite the reduction in available signal level.

Where problems most often arise is when disks are overwritten by a succession of different drives. Remember that HD drives can write only half-width tracks (relative to a 360K drive). So if a track is written "wide" and overwritten "narrow," a "wide-reading" drive will read both the new, wanted, narrow track and the remnant of the old wide track together.

Remember that the directory area of the disk is rewritten whenever you add a file! The above problem may render every one of the files on the disk inaccessible from the addition of a single file, because the entire directory has been corrupted.

For the sake of completeness, I should mention that, while 3½-inch HD disks have a different material from regular (720K) 3½-inch disks, there is no difference in track widths, ruling out the problem of overwriting. Also, the coating materials are similar enough that a 720K diskette can often be formatted for 1.44 MB without any errors reported during the format. However, the non-HD disks are highly marginal with the HD format, and you are highly likely to encounter reliability problems. Recent 1.44-MB systems have implemented a sensor that detects the HD hole to prevent non-HD disks form being incorrectly formatted. It is probably also undesirable to format 3½-inch HD disks as 720K, but I haven't checked into that.

DANNY WILLIS
Munich, Germany

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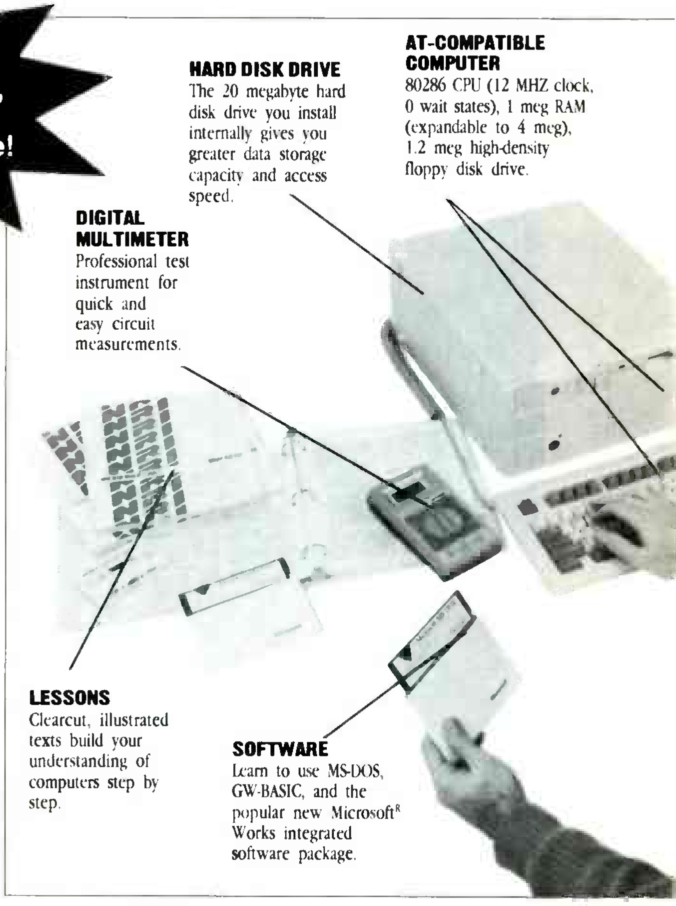

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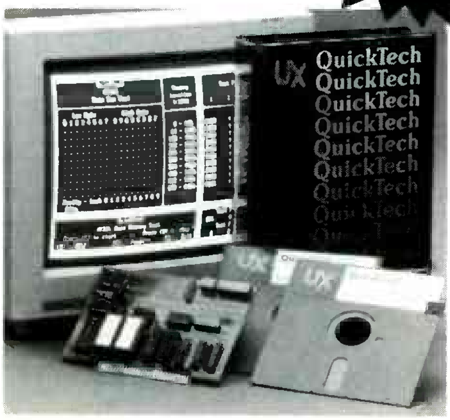

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The *FS74A Channelizer Sr.* TV-RF signal analyzer costs $3495.—**Sencore, Inc.**, 3200 Sencore Drive, Sioux Falls, SD 57107; Phone: 1-800-SENCORE.

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The *R3800* 32-channel logic analyzer costs $3995.—**Rapid Systems, Inc.**, 433 North 34th Street, Seattle, WA 98103; Phone: 206-547-8311; Fax: 206-548-0322.

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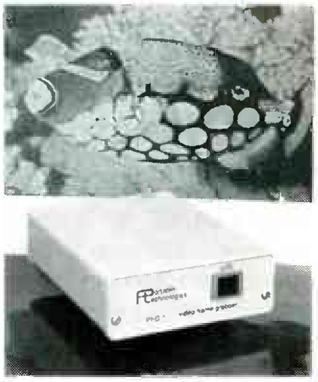

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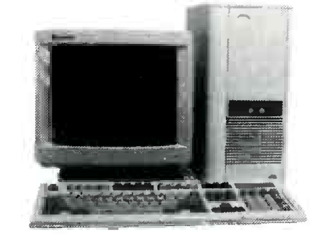

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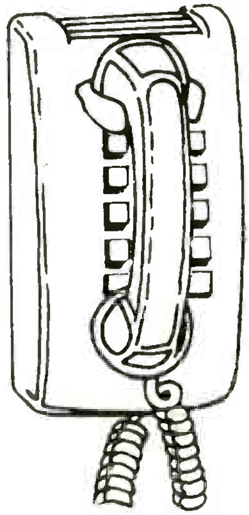

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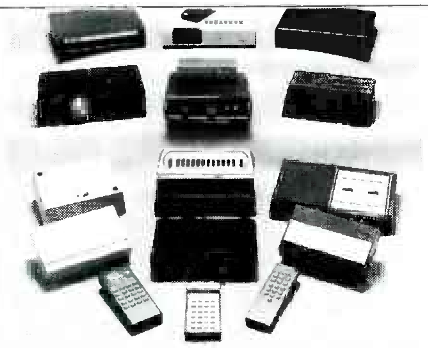

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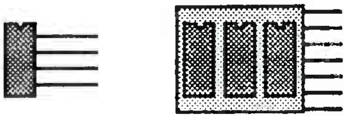

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the image to be displayed on the screen, adjusted for brightness and contrast, printed directly to HP Laserjet II and compatible printers, and saved either as linear files or as TIFF files that can be imported to most desktop-publishing applications. The *PFG-1* also includes a DB9 serial cable, a DB9-to-DB25 adaptor, an RCA video cable, and a 9-volt lithium battery as well.

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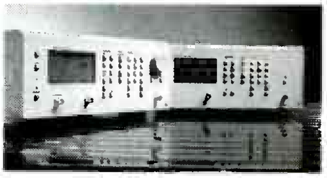

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and repair of consumer audio electronics. The 180-MHz instruments can be used either as stand-alone benchtop tools or, using the GPIB interface, in test systems. The *PM 5328* also features a built-in 200-MHz frequency counter. The signal generators' standard modulation modes include AM, FM, and frequency sweep. A high-stability frequency-reference option is also available to ensure accuracy in higher-performance applications. Modulation can be external as well as internal, and parameters such as modulation frequency, sweep width, and sweep time are user-selectable.

By providing full, clear information about all signal parameters and settings, the multifunction backlit LCD screen simplifies operation of the signal generators. Push-button-activated menus are used for setting frequency, output level, modulation mode, and modulation parameters. The *PM 5328* has a large rotary-control knob with variable resolution, for quick selection of the desired value. Frequencies and levels can also be set by step-by-step adjustments or by direct numeric entry of the value.

Both models can store and instantly recall complete front-panel setups. The *PM 5328* has memory for 99 setups and the *PM 5327* can store 10. Stored settings can be called up remotely, using the GPIB interface. Output amplitude ranges are from −127 to −7 dBm for the *PM 5327* and *−127 to +13* for the *PM 5328*.

The *PM 5327* and *PM 5328* RF-signal generators have base list prices of $4900 and $5650, respectively. The FM-stereo-modulation option has a list price of $750.—**John Fluke Mfg. Co., Inc.**, P.O. Box 9090, Everett, WA 98206; Phone: 800-44-FLUKE.

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The *FG-150* sweep/function generator with built-in frequency counter has a suggested list price of $295.—**BelMerit Corporation**, 14775 Carmenita Road, Norwalk, CA 90650; Phone: 213-802-366; Fax: 213-802-3298.

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The model *5100* component/HDTV waveform monitor costs $3800.—**Leader Instruments Corporation**, 380 Oser Avenue, Hauppauge, NY 11788; Phone: 800-645-5104 (in NY, 516-231-6900).

PEN-TYPE DIGITAL MULTIMETER. Designed for applications where the technician doesn't have much room to maneuver, *Beckman's DM73* is a pen-style, hand-held digital multimeter that features a 3½-digit display with 0.5% accuracy (DC 2V range) and auto-ranging. Its compact

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size, light weight, and simple slide switch for changing functions make the *DM73* easy to use for trou-

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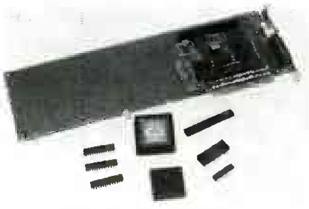
bleshooting and installing electronics in tight places such as computer boards, under a car dashboard, or behind an arcade game. Another convenience feature that comes in handy in awkward spots is the data hold function, which lets the user manually "freeze" the display so that it can be moved from the measurement point to take the reading.

Other features of the *DM73* include an audible continuity check, a buzzer that sounds when changing functions, a built-in scabbard for the ground probe, and a display of the function in use. The DMM has full auto-ranging capability on 12 measurement ranges. DC voltages up to 500V, AC voltages to 250V, and resistance up to 2 megohms are measured using an accurate dual-slope integrating analog-to-digital (A/D) conversion technique.

The *DM73* pen-type digital multimeter, complete with batteries, test leads, and operator's manual, has a list price of $69.95.—**Beckman Industrial Corporation**, Instrumentation Products Division, 3883 Ruffin Road, San Diego, CA 92123-1898; Phone: 619-495-3200.

PC-CARD PROTOTYPING KIT. To provide a broad base of PC-users with low-cost digital-signal-processing (DSP) capabilities, *Signal-Systems*' is offering *DSPerato*, a real-time, DSP expansion-card prototyping kit that features a Motorola 56001 DSP chip. Motorola's 56001 DSP runs at 20 MHz, delivers 10 MIPS, and offers advanced technologies including pipeline instruction fetches; parallel data moves to three separate 24-bit (X-data, Y-data, and program) memories; and easy interfacing to the host computer. *DSPerato* contains a full-length IBM-PC prototype card that already has a bus decode and buffer printed circuit. The rest of the card has uncommitted 0.100 center-plated through holes with power buses and pads. The 56001 DSP and support chips are wired and soldered on those pads.

Two optional high-performance video and audio A/D and D/A converter boards can be attached to the card via 0.100 center pin headers. The 16-bit audio board uses Motorola's 56ADC 16-bit converter;



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the 8-bit video card uses Sony's 8-bit 20-MHz semi-flash converters. For maximum flexibility in custom projects, the user can opt for both converters, just one, or neither to be attached to the DSP card.

Parts needed to populate the DSP card and the converter kits—including all chips, sockets, resistors, and capacitors as well as the 56001 DSP and 8K × 24-bit 45-ns static RAM—are included. The user can add parts as needed to configure the card for custom applications. All assembly instructions and schematics required for connecting the DSP and the converters are also included, along with Signal-Tools software. Signal-Tools' functions include real-time spectrum analysis, digital oscilloscope, and waveform capture and generation. The software features a keyboard- or mouse-driven pull-down menu interface.

Optionally available is a software development kit that contains MACRO-DSP, a 56001 DSP macro assembler for IBM-PC's; a debugger, and linkable object modules.

DSPerato costs $299, the audio and video converter boards cost $149 each, and the software development kit including MACRO-DSP costs $99.—**Signal-Systems**, 15105 S.E. East Avenue, Milwaukie, OR 97267.

800-MHz GROUND-PLANE ANTENNA. Because broad-band scanner antennas perform poorly at higher frequencies, many scanner listeners hear only a small fraction of the signals available on the 800-MHz band. The *MAX800* 800-MHz ground-plane antenna from *Cellular Security Group* is a specialized mono-band antenna designed to alleviate that problem. Based on plans presented in the ARRL Handbook, the element lengths are cut precisely to the proportionate dimensions. The design supports the elements, protects the feed-point, and provides a quick and easy mounting.

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EMThe *MAX800* 800-MHz ground-plane antenna costs $19.95; optional type-N connector models of long 38-inch PVC mounting masts are available for an additional $5.00.—*Cellular Security Group*, 4 Gerring Road, Gloucester, MA 01930; Phone: 508-281-8892. **R-E**

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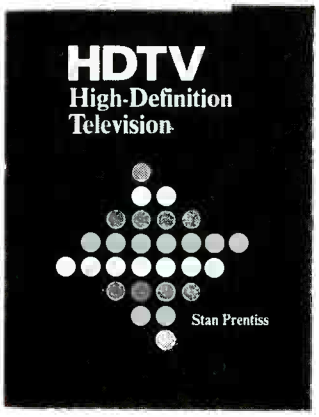
HDTV: HIGH-DEFINITION TELEVISION; by Stan Prentiss. Published by Tab Books Inc., Blue Ridge Summit, PA 17294-0850; Phone: 1-800-233-1128; $16.95.

Already a reality in Japan (albeit with a steep price tag and limited programming), HDTV is eagerly awaited around the rest of



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the world. More than a dozen major corporations currently are competing to perfect the revolutionary technology that promises to bring crystal-clear pictures and high-quality sound to television. This book is intended to help prepare engineers, technicians, students, and marketing managers for the unveiling of HDTV.

The book provides an inside look at both the technical and the legislative aspects of high-definition television. It explores the widely divergent industry standards in North America, Europe, and Japan that are now impeding HDTV production, and analyzes FCC and congressional regulation of HDTV research and development in the U.S. The book explains the competing delivery and receiving systems under development, discussing their pros and cons and describing the methods used to create those systems. In addition, the book covers the progress of HDTV variants that could enhance the performance of standard TV receivers, such as improved-definition television and extended-definition television.

HEATHKIT WINTER 1991 CATALOG. From Heath Company, Department 350-054, Benton Harbor, MI 49022; Phone: 1-800-44-HEATH; free.

Bound into this 60-page catalog is a special "Home Automation" insert that devotes 28 pages to a variety of innovative products for safety, security, convenience, entertainment, and energy management in and around the home. Aimed at do-it-yourselfers,

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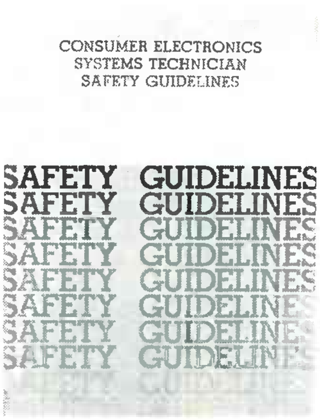
the home-automation products include whole-house automation and security systems, motion-sensing indoor and outdoor lights, wall switches, wireless video broadcasters, wireless phone extensions, flood sensor alarms, an electronically controlled pet door, and automatic-lawn sprinkling systems. The main catalog includes a variety of easy-to-build electronic kits as well as tools, weather instruments, computers, amateur-radio equipment, home-entertainment products, and home-study electronics courses and videos.

CONSUMER ELECTRONICS SYSTEMS TECHNICIAN SAFETY GUIDELINES. From EIA/CEG, Department PS, 2001 Pennsylvania Avenue, N.W.. Washington, DC 2006-1813; $1.00.

Although manufacturers strive to make their products safe to use and to service, and student technicians are taught the inherent dangers in the work, technicians often tend to become complacent with experience. This brochure is intended to remind them of possible dangers and to keep safety considerations a conscious part of their work. It contains important safety guidelines that should be followed and updated UL requirements for safe installation and servicing of antennas, TV's, and other consumer-electronics products.



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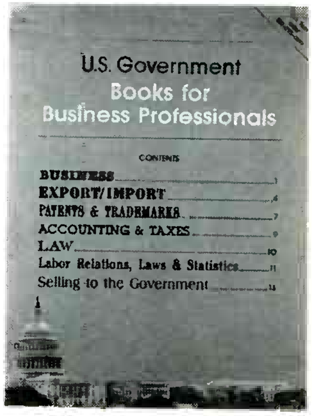

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Whether you own your own company, have joined the ranks of those who are supplementing their day jobs by running a second business from their homes, or come up with patentable creations on your workbench, the publications listed in this catalog contain information you'll find valuable. Intended to create greater awareness of and access to government information for the business community, the 22-page catalog contains the most popular government business books and subscriptions that are sold to the public. Those publications cover such fields as accounting and taxation, selling to the government, exporting, labor law, patents and trademarks, and business statistics. **R-E**

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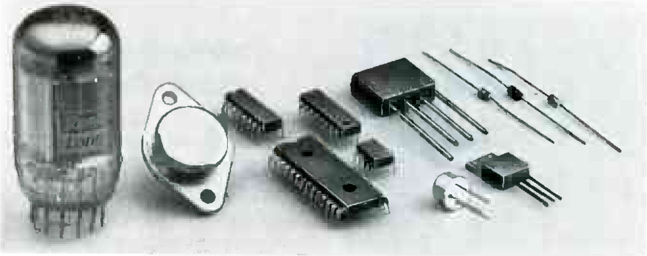

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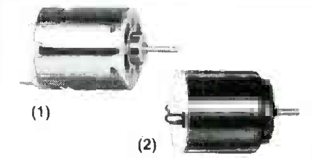

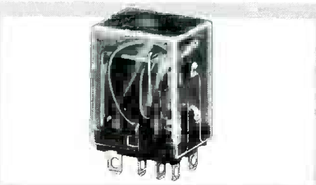

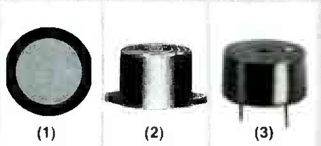

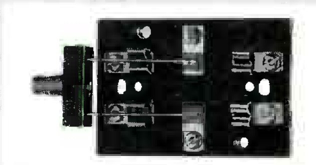

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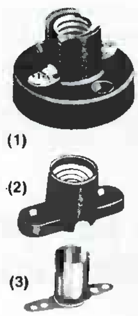

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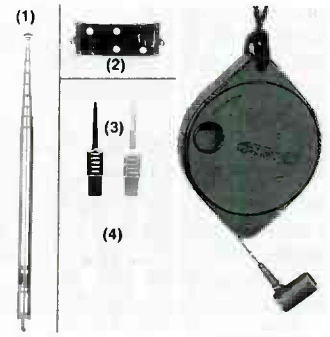

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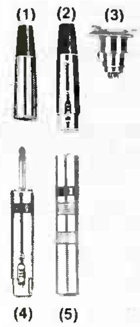

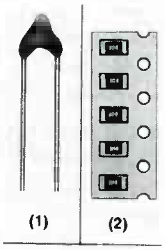

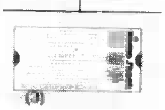

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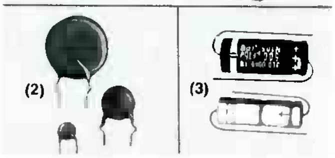

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BUILD THIS DRAM TESTER

Build a sophisticated DRAM tester with function, speed, and margin tests for under $60!

FRED HUFFT

IF YOU SERVICE OR EXPERIMENT WITH personal-computer hardware you have probably handled a lot of memory circuits, commonly referred to as a "RAM" (random-access memory) or "DRAM" (dynamic RAM). When troubleshooting a PC memory problem, expanding RAM capacity or upgrading the cycle speed of a memory bank, it can be very helpful to have a way of function testing and measuring the access time or speed of the DRAM IC's. Many intermittent memory failures have been traced to a slow DRAM in the memory bank. On the other hand, some DRAM's will far exceed their minimum access rating and can be speed tested and sorted for faster functions, saving the cost difference to the faster rated parts.

A number of small DRAM testers are available from about $150 to $1000, with the less-expensive models not having a lot of features. However, if you are interested in building a multi-featured unit that can function test, accurately speed test, and automatically cycle the tests under high-, low-, or normal-voltage margins, all for less than $60 (plus enclosure and AC adaptor), then check out this easy-to-assemble DRAM Tester.

Capabilities

The unit can test 64K × 1, 256K × 1, or 1MEG × 1 DRAM's, and can measure speed or access times from 60 to 200 nanoseconds (ns). There is a switch to select a "HI" and "LO" voltage-margin test and three LED indicators that show the current device-under-test (DUT) voltage. There's also a red/green LED that blinks green to show a test is running, displays a continuous green to show a test has run complete without an error, and will display a continuous red when a test is stopped by the detection of an error.

An 18-pin ZIF (zero insertion force) test socket is provided for 1-MEG DRAM's and a 16-pin ZIF test socket is used for the 64K and 256K DRAM's. A pushbutton TEST switch starts a test sequence which runs about 10 to 14 seconds depending on the access speed. However, a CYCLE switch is provided to continuously recycle the selected test, if desired. When a 1-MEG DRAM is tested, a 0101 data pattern is written to all addresses in the DRAM, then each address is read back and compared for correct data. An error stop will occur immediately during the read test if the data is not correct.

After the 0101 pattern test, a 1010 pattern is written to all locations, then read back and compared. The two-pattern test is automatically run twice; upon successful completion of the two-pattern double test, the tester stops and indicates a continuous green on the PASS/FAIL indicator.

A 256K DRAM receives the same test except that it's written to and read back 4 times during each test and a 64K DRAM receives the write/read test 16 times in each pattern. If the CYCLE switch is on, the test does not stop and will continue until an error is detected. If the MARGIN switch is on, the first two-pattern test cycle will be run at low-margin DUT operating voltage and the second cycle will automatically switch to high-margin DUT operating voltage. Should both the MARGIN and CYCLE switches be on, the tests will alternate from low- to high-margin voltage. All voltage and test signals are applied to both ZIF test sockets simultaneously, but only one DRAM can be tested at a time. DRAM's to be tested can safely be inserted or removed from the ZIF test sockets with the power on.

Dynamic RAM

DRAM's use multiplexed row and column address inputs; 64K DRAM's require only 7 address lines, 256K DRAM's require 9, and 1-MEG DRAM's require 10. Figure 1 shows a block diagram of a typical 256K×1 DRAM, and Fig. 2 shows a typical 1-MEG DRAM. Address decoding and address latches are incorporated in the DRAM. To address the DRAM, row-address data is put on all address lines and clocked by the RAS (row address strobe) signal, then the column address data is put on the address lines and clocked by the CAS (column address strobe) signal. DRAM's have a READ/WRITE input pin, usually labeled W̄, to control the type of operation; a DATA IN pin, D; and a DATA OUT pin, Q.

Data is held in dynamic RAM by the charge on internal capacitors. Since the charge degrades with time, the bits need to be "refreshed" or row addressed at approximately every 4 to 64 milliseconds. That is typically done by a RAS-only cycle through the row addresses—a normal read or write cycle will also accomplish the refresh. A 1-MEG DRAM may have a "test function" input (TF) at pin 4 that allows it to be tested 4 bits at a time; we do not use that function so the TF input is disabled by tying it to ground.

The timing of the address and strobe inputs is critical. A DRAM's "access time," or speed, is the time from RAS, which is the start of the addressing, to the time at which there is valid data at the output pin D. That is very basically how the DRAM works. Figure 3 shows a read-cycle timing chart for a 256K×1 DRAM, and Table 1 explains what the timing symbols mean.

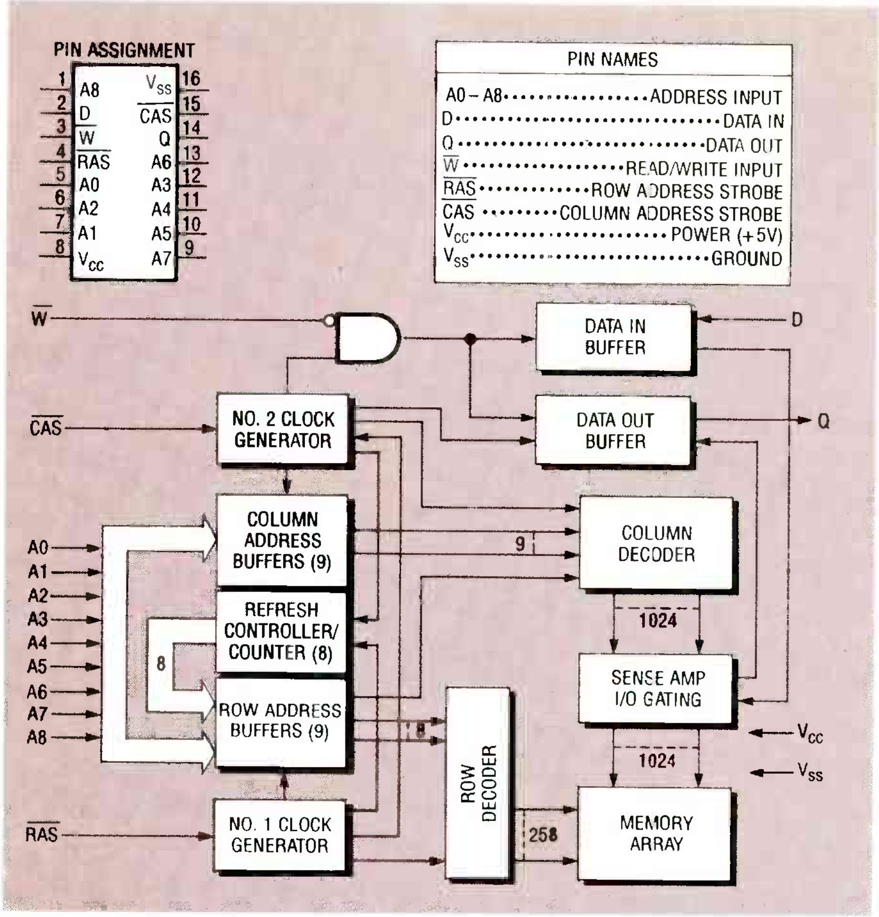


FIG. 1—256K DRAM PIN NAMES AND BLOCK DIAGRAM. DRAM's use multiplexed row and column address inputs; this 256K DRAM requires 9.

TABLE 1

	Parameter
t_{RC}	Random Read or Write Cycle Time
t_{RAC}	Access Time from $\overline{RAS}$
t_{CAC}	Access Time from $\overline{CAS}$
t_{OFF}	Output Buffer and Turn-Off Delay
t_{RP}	$\overline{RAS}$ Precharge Time
t_{RAS}	$\overline{RAS}$ Pulse Width
t_{CAS}	$\overline{CAS}$ Pulse Width
t_{RCD}	$\overline{RAS}$ to $\overline{CAS}$ Delay Time
t_{ASR}	Row Address Setup Time
t_{RAH}	Row Address Hold Time
t_{ASC}	Column Address Setup Time
t_{CAH}	Column Address Hold Time
t_{AR}	Column Address Hold Time Referenced to $\overline{RAS}$
t_{RCS}	Read Command Setup Time

Circuit description

The DRAM tester uses two voltage-regulator IC's and only six logic IC's, thanks to the use of two PLD's (programmable logic devices) which replace about ten individual IC's. Refer to the block diagram in Fig. 4 and the sche-

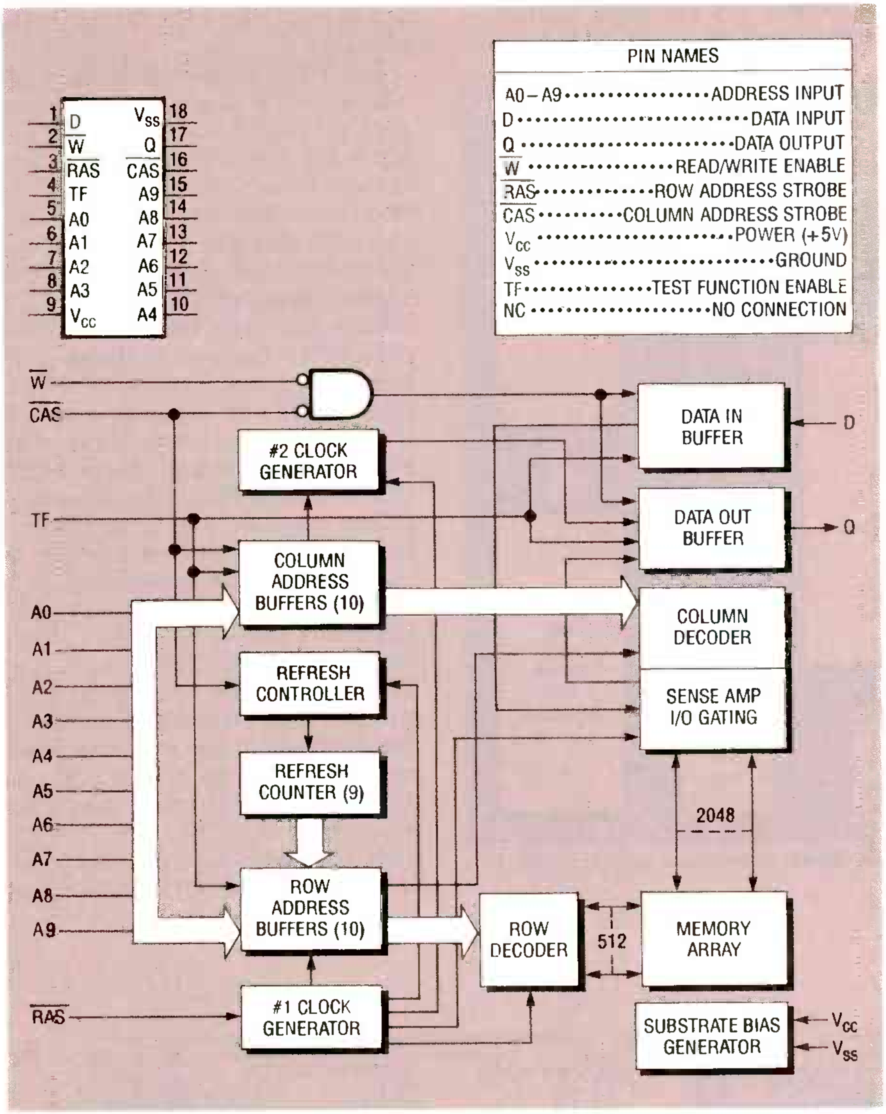


FIG. 2—1 MEG DRAM PIN NAMES AND BLOCK DIAGRAM. Address decoding and address latches are incorporated in the DRAM.

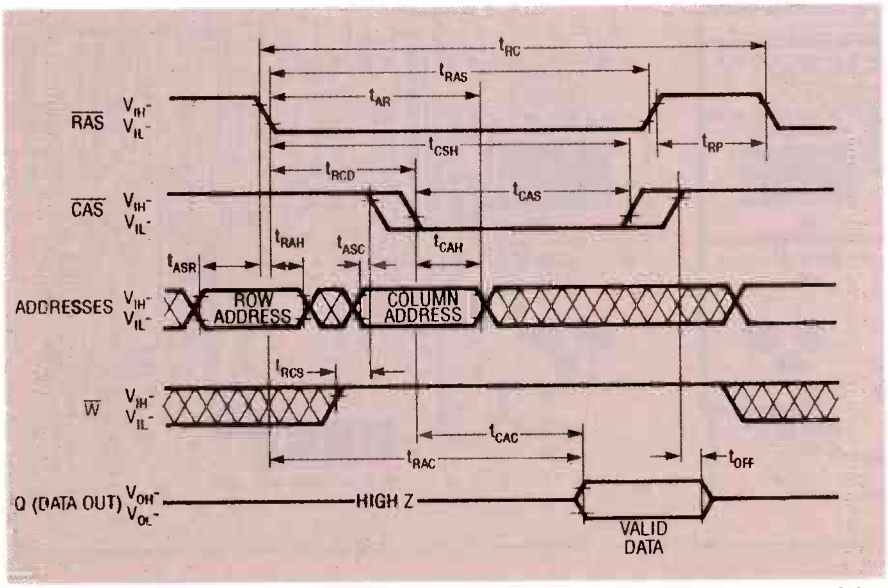


FIG. 3—DRAM READ CYCLE AND TIMING DIAGRAM for a 256K × 1 DRAM. Table 1 explains what the timing symbols mean.

matic in Fig. 5. An AC power adaptor supplies 9 volts DC at 150 mA to a full-wave bridge rectifier made up of D5–D8, which provide automatic input-polarity protection. The 5-volt regulator, IC7, supplies power to everything but the DUT (device under test). DUT power is supplied by IC8, an LM317LZ adjustable regulator which is controlled by logic in the PLD, IC5. For a normal test, IC8 outputs 5 volts to the DUT. Otherwise, 4.5 volts is supplied for the low-margin test and 5.6 volts for the high-margin test.

As mentioned before, IC5 and IC6 are TTL PAL devices: IC5 is an MMI/AMD PAL16L8B-2CN low-power, 25-ns device that contains the oscillator circuitry for our system clock. Components R15, R16, C12, and C5 are also part of the oscillator. The additional components R14, R5 (the access-time potentiometer), R19 (the calibration trimmer), and R17 (the dial-spread trimmer) form the speed-test circuit which varies the basic system clock.

The clock output at IC5 pin 15 is fed into IC6 pins 1 and 6. When the START TEST switch S1 is pressed, a START/RESET signal is generated through R7, C2, and R8 which resets IC2 and IC3 at pin 11; the signal is also applied as an input to IC6 pin 8. Logic in IC6 will gate an output clock signal, designated CLK1, at pin 14. That drives pin 10 of IC2 which is part of a 24-stage ripple-carry binary counter consisting of two 74HCT4040's (IC2 and IC3). As the clock increments the IC2/IC3 ripple counter, the Q0–Q7 and Q10–Q17 outputs drive IC1 and IC4, which are 74HCT257 quad 2-input multiplexers.

Multiplexers IC1 and IC4 each select four bits of data from two different sources under the control of a common select input at pin 1. Logic in IC6 generates the RAS signal which is input at pin 3 of IC5, present at pin 3 of test-socket ZIF1 and pin 4 of ZIF2, and is also the input select signal at pin 1 of IC1 and IC4. The outputs of IC1 drive address lines A0–A3 and the outputs of IC2 drive A4–A7 of the DUT at test sockets ZIF1 and ZIF2. A 256K DRAM requires an additional address line, A8, and a 1-MEG DRAM requires two additional address lines, A8 and A9. To generate the A8 and A9 address lines, Q8, Q9, Q18, and Q19 from IC2 and IC3 are logic inputs to IC6 which generates the A8 output at pin 19 and the A9 output at pin 12.

Both PAL's (the 16R4 and the 16L8) are rated at 25-ns internal gate propagation delay. That delay is an integral part of the system timing, and is used to determine the timing of the low CAS signal at pin 12 of IC5 about 40 ns after RAS goes low. The CAS signal is applied to the DUT which gates the column-address data after the row-address data has been gated. At the intersection of the row address and column address, we have the selected bit location. Output Q20 (IC3 pin 12) from the 24-stage ripple counter will determine if the operation will be a write or read cycle in the DRAM.

From the start of the test, Q20 applies a low to the DUT READ/WRITE inputs at ZIF1 pin 2 and ZIF2 pin 3. The low signal puts the DRAM in the write mode for the first half of the test, where we cycle through all of the address locations. Note that, as the ripple counter gets to Q20, we have cycled through all address locations in a 1-MEG DRAM once,

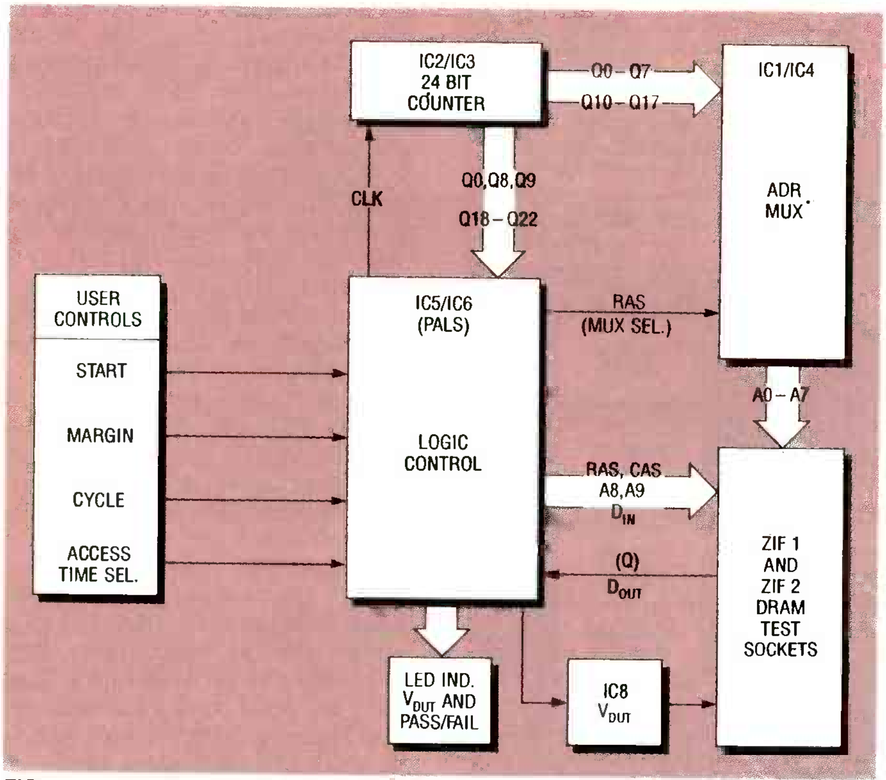
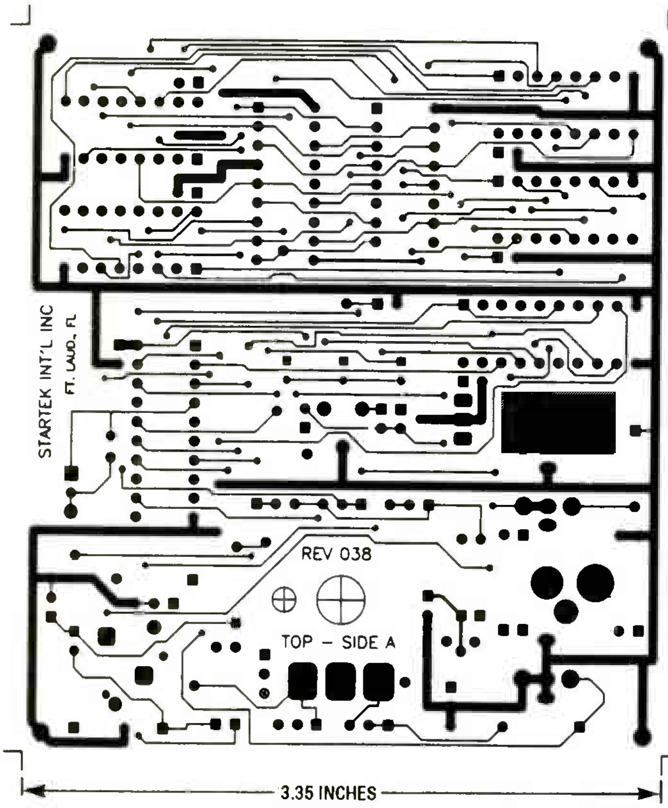
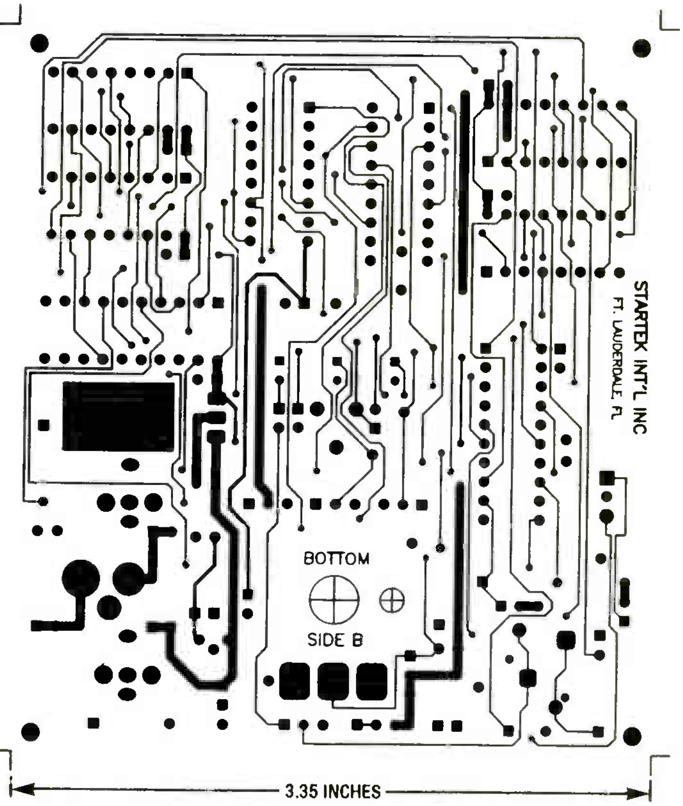


FIG. 4—DRAM TESTER BLOCK DIAGRAM. The DRAM tester uses only six logic IC's, thanks to the use of two PLD's.



TOP, OR COMPONENT SIDE of the DRAM tester PC board. Parts are actually mounted on both sides of the board.



BOTTOM, OR SOLDER SIDE of the board.

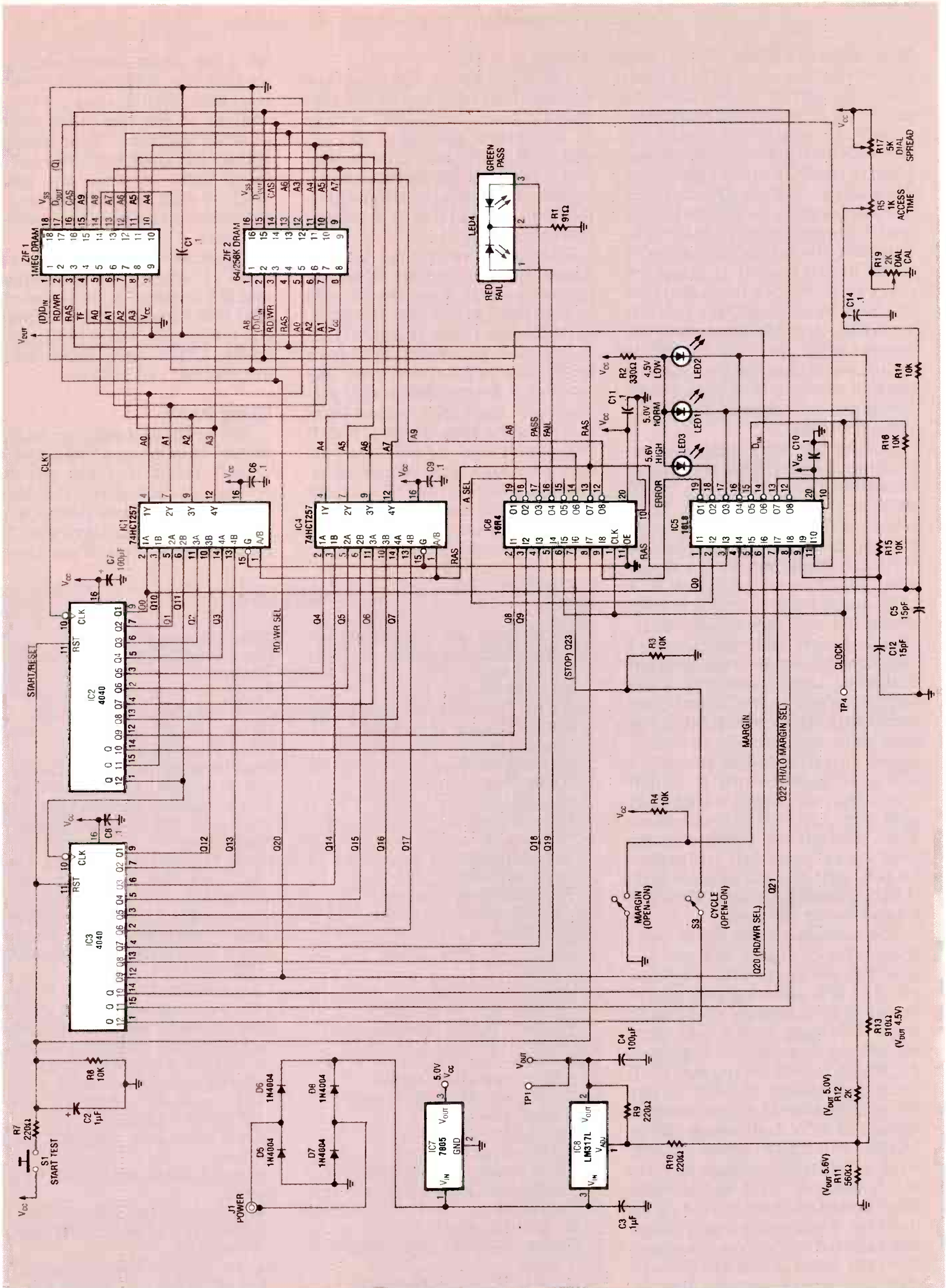


FIG. 5—DRAM TESTER SCHEMATIC. The 5-volt regulator, IC7, supplies power to everything but the DUT, which is powered from IC8, an LM317LZ adjustable regulator. IC8 normally outputs 5 volts to the DUT; 4.5 volts is supplied for the low-margin test and 5.6 volts for the high-margin test.

four times in a 256K DRAM, and sixteen times in a 64K DRAM. The Q20 output is also input to pin 6 of IC5, which will generate a D_{IN} signal, which will determine the data bit (high = 1, low = 0) applied to the DUT at ZIF1 pin 1 and ZIF2 pin 2. Signals Q0 and Q21 are also applied to IC5 at pins 1 and 7 respectively; Q0 is used to alternate the bit pattern at every other location as it is triggered every cycle or clock time, and Q21 is used to change the pattern from 010101 to 101010 during the second write cycle. Every DRAM location will have both a 1 and a 0 written to it and read back 1 to 16 times per test, depending on the type of DRAM.

During the read cycle, the access time of the DRAM is the time between the RAS and D_{OUT} (valid data out) signals, or the time from the first address strobe until valid data is at the Q output of the DUT. The Q output is a three-state signal that switches to a high-impedance mid-logic level when the CAS signal goes inactive. As each address is cycled through during the read portion of the test, the data bit read out is applied to pin 11 of IC5 and compared with the expected bit. If the data does not match, an ERROR signal is generated at pin 19 of IC5 that goes to pin 9 of IC6 where the FAIL output will go high and the CLKI output will stop. That will halt the ripple counter and make pass/fail indicator LED4 light a continuous red. (LED4 should have been blinking green during the test.)

The MARGIN switch S2 is "on" when the contacts are open—that removes the ground from pin 5 of IC5, allowing pull-up resistor R4 to switch the input high. The logic in IC5 will then switch the low output from pin 17, which selected a normal DUT operating voltage of 5.0V, to pin 16, which selects a low-margin voltage of 4.5V. Indicators LED1, LED2, and LED3 show which DUT operating voltage is currently selected, and will remain illuminated after an error stop to indicate what operating voltage was selected at the time of failure. The Q22 input at pin 8 of IC5 will switch the low-margin test to high, and select the pin-18 output of IC5, which lights LED3 to indicate a high-margin operating voltage of 5.6V.

The IC5 outputs that select the appropriate LED indicator also directly control the DUT voltage by applying a ground to R12 via pin 17, R13 via pin 16, or neither when pin 18 (high margin) is selected. That affects the adjustment pin regulator IC8 which produces V_{DUT}.

The CYCLE switch S3 is "on" when the contacts are open, allowing the pull-down resistor R3 to hold pin 7 of IC6 low. The highest bit in our ripple counter, Q23, is the STOP bit. When Q23 goes high, the two-pattern test has run twice. Switch S3 simply prevents the high Q23 output from reaching the logic input of IC6. If you prefer cycling the two-pattern test once and stopping instead of twice, simply disconnect Q23 from S3 and connect Q22. However, if that is done, the margin test would have to be run with the CYCLE switch also "on" so that the high-margin test is run. With actual usage, it is convenient to use the CYCLE switch most of the time. Just increase the access time until the DRAM fails, then decrease the speed slightly and restart the test to quickly determine the speed of the part.

Capacitors C1, C3, C6, and C8–C11 are for power bypass, and R1 is used to limit the current flow through LED4. Resistor R2 limits the current through LED1, LED2, and LED3, which are discrete red LED's.

Using PAL's

The programmable array logic device, known as a PAL, was invented about 15 years ago at a company called Monolithic Memories, which is now part of AMD (Advanced Micro Devices). The PAL provides a way of combining

PARTS LIST

All resistors are ¼-watt, 5%, unless otherwise noted.
R1—91 ohms
R2—330 ohms
R3, R4, R8, R14–R16—10,000 ohms
R5—1000 ohms, linear taper potentiometer
R6, R18—not used
R7, R9, R10—220 ohms, 1%
R11—560 ohms
R12—2000 ohms, 1%
R13—910 ohms
R17—5000 ohms, 4-turn trimmer potentiometer
R19—2000 ohms, trimmer potentiometer

Capacitors
C1, C3, C6, C8–C11, C14—0.1 µF, monolithic
C2—1 µF, tantalum
C4, C7—100 µF, electrolytic
C5, C12—15 pF, monolithic

Semiconductors
IC1, IC4—74HCT257 quad 2-channel three-state multiplexer
IC2, IC3—74HCT4040 12-stage binary counter
IC5—AMD 16L8B-2 PAL
IC6—AMD 16R4A-4 PAL
IC7—LM7805 5-volt regulator
IC8—LM317LZ low-power adjustable regulator
D1–D4—not used
D5–D8—1N4004 1-amp rectifier diode
LED1–LED3—red light-emitting diode, ⅛-inch diameter
LED4—red/green 3-lead common-cathode LED module

Other components
S1—normally-open pushbutton switch
S2, S3—SPDT sub-mini slide switch
J1—2.1 mm DC power input jack
ZIF1—18-pin ZIF socket
ZIF2—16-pin ZIF socket
Miscellaneous: PC board, four 16-pin IC sockets, two 20-pin IC sockets, knob for R5, cabinet, 120-VAC-to-9-VDC 300-mA wall adapter, solder, etc.

Note: The following items are available from Startek International Inc., 398 NE 38th St., Ft. Lauderdale, FL 33334. For information call (305) 561-2211, for orders call (800) 638-8050, FAX (305) 561-9133.

• Complete DRAM tester kit including programed PAL's (does not include cabinet and AC adaptor), KIT #DT-90K—$59.95.

• Complete DRAM-tester kit including programed PAL's, cabinet, and AC adaptor, KIT #DT-90CK—$89.95.

• PC board only, #DT-90PCB—$18.00.

• Programed PAL's—$7.50 each.

• A factory assembled, calibrated, and tested DRAM tester—$119.00.

Add 5% shipping/handling charge ($4.00 minimum, $10.00 maximum.) Florida residents must add sales tax. VISA, MC and COD-CASH orders accepted.

a number of discrete logic IC's in a single custom-programed IC. The PAL device has a programmable AND array followed by a fixed OR array. In the DRAM-tester circuit we use two very common PAL's, a 16L8 and a 16R4. Both are low-power devices, and relatively inexpensive.

The use of PAL's results in reduced parts count and power consumption, a smaller PC board, faster logic, increased reliability, and, usually, overall reduced cost. A reduced parts count means less-complex PC boards are required, and circuit changes can frequently be made in the PAL program without affecting the PC board. On the down side, designing with PAL's does require support tools consisting of design software and a device programmer. (Those items are needed by the circuit designer; the builder does not require those items, as programed PAL's are available from the source listed in the parts list.) The PAL design software provides the link between high-level logic expressions and the low-level programming details which the device programmer uses.

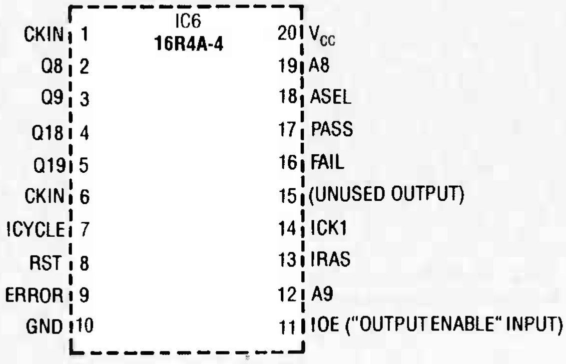
In our circuit, IC5 (a 16L8 PAL) has 10 dedicated inputs, 2 dedicated outputs, and 6 combinatorial input/output pins. IC6 is a 16R4 PAL which has a 4-bit register, a clock register input, 8 dedicated inputs, 4 registered outputs with an output-enable pin, and 4 combinatorial input/output pins. Both are 20-pin DIP TTL devices, which are one-time programmable by opening fuse links (with an appropriate device programmer) to configure the AND and OR gates within the device. The PAL devices implement the Boolean logic transfer function, the sum of the products. The AND array creates custom product terms, while the OR array sums selected terms at the outputs of the device.

Figure 6 shows the pinouts for the 16L8 and 16R4 PAL's with the input/output signals and logic equations used to generate each output. Figure 7 shows the logic diagram for the 16L8 and Fig. 8 shows the 16R4. A PAL is manufactured with all "fuses," or connections intact. The undesired fuses are blown open by the programmer, leaving only the desired logic connections.


```
/** LOGIC EQUATIONS **/

DIN           = !Q21 & !Q0 # Q21 & Q0;
CAS           = !ASEL & RAS;
HIGHMARG. OE  = MTEST & Q22;
LOWMARG. OE   = MTEST & !Q22;
NORMMARG. OE  = !MTEST;
HIGHMARG      = Q22;
LOWMARG       = !Q22;
NORMARG       = Q22 # !Q22;
ERROR         = RD & RAS & (DOUT & !DIN # !DOUT & DIN);
CKOUTA        = CKINA & !CKOUTB & !(CKINB & !CKOUTA);
CKOUTB        = CKINB & !CKOUTA & !(CKINA & !CKOUTB);
```

a




```
/** LOGIC EQUATIONS **/

ASEL   = !RAS;
A8     = !RAS & Q8 # RAS & Q18;
A9     = !RAS & Q9# RAS & Q19;
RAS    = CKO & !CKIN;
PASS.D = !FAIL & !Q18;
FAIL.D = ERROR & CKO # FAIL & !RST;
CK1.D  = !RST & CK:1 & !FAIL & CYCLE;
```

b

FIG. 6—PAL PINOUTS AND LOGIC EQUATIONS. 6-*a* shows the pinouts for the 16L8 and 6-*b* shows the 16R4. The logic equations are used to generate the outputs.

Assembly

The DRAM tester is easy to assemble. Parts are installed on both sides of a double-sided plated-through PC board measuring 3.35 × 3.8 inches. Programed PAL's, as well as the other parts including the PC board, are available from the source listed in the parts list. The professional-looking case you see is also available at extra cost. Parts assembly order is not critical, however, it's recommended that you install all resistors first, then diodes, IC sockets (not including the ZIF sockets), IC7 and IC8, and then the capacitors. Follow Fig. 9 for correct placement of parts.

Next install power-jack J1, and switches S1, S2 and S3. Be sure S2 and S3 are straight so that they will properly fit in the cabinet openings. Next install potentiometers R5, R17, and R19; R5 mounts under the PC board with the pins bent upward to fit the connection holes from under the PC board.

The two-color (red/green) LED (LED4) is probably the most diffi-

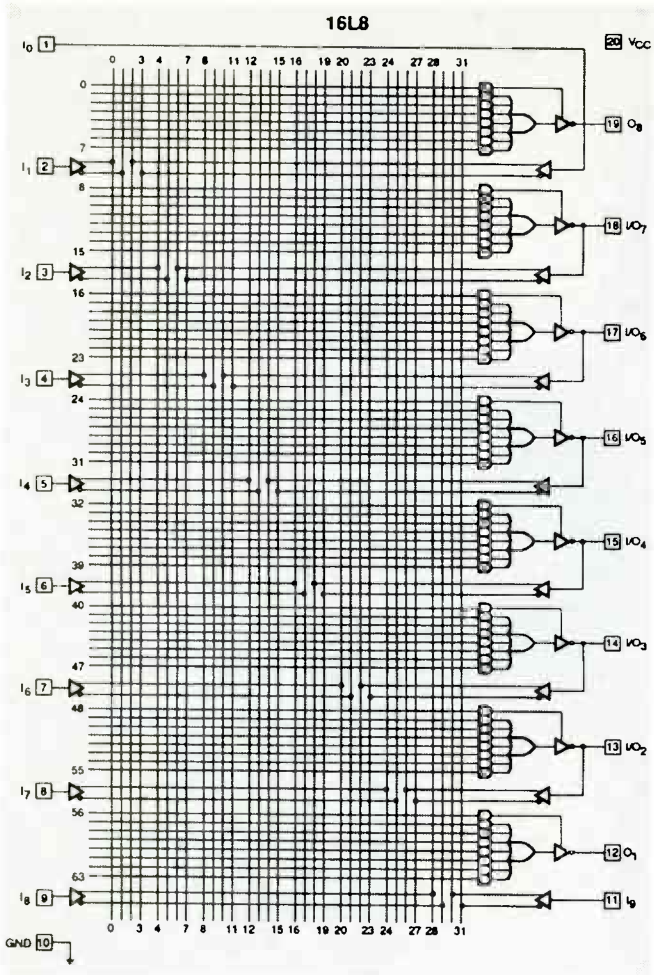


FIG. 7—16L8 LOGIC DIAGRAM. This 20-pin DIP device is one-time programmable by configuring the AND and OR gates within the device.

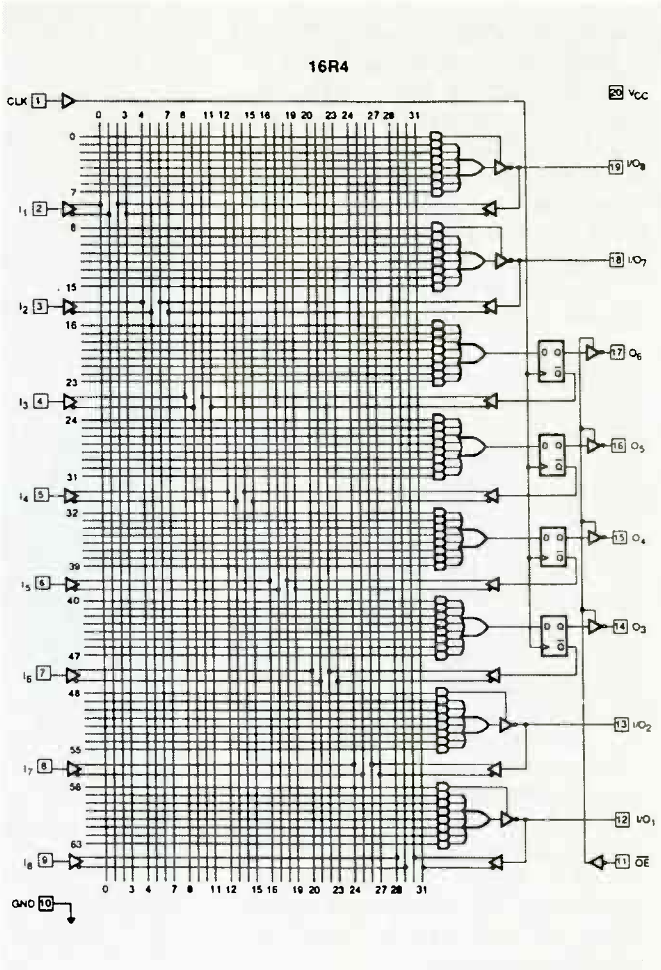


FIG. 8—16R4 LOGIC DIAGRAM. A PAL is manufactured with all "fuses" intact. The undesired fuses are blown open by the programmer, leaving only the desired logic connections.

cult component to install. Be sure to observe polarity; the slightly shorter lead is the red-LED anode (+), the center lead is the common cathode (−), and the remaining lead is the green-LED anode. Holding the LED with the shorter lead on your left, bend the center lead at a 90-degree angle, snug against the component body, toward yourself, and likewise bend the other two leads in the opposite direction, spreading them slightly. Align LED4 over the proper PC-board location and bend the three leads down to fit the holes. Check for proper alignment with the cabinet before soldering.

Install LED1, LED2, and LED3. Note that the flat side of the LED's is the cathode. Allow the LED's to stand about 7⁄32-inch above the PC board. Install the two ZIF sockets and insert IC1–IC6 into the appropriate sockets. Recheck all component connections and polarities. If you are satisfied that everything looks correct, you're ready to continue. Figure 10 shows a photo of a completed board.

Checkout

Set R17 and R19 to midpoint adjustment. With no device in either test socket, connect a 9-volt DC power supply, rated at 200 mA or more (the actual current draw will be about 150 mA), to J1. (The polarity does not matter as we have a diode-bridge power input.) A continuous red should be displayed on LED4, the pass/fail indicator.

Using a DC voltmeter, make the following measurements. (Note that a ground pad is located in each corner of the PC board.) These voltages should be within ± 0.1 volt:

- IC7 pin 3 (V_{CC}) should be 5.0V.
- With the MARGIN switch (S2) off (slider to right), measure V_{DUT} at TP1. It should be 5.0V.
- With the MARGIN switch on, the low-margin DUT voltage indicator should be on and TP1 should measure 4.5V.
- Place a DRAM IC in the appropriate ZIF test socket, turn the access-time potentiometer (R5) fully clockwise and press test-switch S1. If the device under test is good and the tester is working properly, LED4 will blink green and, if the MARGIN switch is on, the tester should alternate between high- and low-margin voltages. If you do not get a correct indication, try a power off and on reset. Turn on the CYCLE switch (slider to the left) and the tester should repeat the test without having to press the TEST button.
- When the high-margin voltage indicator LED3 is on, the voltage at TP1 should be 5.6V.

If all of the above voltages check out properly, only the "speed" or access-time calibration remains. If you have access to a 100-MHz oscilloscope, look at TP4 with no IC in either test socket. That is the master clock and it should run continuously. Allow the unit

continued on page 60

DAVID PLANT

PULSE-MATE

This single-shot and continuous-pulse generator is inexpensive and easy to build, yet it offers automatic level setting and both positive and negative pulses.

THERE IS AN OLD AXIOM THAT A MAN'S work is only as good as his tools—and a good pulse generator is always a good tool to have. Those of us who don't often need pulse generators—the technician working at home on a project, for example—can usually get by with a 555 timer added to a prototype board and used as a trigger. But there's not always enough room on the board to do that, and it is always a pain in the neck.

The solution to that problem is our Pulse-Mate, a compact single-shot and continuous-pulse generator. The easy-to-use design has automatic level setting and positive and negative pulse output. It can be powered from the device under test in the range from 4.5 to 18 volts DC, and has short-circuit protection for itself and the device under test.

The circuit

Referring to Fig. 1, the circuit basically has three sections. Foremost is the actual pulse generator built around the ubiquitous 555 timer, which can be switched from monostable mode (one shot) to astable mode by S2. The value of R8 is selected to create an approximate square wave at mid frequency range and R11 selects the actual rate desired. With S2 in the "astable" position, R11 and C2 give a range of about 5- to 200-Hz., which will satisfy most needs. (Note that S2 is part of potentiometer R11.) If you need to generate higher frequencies, a reduction of C2 can bring the range up well above audio, but at a loss of the low-frequency pulsing which can be quite handy.

With S2 in the "one shot" position, pushbutton S1 will trigger IC1 for as long as it is held down. The timer's trigger input (pin 2) is held high by R1 to prevent false triggering from hand capacitance. When the trigger pin is brought to ground by S1 or keyed by the discharge pin (pin 7) in the astable mode, pin 3 goes high to about 3.3 volts (when IC1 is powered from 5 volts). For better circuit stability, power to IC1 is regulated.

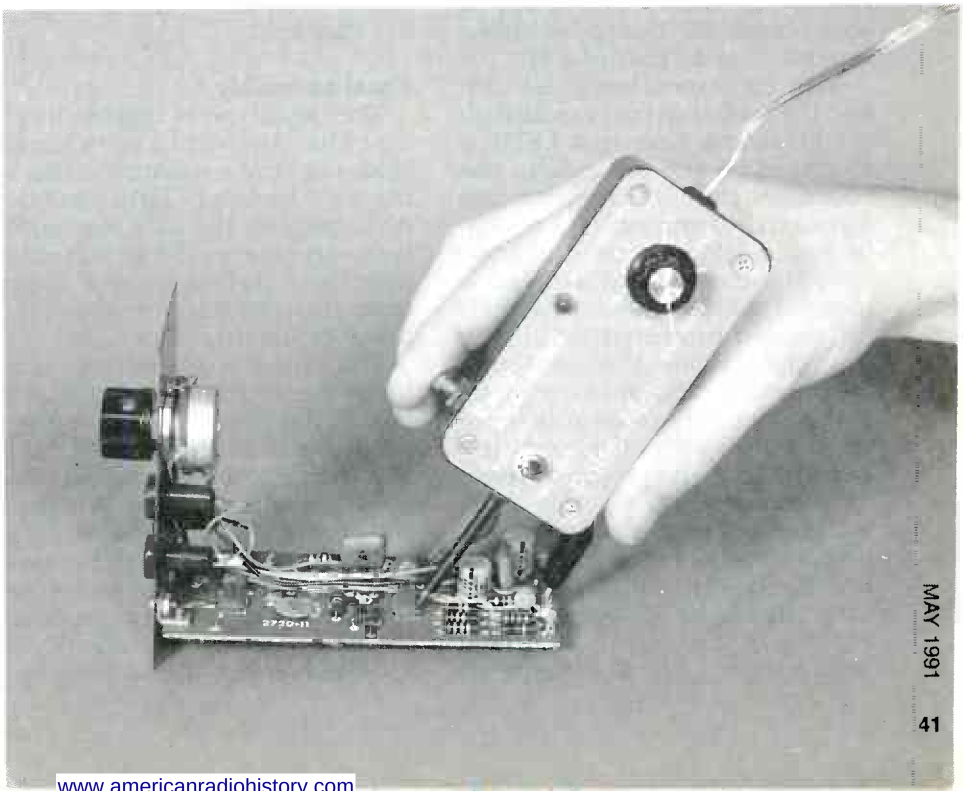
The second section of the circuit consists of Q1 and Q2 which provide the high-rise-time pulse required for digital work. When Q1 is turned on by the positive output of IC1, its collector goes low, giving a negative output pulse at the probe if S3 is in the "low" position. The low output from Q1 also turns Q2 off; Q2's collector now goes high, which provides a positive pulse at the probe if S3 is in the "high" position. Transistor Q2 also drives Q3, which drives indicator LED1.

Because Q1–Q3 operate at the incoming supply voltage, we strongly recommend that you use 2N4400 or equivalent transistors rather than garden-variety NPN's, as their base-emitter drop is less and they have a faster rise-time. The Pulse-Mate's output waveform is shown in Fig. 2. The probe current is limited to under 5 mA by R6 to protect both the device under test and the Pulse-Mate.

The third section consists of a voltage regulator consisting of Zener-diode D1 and Q4. That configuration was used rather than the popular three-terminal devices, such as the 7805, because, when powered from 5 volts, the regulator's internal voltage drop wouldn't leave enough to power IC1. As the supply voltage increases beyond 6.2 volts, the Zener diode conducts and limits Q4's output to 6 volts for IC1.

Construction

A parts-placement diagram is shown in Fig. 3, and we have provided the foil pattern for the PC board if you would like to make



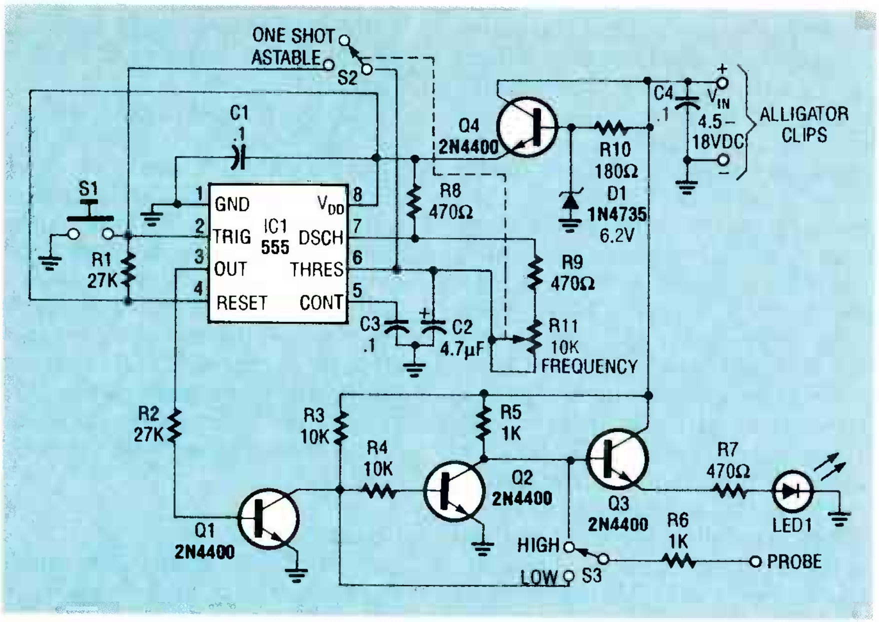


FIG. 1—THE CIRCUIT HAS THREE SECTIONS: the pulse generator built around the 555 timer, Q1 and Q2 which provide the high-rise-time pulse required for digital work, and a voltage regulator consisting of Zener-diode D1 and Q4.

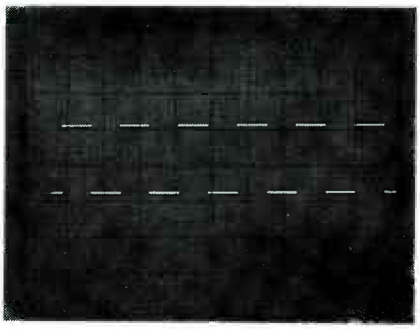


FIG. 2—THE 2N4400 TRANSISTORS have a fast rise-time; here's what the output waveform looks like.

your own—there's also a drilled and plated PC board available separately or as part of a kit.

With the exception of S1, S3, and the probe, all parts mount on the PC board. Note that LED1 is mounted on the foil side of the board so that it can protrude through the front panel as shown in Fig. 4. (Mount the LED ³⁄₁₆-inch above the board so there is room to solder it.) Note that R11-S2 is also mounted facing up from the foil side. You don't have to connect S1, S3, and the probe at this time. Take a minute to inspect your work; if everything looks alright, the project is ready for initial testing.

Observing proper polarity, connect 5 volts DC to the board. With R11-S2 in the "off" position, LED1 should be off. Shorting the S1 inputs with a clip lead will turn on the LED. If there is no light, check the LED's polarity and the mounting of Q1–Q4. Pin 8 of IC1 should show 4.5 VDC, Q1's collector should be low (100 mV or less), and Q2's collector should be high (roughly 5 volts). Now check the output pulse by putting S2 in the "on" position. The LED will flash at about 5 Hz, and advancing potentiometer R11 will increase the flash rate to the point where the LED will appear to be continuously lit. If there is no flashing, check the output of IC1 pin 3 for a positive pulse (or a continuous high of about 3.3 volts if the S1 inputs are shorted).

Final assembly

The prototype is installed in a case that fits well in one's hand. However, any enclosure measuring 2 × 4 inches or larger will do. Also, because the case is a hand-held size, the probe is mounted directly to it. If you use a larger case, you may want to mount the probe off-board.

The probe is made from a 2-inch screw that is ground to a point after first fitting on an appropriate nut; removing the nut will then deburr the screw after the tip is ground down. With one washer fitted over the screw, it is passed through a hole in the case and the nut then secures it in place (don't tighten it right now). By the way, be careful when drilling the holes in the case; once a hole is made, it's there to stay. The leads of R6 should be insulated with heat-shrink tubing.

PARTS LIST

All resistors are ¼-watt, 5%
R1, R2—27,000 ohms
R3, R4—10,000 ohms
R5, R6—1000 ohms
R7–R9—470 ohms
R10—180 ohms
R11—10,000-ohm linear potentiometer with switch

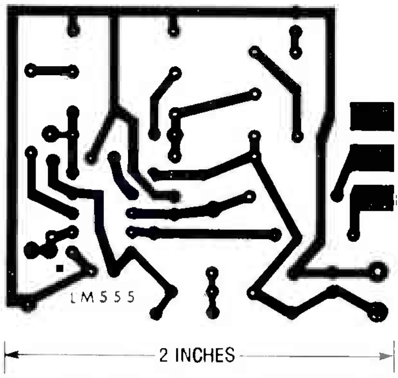
Capacitors
C1, C3, C4—0.1 μF, ceramic disc
C2—4.7 μF, 16 volts, electrolytic

Semiconductors
IC1—LM555 timer
Q1–Q4—2N4400 NPN switching transistor
D1—1N4735 6.2-volt Zener diode, or equivalent
LED1—any color light-emitting diode

Other components
S1—momentary pushbutton switch
S2—SPST switch (part of R11 in prototype)
S3—SPDT toggle switch

Miscellaneous: project case (Radio Shack #270-220 or equivalent), knob for R11, 2-inch screw with washer and nut for probe assembly, red and black insulated alligator clips, rubber grommet, heat-shrink tubing, wire, solder, etc.

Note: The following items are available from Project-Mate, 2727 West Manor Pl., Suite 207, Seattle, WA 98199 (206) 283-4700: A kit containing a PC board and all parts including probe hardware, grommet, heat-shrink tubing, alligator-clip assemblies, and front-panel artwork (does not include S1, S3, project case, and knob) is $24.50 plus $2.50 shipping and handling. A PC board only is $6.00 plus $2.50 shipping and handling. WA residents must add 8% sales tax.



HERE'S THE FOIL PATTERN for the Pulse-Mate's single-sided PC board.

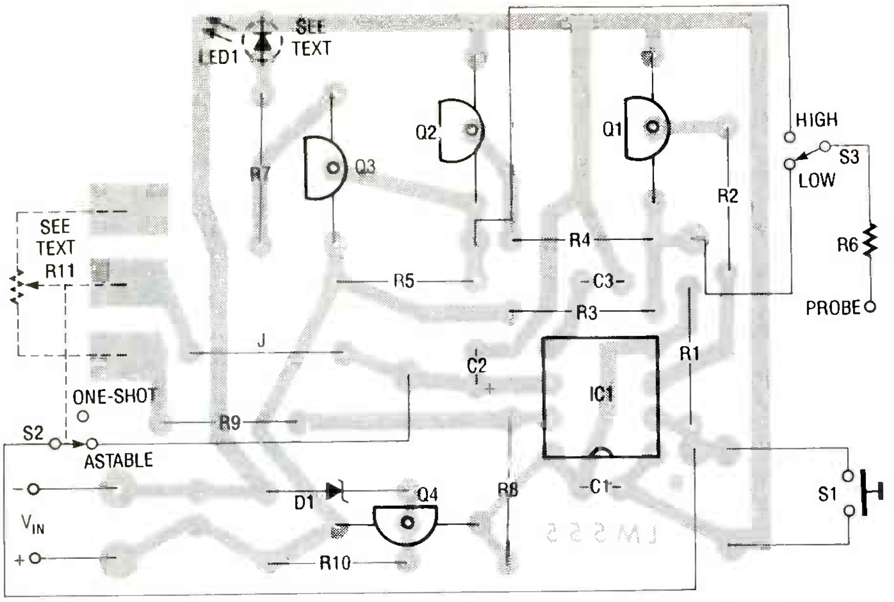


FIG. 3—PARTS-PLACEMENT DIAGRAM. Note that LED1 and R11-S2 mount on the foil side of the board.

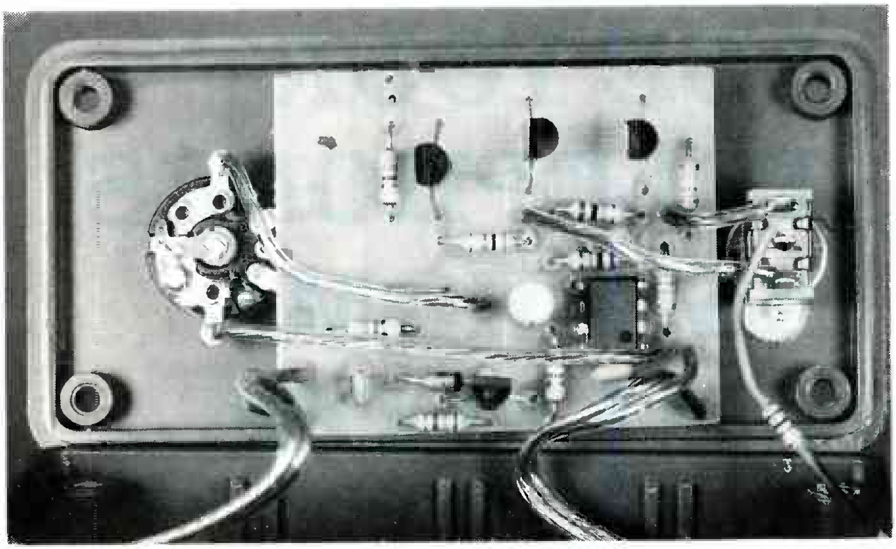


FIG. 4—IT'S A TIGHT FIT, but you end up with a neat little handheld instrument. Notice how LED1 is mounted on the foil side of the board and protrudes through the front panel.

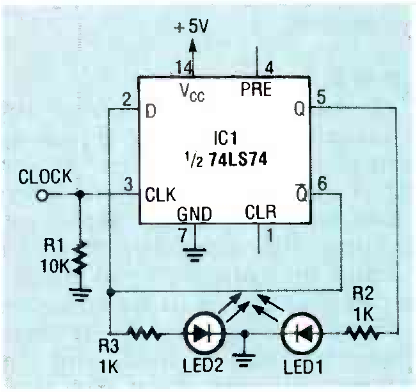


FIG. 5—THIS TEST CIRCUIT uses a 74LS74 positive-edge-triggered flip-flop. Triggering the clock input by hand causes the LED's to change state in an erratic manner. Triggering it with the Pulse-Mate causes the LED's to switch back and forth predictably.

except for the ends; one end is secured between the head of the probe screw and the washer, and the nut can then be tightened. The other end of R6 is soldered directly to the common terminal of S3. Leaving the sharpened tip of the probe screw exposed, cover the length of it with heat-shrink tubing.

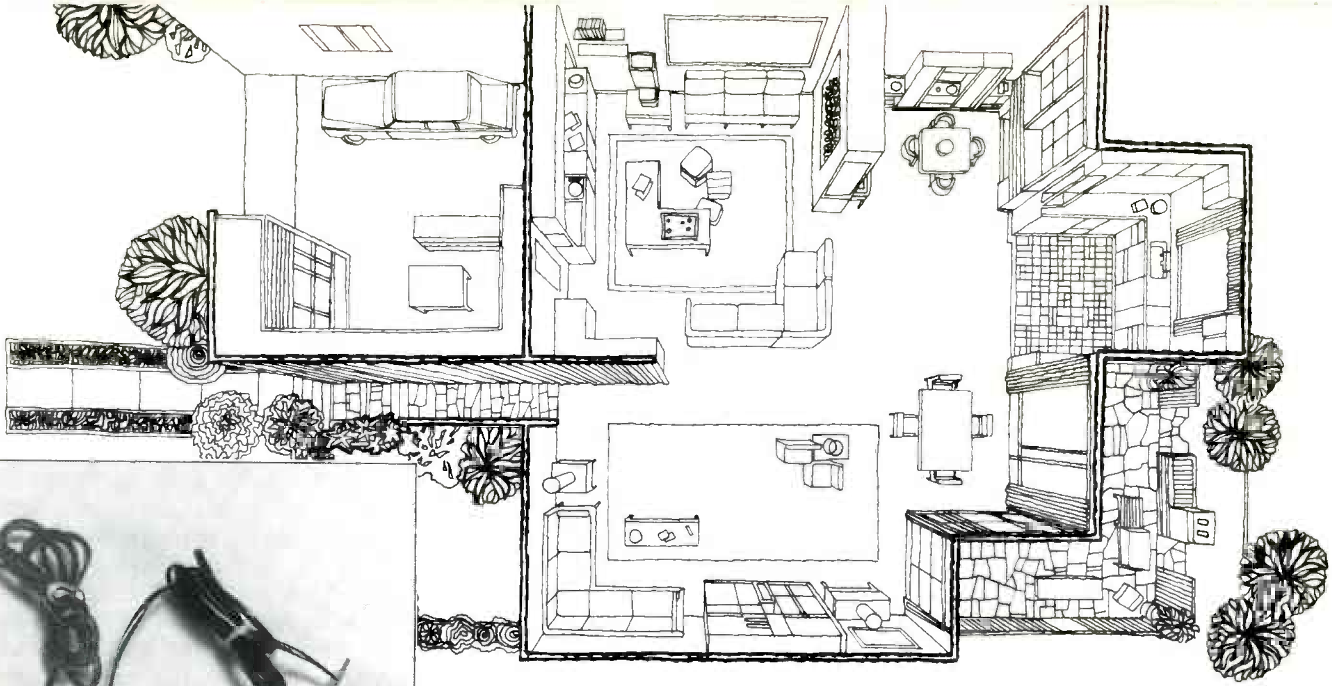
Connect S3 and S1 to the board; the lead length depends on the case you use. The power leads on the prototype are arbitrarily 24 inches long. They are soldered to the board then passed through a grommet in the case. Attach the alligator clips to the power leads; use red and black insulators for positive and negative, respectively. The circuit board is secured to the front panel of the case by the mounting hardware of potentiometer R11 and the wiring to S3. You can also use separate mounting hardware if you like.

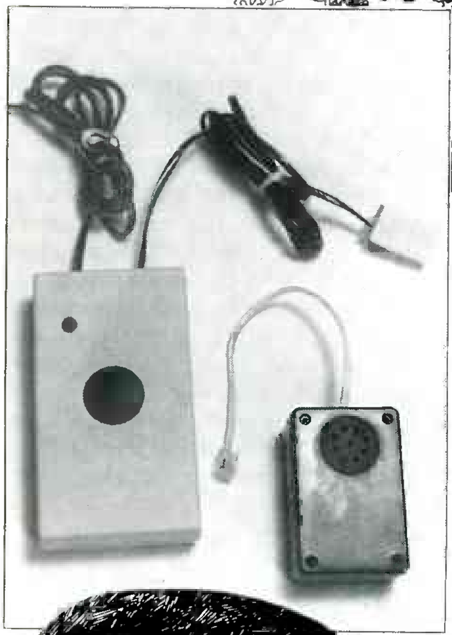
You may want to make a nameplate as a finishing touch for the project, although it's best to make sure the circuit is working properly before labeling. At any rate, the one on the prototype was made using an aluminum nameplate kit sold by Kepro Circuit Systems, Inc. (630 Axminister Dr., Fenton, MO 63026). With it, a full-sized positive is made by transferring black press-on type and other designs to a clear piece of acetate. A blue panel (cut to 1/2" over-size) is contact exposed—like a photosensitized PC board—and developed. The unexposed portions under the transfer patterns are washed away leaving a blue panel with white lettering. Of course labeling can also be done in a variety of other ways including engraving, rub-on decals, adhesive labels, etc.

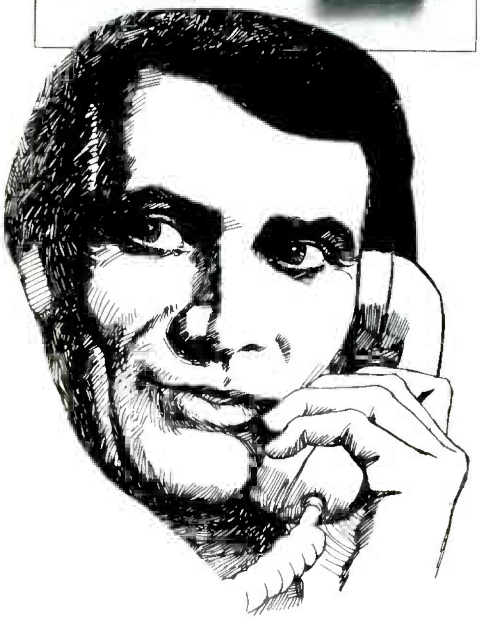
Application

The device can be tested using a spare LED. For a positive-pulse test, connect the cathode of an LED to ground and connect the probe to its anode. Pressing S1 will light the diode. For a negative-pulse test, connect the LED's anode to 5 volts and its cathode to the probe and press S1 to light. (Note that the LED will not light to full brightness in this part of the test because R6 limits the probe current to 5 mA.)

If you want to further test the device, build the simple circuit shown in Fig. 5 using a 74LS74 positive-edge-triggered flip-flop. When power is applied, one of the LED's will light. Stroking the clock input with +5 volts in series with a 1K resistor should cause the LED's to change state. (They will, but in an erratic way because it's virtually impossible to generate a clean clock pulse by hand. Now connect the Pulse-Mate's probe (positive mode) directly to the circuit and the LED's will switch back and forth predictably. You now have a useful piece of test equipment for troubleshooting, project building, digital experimenting, and whatever else you can think of. **R-E**







USE YOUR TELEPHONES AS A HOME INTERCOM SYSTEM

It's quick and easy to add an intercom feature to your existing home telephones.

FRANK POLIMENE

INTERCOMS HAVE BEEN AROUND FOR many years, providing a valuable tool in communications for home and industry. Unfortunately, these systems either require added hardware or hours of labor installing wires. Responding to demand, many manufacturers have incorporated the intercom as an added feature in their telephones. However, replacing your existing equipment is an expense that usually outweighs the justification.

The Phone-Com project we will describe may be used concurrently with any touch-tone phone system, and it provides features that make it practical, easy to use, and inexpensive. Because it connects to your existing telephone equipment, there are no unsightly boxes to clutter up your desk.

How it works

To engage the intercom at any time, all you have to do is pick up any phone and press the "#" key. That causes one or more *alert modules* to sound an alarm, signalling other people in the home to pick up a phone. If you answer a call that comes in for someone else, pressing the "#" key will place the call on hold, and the alarm will sound on the alert modules signalling someone else in the home to pick up the phone. That someone else may then release the call on hold by pressing the "#" key or talk to you in pri-

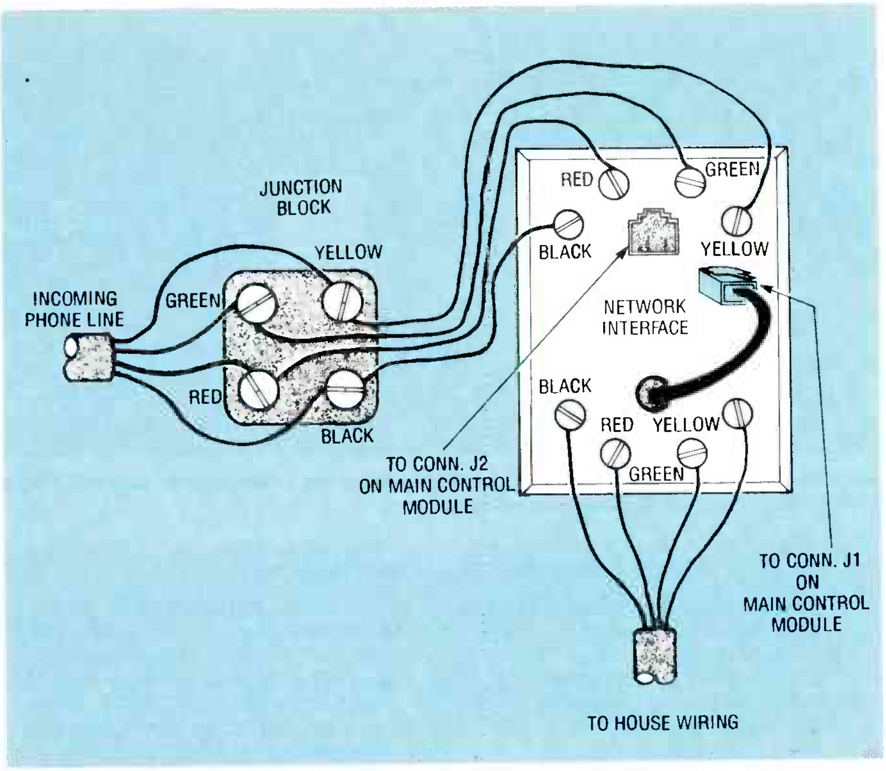


FIG. 1—THE PHONE-COM TAKES ADVANTAGE of a device called a "network interface," installed in most newer homes; it is simply a connector box that separates the outside phone line from your internal wiring.

vate before answering the call. Since the system is voice operated (VOX), the intercom will disengage and return to normal operation after approximately 30 seconds if no conversation is heard.

The Phone-Com takes advantage of a device called a "network interface," installed in most new homes over the past 10 years. Despite the complicated name, it is simply a connector box that separates the outside phone line from your internal wiring (see Fig. 1). Since a network interface is used by the phone company to determine whether problems are internal or external, a substantial premium service charge may be imposed if you don't have one. Therefore, it is highly recommended that one be installed, even if not for this project.

Theory of operation

Take a look at the schematic in Fig. 2. In the stand-by mode, relay RY1 is not energized and the only connection to the phone line is the coupling-capacitor C1. The

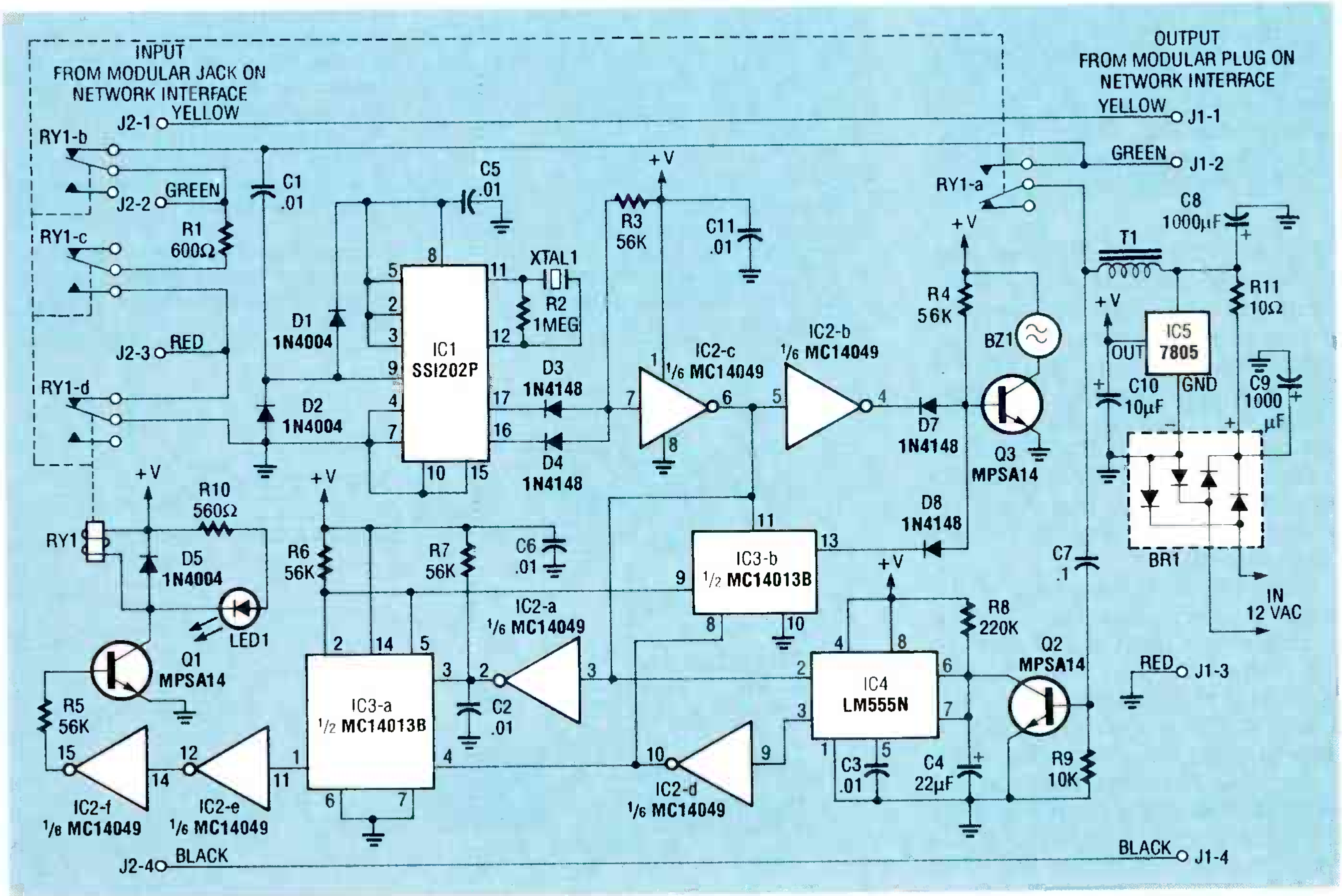


FIG. 2—CONTROLLER SCHEMATIC. The SSI202P is a telephone tone decoder whose BCD output is dependent on which tones are present at pin 9.

PARTS LIST—CONTROLLER

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

R1—600 ohms, ½-watt
R2—1 megohm
R3–R7—56,000 ohms
R8—220,000 ohms
R9—10,000 ohms
R10—560 ohms
R11—10 ohms

Capacitors

C1—0.01 µF, 200 volts, ceramic disc
C2, C3, C5, C6, C11—0.01 µF, 50 volts, ceramic disc
C4—22 µF, 16 volts, tantalum
C7—0.1 µF, 50 volts, ceramic disc
C8, C9—1000 µF, 16 volts, electrolytic
C10—10 µF, 35 volts, electrolytic

Semiconductors

IC1—SSI202P telephone tone decoder
IC2—MC14049 hex inverting buffer
IC3—MC14013B dual D-type flip-flop
IC4—LM555N timer
IC5—7805 5-volt regulator
Q1–Q3—MPSA14 or equivalent Darlington transistor
D3, D4, D7, D8—1N4148 diode
D1, D2, D5—1N4004 diode
LED1—red light-emitting diode
BR1—3N246 full-wave bridge rectifier

Other components

BZ1—100-dB Mallory Sonalert module
XTAL1—3.58-MHz crystal
RY1—DPDT mini relay, 1-amp contacts, 12-volt coil
T1—600/600 ohm audio isolation transformer
J1, J2—modular telephone jack

Miscellaneous: 12-VAC 500-mA plug-in transformer, PC board, project case, etc.

SSI202P (IC1) is a telephone tone decoder whose BCD output is dependent on which tones are present at pin 9. The two most-significant bits (pins 16 and 17) will only be high during a "#" key depression. The high on pin 7 of IC4 and pin 4 of IC2 allow Q3 to turn on, thereby energizing the audible alarm. The alarm will remain on for as long as the "#" key is depressed.

Pin 6 of IC2 is now low, which sends a clock pulse to IC3. That transfers the high at IC3 pin 2 to the output at pin 1, which energizes the relay through Q1, R5, and IC2. The trigger input of IC4, also being low, starts the VOX-timer IC4. The clock pulse to IC3 is delayed slightly by R7 and C2 until the output of IC4 pin 3 has enough time to remove the reset signal at IC3 pin 4. When the "#" key is released, pin 11 of IC3 goes high and toggles the output of

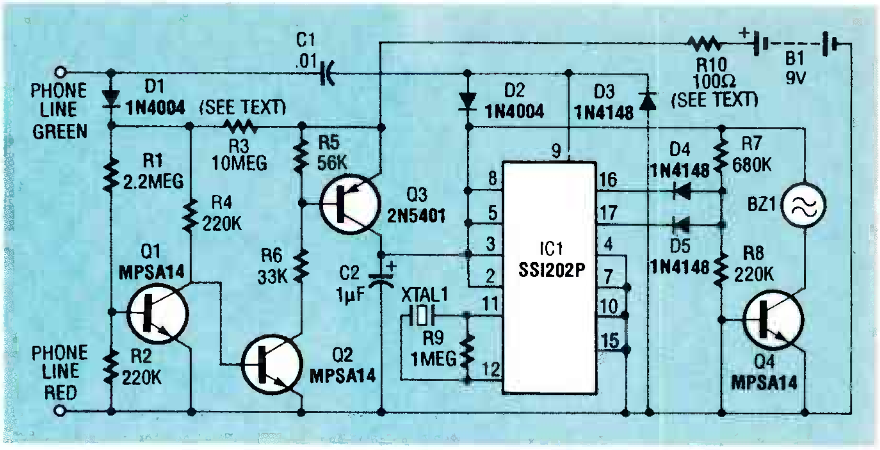


FIG. 3—ALERT MODULES plug into any phone jack; the circuit is only active during an "off hook" condition to conserve battery power.

PARTS LIST—ALERT MODULE

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

R1—2.2 megohms
R2, R4, R8—220,000 ohms
R3—10 megohms (see text)
R5—56,000 ohms
R6—33,000 ohms
R7—680,000 ohms
R9—1 megohm
R10—100 ohms (see text)

Capacitors

C1—0.01 µF, 500 volts, ceramic disc
C2—1 µF, 16 volts, electrolytic

Semiconductors

IC1—SSI202P telephone tone decoder
Q1, Q2, Q4—MPSA14 or equivalent Darlington transistor
Q3—2N5401 or equivalent PNP transistor
D1–D3—1N4004 diode
D4, D5—1N4148 diode

Other components

B1—9-volt alkaline or 7.2-volt Ni-Cd battery (see text)
XTAL1—3.58 MHz crystal
BZ1—100-dB Mallory Sonalert module
PL1—4-wire modular phone plug

Miscellaneous: 9-volt battery connector, PC board, project case, etc.

Note: The following items may be purchased from BCT Electronics, 8742 Belair Road, Baltimore, MD 21236 (301) 256-0344. MC/VISA, AX, and DISCOVER accepted. Add $2.50 S&H for each total order.

- **Drilled, etched, and screened controller PC board—$7.95**
- **Drilled, etched, and screened alert module PC board—$4.95**
- **SSI1202P IC—$11.95**
- **Complete controller kit (includes PC board and all components except phone jacks and housing)—$39.95**
- **Complete alert module kit (includes PC board and all components except phone plug and housing)—$24.95**

Network Interfaces may be purchased at Radio Shack or most electronic suppliers for around $5.00.

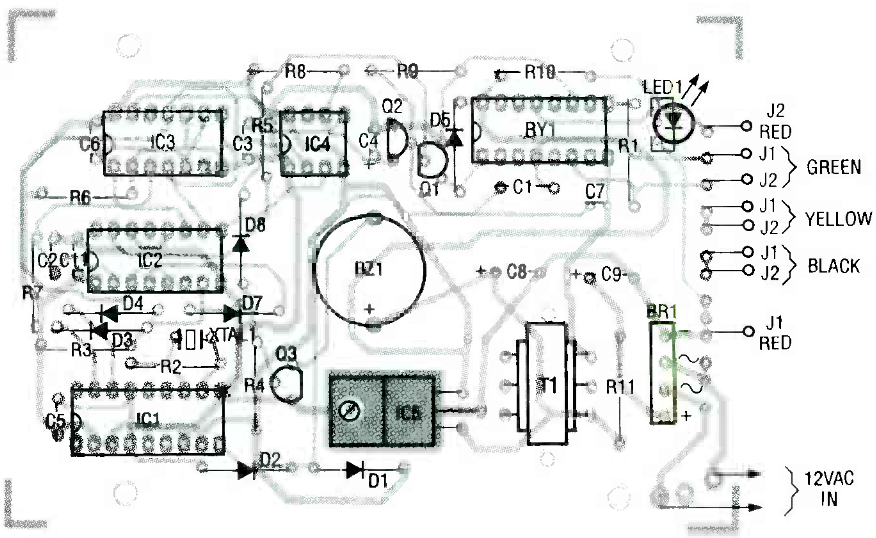


FIG. 4—PARTS-PLACEMENT DIAGRAM for the controller. It can be installed in any kind of case you can find.

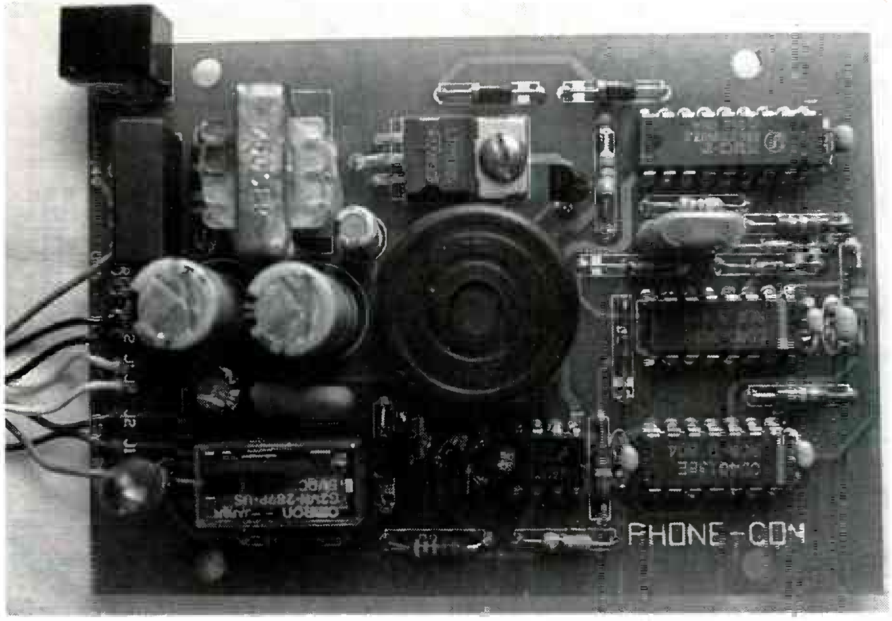


FIG. 5—THE FINISHED CONTROLLER BOARD is very neat and compact, so it doesn't take up much space.

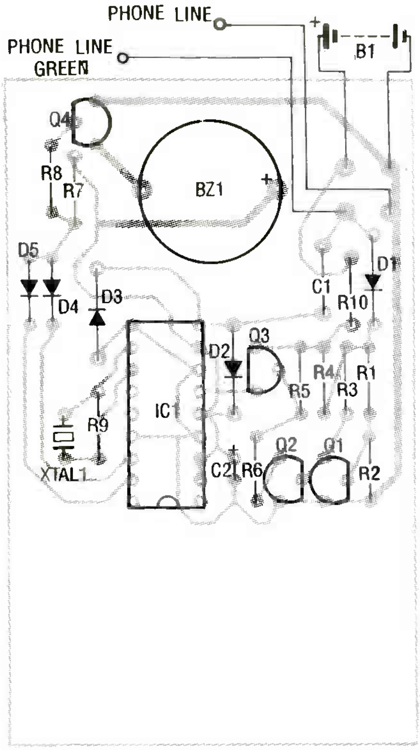


FIG. 6—PARTS-PLACEMENT DIAGRAM for the alert module. It's good to have at least one on every floor in your home, in a central location.

IC3 pin 13 to a low state, preventing the alarm to sound during the next depression of the "#" key (manual turn off).

If conversation continues, IC4 is prevented from time-out through C7 and Q2. If conversation stops for more than 30 seconds, C4 charges to the threshold voltage at IC4 pin 6 and IC4 pin 3 returns to a low state. That places a high on the reset pin (pin 4) and the set pin (pin 8) of IC3, which turns off RY1, returning the system to the stand-by mode. Any calls in process are held by maintaining central-office loop current through R1 while in intercom mode.

Alert module

Alert modules plug into any phone jack (see Fig. 3), and can be powered by either a 7.2-volt rechargeable Ni-Cd or 9-volt alkaline battery. However, the circuit is only active during an "off hook" condition to conserve the battery. During normal operation, there is approximately 50 volts on the phone line. That allows base current to flow through R1 which turns on Q1 and holds Q2 in an off state preventing power to IC1 and the audible alarm. When the line voltage falls below 10 volts, as evident in an off-hook condition, Q2 turns on, thereby placing IC1 in the stand-by mode.

Telephone tones are decoded by IC1 as previously discussed. A "#" key activation will activate the alarm. Diode D1 is important in that it protects IC1 and the rest of the semiconductors from damage when the AC ringing voltage is present on the phone line. If you're using a rechargeable battery, charging current is supplied through R3 during on-hook conditions.

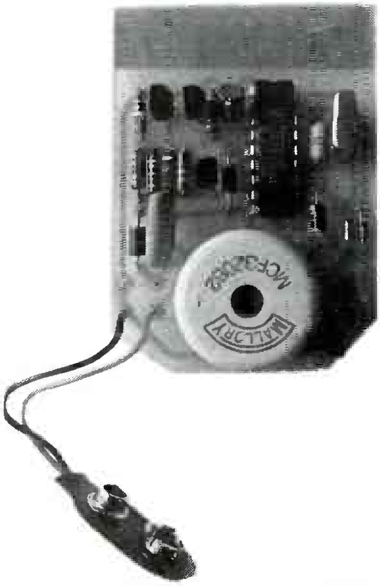


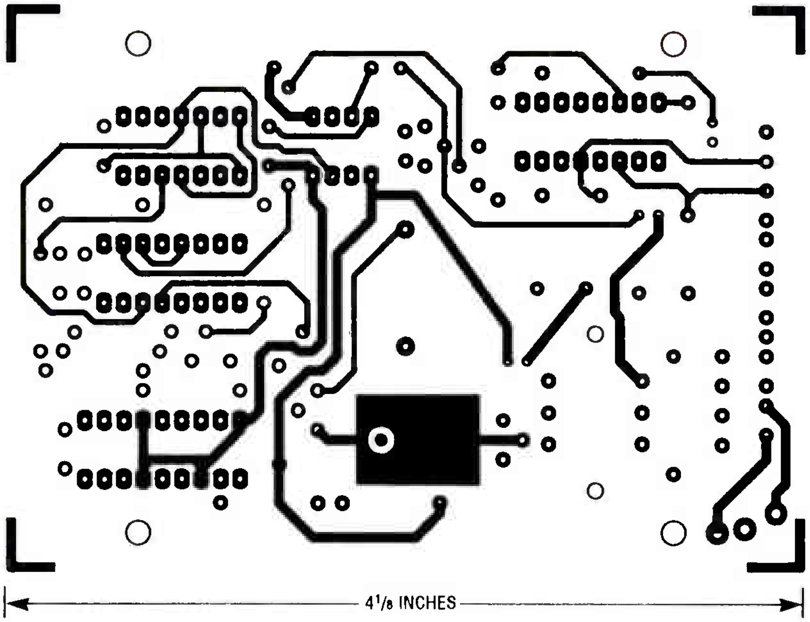
FIG. 7—A FINISHED ALERT MODULE. It can plug into any ordinary phone jack; use a T-connector if you must connect both a phone and an alert module to the same jack.

Construction

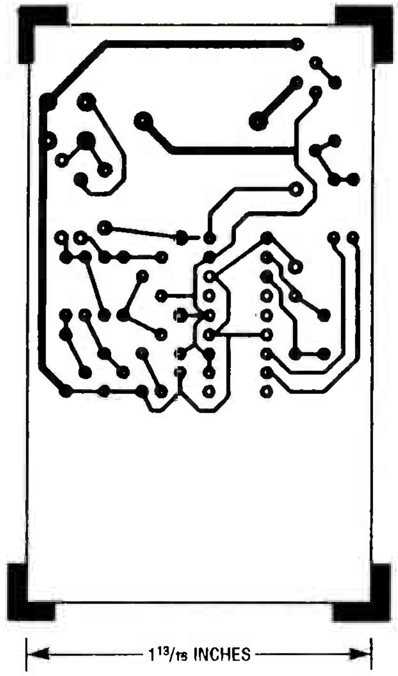
The Phone-Com controller is built on one PC board, and the alert modules are built on separate boards. Determine the number of alert modules you will need including the master control unit. The modules are loud enough to cover approximately 1000 square feet each, even when placed behind furniture. It is recommended that one module be installed in a central location on each floor of your house. Construction is straightforward, however, care should be taken when handling the static-sensitive decoder chips.

We have provided foil patterns for both boards, although the project can be built using point-to-point wiring. Double check your wiring before connecting the modules to the phone line if you don't use the boards. Figure 4 is a parts-placement diagram for the controller board. The finished board, shown in Fig. 5, can be installed in any kind of case you see fit.

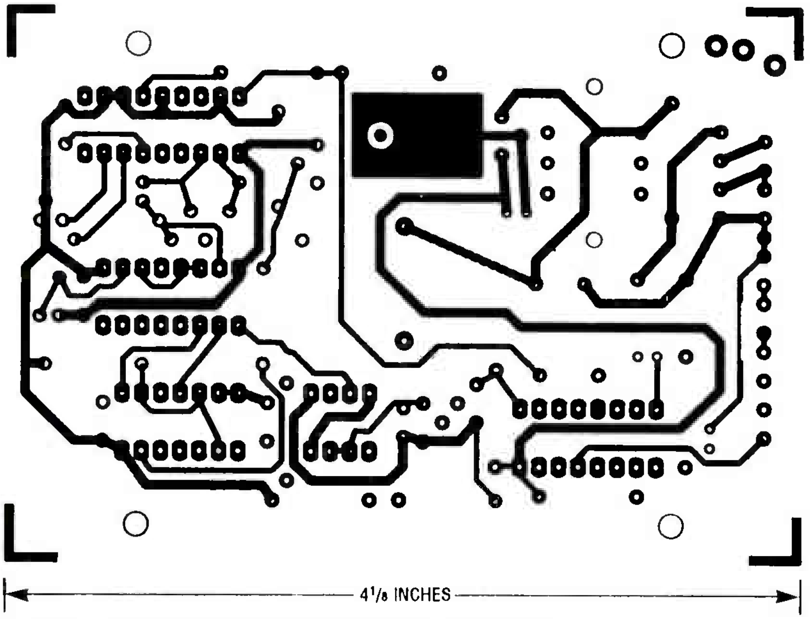
The values for R3 and R10 depend on what type of battery you are using. Use 10 megohms for R3 and 82 ohms for R10 for a 9-volt alkaline battery. If a rechargeable battery is used, change the value of R3 to 82K and R10 to 10 ohms. Any audio



THE CONTROLLER BOARD is double-sided; here's the component side shown at actual size.



FOIL PATTERN for the alert module, also shown at actual size.



SOLDER SIDE of the controller board shown at actual size.

transformer with approximately a 500-ohm primary may be used for T1.

Figure 6 is a parts-placement diagram for the alert module, and Fig. 7 shows a finished unit. Again, the board can be installed in any case you like.

Follow the red/green color code shown in Figs. 2 and 3 when connecting the system to the phone line. A "T" adapter may be used if you need to connect additional equipment to the same jack. Velcro strips offer an easy way to secure the modules to a wall.

Installation and check out

Determine where your network interface is by locating the area where the phone line enters the house. In some cases, the device is mounted on the outside. It is a small box with a short wire loop connecting to a modular jack. Refer back to Fig. 1 on how to install a network interface if it's not already present. During the next few steps, your phone system will be inoperative until installation is complete.

Disconnect the short wire from the jack on the network interface. Connect that wire to J1 on the main control module. Make sure all phones on the same extension are on-hook, and connect the controller to a 12-volt AC source. Pick up a telephone receiver and press the "#" key. The alarm will sound and the LED should be on. You will also be able hear yourself talk through the handset. Hang up the phone. The LED should remain on for approximately 30 seconds, then turn off.

Connect the remaining wire from the main control module to the jack on the network interface. Pick up the receiver again and initiate a call to determine normal operation. If you are unable to dial out, the red and green wires (tip and ring) have been reversed somewhere in the system. Remember that positive phone-line voltage must be present at J2 pin 2.

It may be necessary to toggle the "#" key once or twice to get everything going when the system is first installed or after a power failure. Install the alert modules and determine the correct polarity by measuring a positive voltage at the anode of D1. Reverse the wires in the module if it turns out to be necessary. If a rechargeable battery is used, you should allow it to charge for at least 24 hours before activating the system. **R-E**

Inside SWITCHING POWER SUPPLIES

HARRY L. TRIETLEY

We'll take an in-depth look at two switching regulator IC families, with some applications, and guide you through basic troubleshooting techniques.

IN OUR LAST EDITION, WE EXAMINED the basics of switching regulator power supplies. Now we'll dive into some real-world applications. We'll examine the 3524/5/7 and 3842 IC families in detail, summarize others, and show some typical circuits. In the process we'll study how to select components for those circuits and learn more about how switching regulator IC's are protected against such problems as startup current surges, undervoltage, and overload. We'll finish up with some basic troubleshooting hints.

Let's first start off with an explanation of the standard nomenclature used in naming the IC's we will discuss in this article. The first digit "1" indicates full military temperature range of −55 to 150°C, "2" indicates an industrial temperature range of −25 to 85°C, and "3" is a commercial temperature range of 0 to 70°C. Hereafter, we will refer only to the commercial version IC's, with prefix "3." Keep in mind that all those IC's are also available in military and industrial versions. A suffix of "A," "B," or "C" indicates an enhanced version of the IC, which we will discuss in more detail later in this article.

Manufacturers may use many different prefixes, some of which include

SG—Signetics, SGS-Thomson, Motorola, and Linear Technology.
CS—Cherry Semiconductor.
XR—Exar.
CA—GE-RCA.
IC—IPS.
LTSG—Linear Technology.
LM—National Semiconductor.
UC—Unitrode, Motorola, Linear Technology, and Signetics.
UD—SGS-Thomson.
IP—IPS.
LAS—Lambda.

The SG3524/5/6/7 IC

Figure 1 shows the internal circuit of the switching regulator IC SG3524. In that circuit, the oscillator produces both ramp and pulse outputs. Ignoring the current limit (CL) and shutdown circuits for the moment, the comparator's output goes high when the ramp exceeds the output of the error amplifier. The NOR gates then go low, turning the output transistors off.

Each NOR gate can be high only when its three inputs are low. The oscillator output toggles the flip-flop, enabling one gate, and then the other to respond to the comparator. That action gates one transistor on at a time, providing push-pull operation. The selected transistor turns on at the start of each cycle, and turns off as soon as the ramp exceeds the error signal. At the end of each cycle, the oscillator pulse momentarily forces both gates low, protecting against the possibility of both transistors being on at the same time.

The current-limit amplifier protects against current overloads. Its output is an open-collector type—open-circuit when high, pull-down to ground when low. The current-limit amplifier and the shutdown transistor can be used to force the comparator output high, shutting down both transistors.

Figure 2 shows the SG3524 in a simple DC-DC converter. The oscillator frequency of about 60 kHz is set by R5 and C2. (The flip-flop divides the push-pull output frequency to 30 kHz.) The current-limit amplifier goes low when its input exceeds 0.2 volts, limiting R11's current to 2 amps in case of overload or transformer

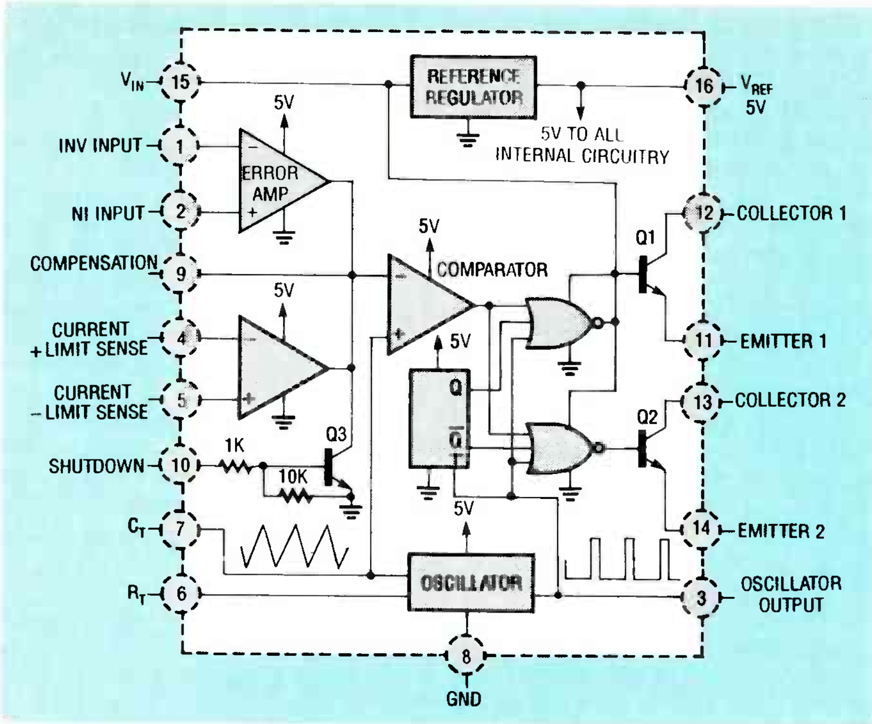


FIG. 1—INTERNAL BLOCK DIAGRAM of the SG3524 switching regulator IC.

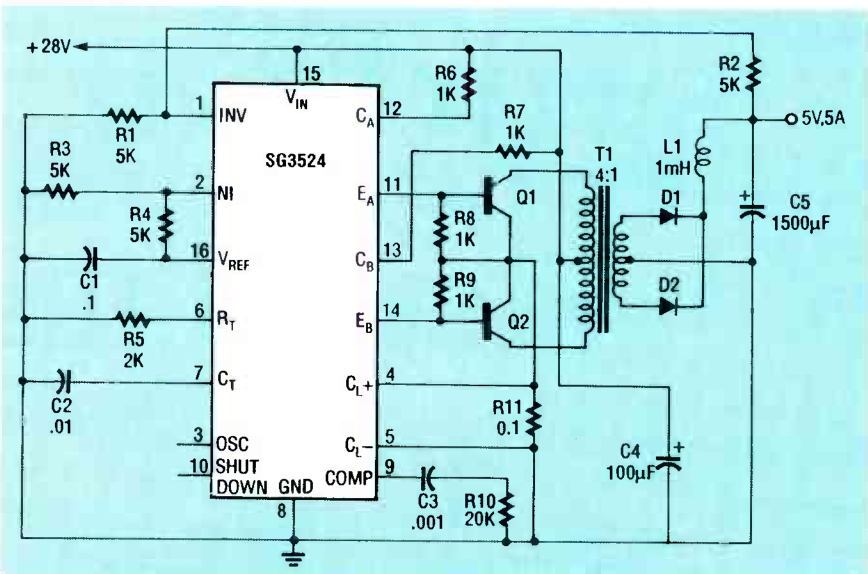


FIG. 2—THE SG3524, TWO SWITCHING transistors, a transformer and a few components create a complete 5-volt push-pull switching regulator.

saturation. Transistors Q1 and Q2 are used for switching transformer current. (The on-chip transistors are rated at only 100 mA.) Supply pulses produced by the circuit are filtered by C4.

The output of the error amplifier is proportional to the difference between the reference input (pin 2) and the feedback (pin 1). If the output increases, the error voltage drops. The ramp then reaches the error voltage more quickly and the transistors turn off sooner, until the output is reduced back to 5 volts. Since the feedback voltage and ground are directly connected, input-to-output isolation is not provided.

Resistors R6 and R7 limit the current through the internal drive transistors, which are used to switch Q1 and Q2. Frequency compensation for closed-loop stability is provided by R10 and C3. Transistors Q1 and Q2 should be high-speed switching power transistors rated at least 5 amps and 60 volts. Shottky or fast-recovery diodes should be used for D1 and D2. Because the output is balanced, the transformer core does not need to be gapped, a small ferrite core will do.

At high frequencies, the equivalent series resistance (ESR) of filter capacitor C5 is higher than its capacitive impedance. Low series-resistance electrolytics should be used, preferably capacitors designed specifically for switching supplies.

The enhanced SG3524A

Figure 3 shows the enhanced version SG3524A, which is pin-compatible and interchangeable with the non-A version. The enhanced version adds an under-voltage lockout circuit which disables the regulator until its input rises above 8 volts. That holds current drain to standby levels during turn-on, guarding against problems during startup, surges, and brownouts. A pulse-width modulator latch is also added, which eliminates multiple pulsing in noisy environments. Set by the comparator and reset by the clock pulse, it can switch only once per comparison cycle.

Further protection is provided by thermal protection circuitry (not shown). Performance specifications also are improved—the 5-volt reference is trimmed more closely (±1%) and the error amplifier's output can swing up to the 5-volt rail.

Let's look at one more member of this family, and an application. Figure 4 shows the workings of the SG3525A/7A. The 3525A and 3527A differ only in their output logic; the 3525A is low when off, while the 3527A is high when off. (The pinouts of the 3525A/7A do not match those of the 3524 IC series.)

Operation is similar to the 3524, but with added features. The oscillator has a sync input, making it easy to lock the frequencies of several supplies, eliminating problems with beat frequencies in multiple-supply boards or systems. The shutdown circuit (also included in the 3524A) and soft-start feature simplify the design of protective circuitry, as will be seen in the next application. The totem pole (push-pull) outputs, rated at maximum 500 mA, provide fast,

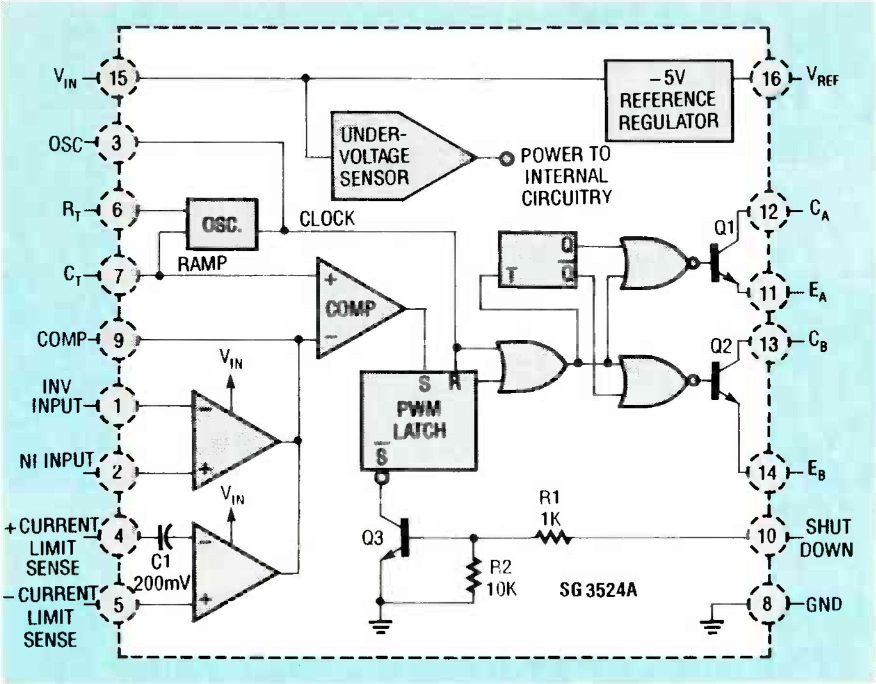


FIG. 3—THE SG3524A IMPROVES the basic device by adding undervoltage lockout, a pulse-width modulator (PWM) latch, thermal protection, and improved reference accuracy.

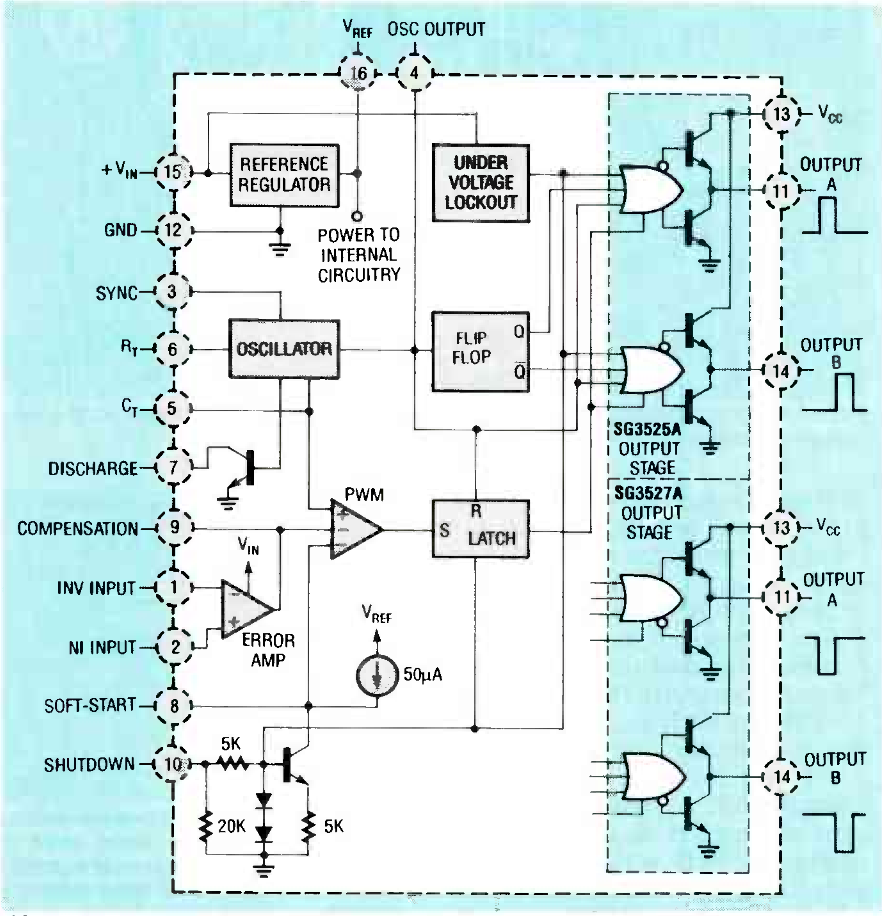


FIG. 4—THE SG3525A AND SG3527A PUSH-PULL switching regulators provide 500-mA, totem-pole outputs and oscillator synchronization.

solid switching for high and low transitions. The 3524's separate current-limit amplifier has been omitted.

Figure 5 shows a 15-watt DC-DC converter. The 200-kHz frequency (100 kHz final output) is set by R2–C2. The internal discharge transistor (pin 7) allows control of the discharge time at the end of each ramp. That provides an ensured stoptime between output pulses so that, even with switching delays, both transistors cannot be on at once. A 47-nanosecond time constant is provided by R16-C2.

The 5-volt reference (pin 16) is connected to the noninverting input (pin 2) by current limiting resistor R3, while C9 provides high-frequency bypassing. Negative feedback voltage is divided by R1-R4, dividing the 6-volt output down to 5 volts. The basic theory of operation is similar to that of Fig. 2; the ramp is compared to the error signal to control the on-off switching of the outputs. On each cycle, the internal flip-flop selects either output A or B. The selected output is switched high at the start of each ramp and reset to low by the latch when the ramp voltage exceeds the error amp's output. As in Fig. 2, the direct feedback connection means there is no input to output isolation.

Compensation for closed-loop stability is provided by R6, R7 and C4. Switching spike currents are limited by R10, R11, and R12 in the output stages. Components C5 and R17 act as a "snubber," limiting switching transients from the primary.

When input power is first applied, Q1 will be off and soft-start capacitor C3 will be discharged. As C3 is charged from the internal 50-μA current source, its voltage will rise, gradually increasing the voltage to the pulse-width modulator (PWM) control's bottom input. That gradually increases the amount of time per cycle that the output is turned on, providing a "soft" rise of the output voltage, which allows the filter capacitors to charge slowly, reducing startup current surges.

If R9's current exceeds about 3 amps (0.7-volt drop), Q1 will turn on, energizing the shutdown circuit which pulls pin 8 low and discharges C3. As the current drops below 3 amps, Q1 turns off, C7 discharges, the shutdown input goes low and the soft-start capacitor provides a "soft" recovery for the power supply.

Power transformer T1 is wound on an EE25 ferrite core (0.25-inch center leg). It feeds a

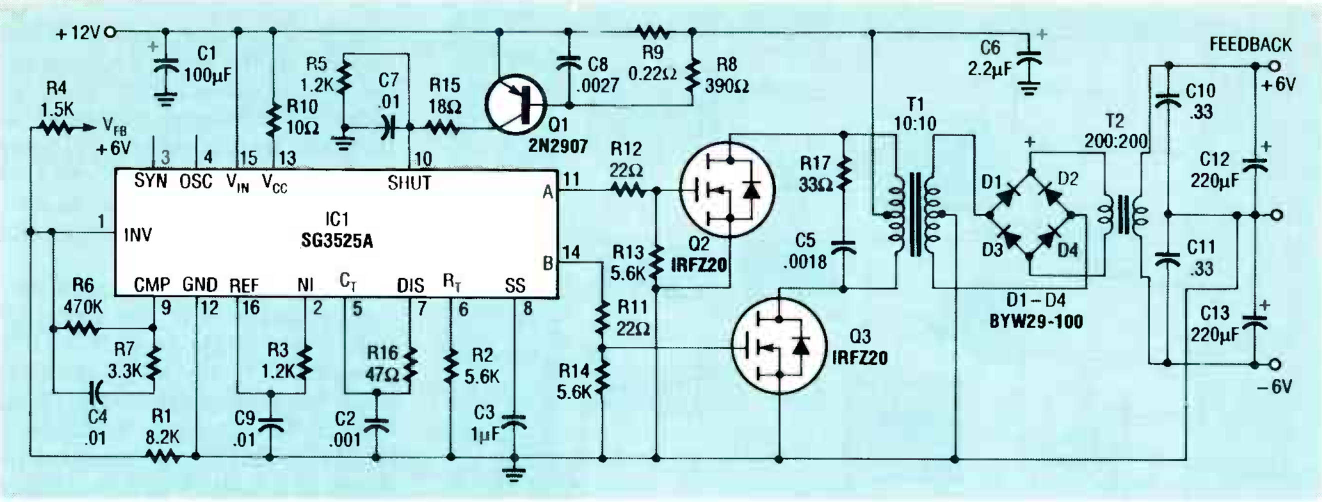


FIG. 5—A PUSH-PULL SWITCHING REGULATOR produces plus and minus 6 volts at 15 watts.

conventional full-wave bridge, providing + and – outputs. Coupled inductor T2, consisting of two coils wound on a cylindrical ferrite core, and the output capacitors filter the output to 50 millivolts peak-to-peak. Transistors Q2 and Q3 are 50-volt, 5-amp, N-channel power MOSFET's. Fast-recovery diodes must be used in the rectifier due to the high frequency; D1–D4 are 100-volt, 8-amp diodes with 35-nanosecond recovery.

Current-mode regulators

We now turn to a different class of switching regulators—current mode. Although the basic operating theory remains the same (pulse-width modulation), current-mode switching regulators differ in that the internal ramp is eliminated. In its place, the ramp-like increase in the transformer's inductive current is used for control.

Figure 6 shows the basics of a current-mode comparator. The pulse from an R-C clock sets the flip-flop, producing a high output. FET Q1 turns on and transformer current begins to flow. As the inductive current ramps upward, the feedback from current-sensing resistor R2 increases. Eventually, the feedback voltage equals the error amplifier's output, at which point the comparator resets the flip-flop, Q1 then turns off until the next clock pulse.

As with previous regulators, the feedback voltage, V_{FB}, represents the filtered output. If the feedback becomes lower or higher than the reference voltage, the error signal will increase or decrease accordingly, increasing or decreasing the on time until the proper voltage is restored.

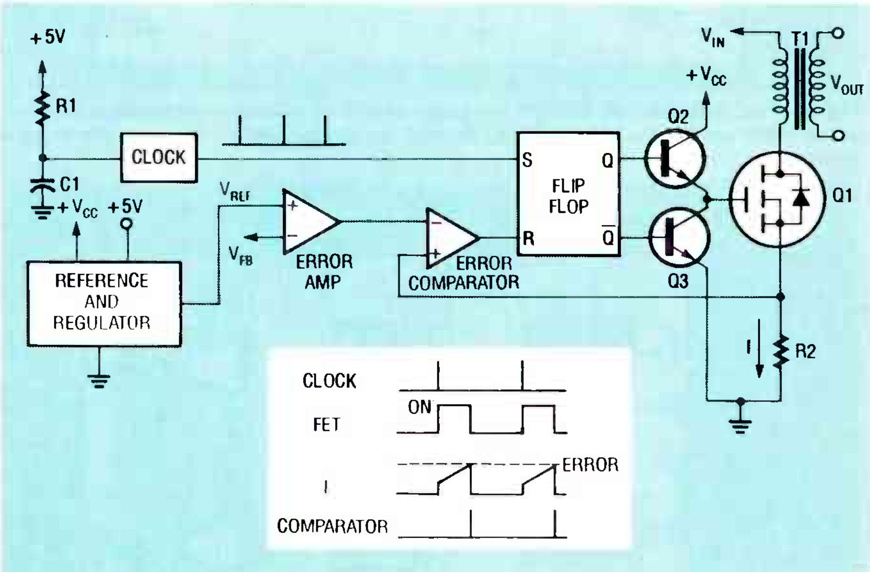


FIG.6—A CURRENT-MODE comparator uses the current feedback signal as the ramp, providing pulse-by-pulse current limiting.

Current-mode regulation offers two major advantages; pulse-by-pulse current limiting, and feedforward line regulation. Notice that the circuit in Fig. 6 contains no current-sensing comparator. Instead, each current pulse ends as soon as it exceeds the level set by the error amplifier. No matter what the cause of overload, whether transformer saturation, an output short, or input overvoltage, the circuit will limit current instantly. Pulse-by-pulse limiting also eliminates the need for a separate soft-start circuit.

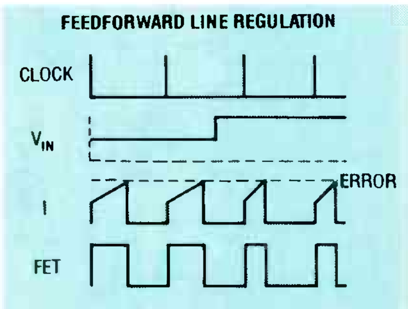


FIG. 7—FEEDFORWARD compensation of input variations is achieved when the ramp rate of the transformer's primary current increases as the input voltage increases.

Feedforward line regulation is illustrated by the waveforms shown in Fig. 7. With a fixed load, the input voltage suddenly increases. On the very next pulse, the inductive current, I, ramps more quickly due to the increased transformer voltage. Since the feedback and the error signal have not changed, the limit is reached more quickly and the pulse width becomes shorter. Changes in line voltage are, therefore, compensated before they have a chance to affect the output.

UC3842/3/4/5

Figure 8 shows the block diagram of current-mode PWM controller IC UC3842. Compared with the circuit in Fig. 6, the UC3842 adds an undervoltage lockout and an output NOR gate. The undervoltage lockout, with hysteresis, disables the output pulses until V_{CC} rises above 16 volts. Once started, it will not drop out unless V_{CC} goes below 10 volts, a feature which prevents constant toggling between "operate" and "lockout." When disabled, the output (pin 6) goes to a high-impedance state. A "bleeder" resistor should be connected from pin 6 to ground to prevent leakage current from turning the switching FET on.

The output NOR gate implements lockout, but also serves another protective function. When the oscillator pulse is high, the NOR output will be low, the OR output high, and pin 6 low. The output cannot go high until the clock goes low. The clock is set up so that timing capacitor C1 charges through R1, and discharges through the constant current sink. By choosing a larger capacitor and smaller resistor, the charging time (clock low) can be decreased and the discharge time (clock high) increased. That allows you to establish the maximum on time, or duty cycle, which is especially important in circuits where duty cycles higher than 50% can lead to transformer core saturation.

The D2–D4-R1-R2 network between the error amplifier and the current-sensing comparator reduces the error signal so that excessive power is not lost in the current-sensing resistor. The one-volt Zener diode clamps the error signal so the maximum turn-off level will never exceed one volt.

UC3843 is similar to the 3842 but has a lower lockout voltage.

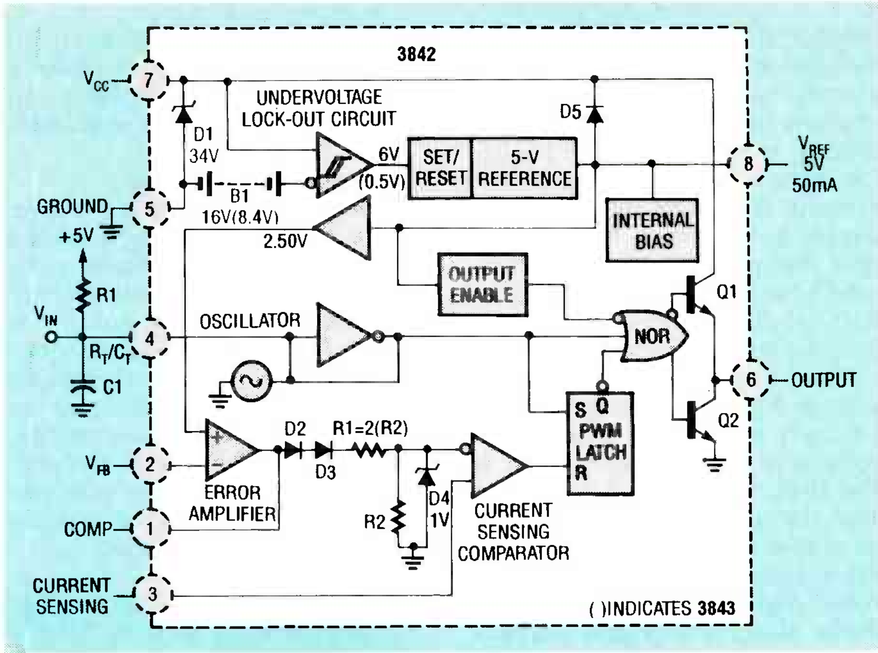


FIG. 8—INTERNAL BLOCK diagram of the UC3842 current-mode switching regulator IC. The UC3843 IC is similar but operates with a lower undervoltage lockout.

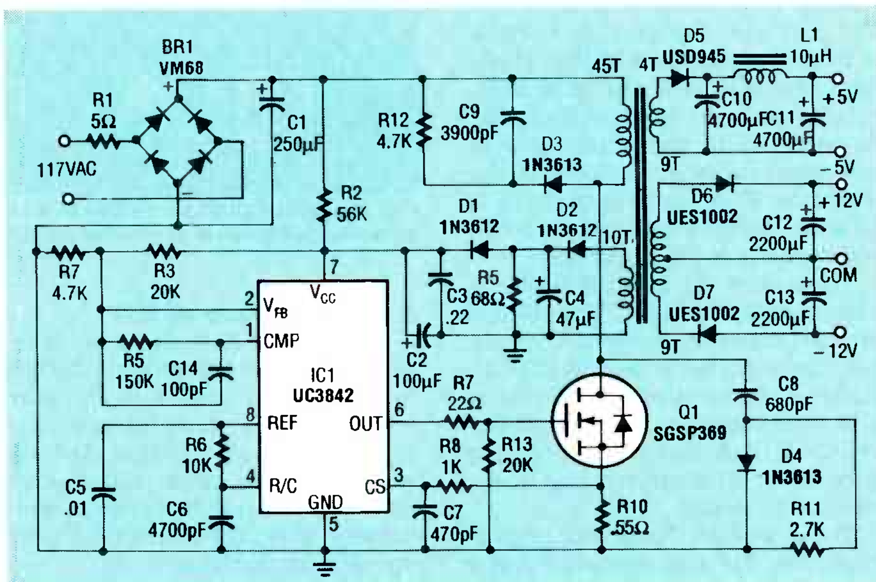


FIG. 9—THIS OFF-LINE CURRENT-MODE regulator produces isolated +5 volts and ±12 volts from 117-volt line power.

Intended for use at lower voltages, it operates at 8.4 volts, and drops out at 7.9 volts. UC3844 and UC3845 (not shown) have one added feature; a flip-flop which disables the output on alternate clock cycles. That guarantees the duty cycle will always be less than 50% for circuits where that is critical.

An off-line flyback converter

Figure 9 shows an SGS-Thomson UC3842 IC in an "off-line" flyback regulator. The circuit provides +5 volts at 4 amps and ±12 volts at 300 mA, and can deliver 27 watts.

The term "off-line" means that the regulator is on the primary side of the transformer and operates directly "off the line." The primary advantage of such a circuit is that large amounts of power can be coupled through a small, high-frequency transformer. Line operation requires high-voltage transistors and diodes, and prevents direct coupling between the output and the feedback circuit.

The line voltage is rectified and filtered by BR1 and C1. Initial startup current to the IC is provided by R1. The UC3842's undervoltage lockout circuitry prevents startup until the voltage on C2 reaches 16 volts. The 50-kHz operating frequency is set by R6-C6, with a maximum duty cycle of about 95%. The internal 5-volt supply is filtered by C5 to eliminate switching spikes. Current-mode feedback is provided by R10, while C14 and R5 are used for frequency compensation.

Once the circuit has started, voltage feedback comes from the 10-turn control winding. The voltage at pin 2 is compared to the internal 2.5-volt reference. The voltage difference increases or decreases the duty cycle until the voltage at pin 7 equals 13.1 volts. Allowing for diode voltage drops, that corresponds to a peak voltage of about 14.6 volts on the control winding. The control-to-secondary turns ratios are chosen to produce 5- and 12-volt DC outputs. Notice that control is from the control winding's voltage, the outputs are only indirectly regulated. Power losses due to currents in the windings, diodes and inductor will affect the outputs. Five-volt regulation is 10% accurate, while the ±12-volt regulator has 5% accuracy.

Transistor Q1 is a 500-volt, 5-amp power MOSFET. The diodes are fast-recovery diodes. A "snubber" network is formed by D3-C9-R12 to hold turn-off spikes below Q1's breakdown voltage. Snubber D4-C8-R11 slows the turn-off rise time until Q1's current has had a chance to decay.

Transformer design is important; the air gap must be large enough to prevent core saturation but small enough to maintain the required inductance. (Note that an air gap is not needed in balanced push-pull circuits.) In the Fig. 9 circuit, an EC35 ferrite core is used (3/8-inch dia. center leg, Ferroxcube EC35-3C8) with a 0.5 mm gap in the center leg.

The primary winding consists of 45 turns of 26 AWG wire. The 12-volt windings are each 9 turns of 30 AWG wire, wound together (bifilar). The 5-volt secondary is only 4 turns, but instead of using a heavier gauge wire, four bifilar, 4-turn windings of 26 AWG wire are used, with their ends connected in parallel. The control (feedback) winding consists of two bifilar, parallel 10-turn 30 AWG windings. Now let's take a look at how an optoisolator can be used in a switching regulator.

Optocoupled feedback

Optocouplers provide a convenient way of coupling isolated feedback. Figure 10 shows a circuit in which the 5-volt secondary of a switching regulator is controlled. If the output goes above 5 volts, the inverting input decreases below 2.5 volts and the optocoupler's LED current decreases. That decreases the coupler's output transistor current, increasing V_{FB} until the isolated output returns to 5 volts.

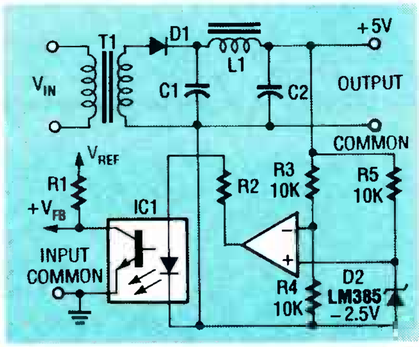


FIG. 10—OPTOCOUPLER FEEDBACK allows precise control of an isolated output.

A wide selection of IC's

Once a new IC technology is established, the offerings multiply as designs advance and the market expands. Switching regulators are no exception. Voltage mode, current mode, single-ended and push-pull IC's cover a wide variety of power levels and user-specific applications.

Table 1 summarizes some of the many IC families available. Most of the devices shown can be multiple-sourced. The part number prefixes vary from manufacturer to manufacturer, and many offer additional, proprietary devices.

It's not possible to fully describe all devices in an abbreviated table, but the listing should help direct you to data sheets for IC's to meet your needs. The 8-pin devices tend to be simpler to apply, while the 16-pin and larger IC's generally offer more complicated protective and "housekeeping" features.

The 3524/5/7 and 3842-7 families have been fully covered in this article. The 4191-3 family, with its low operating voltage and 200-μA current drain, is ideal for battery and micropower applications. Companion micropower device 4391 provides regulated negative outputs from positive supplies. LT1070 is the only IC in the listing housed in a power IC package.

Troubleshooting hints

When troubleshooting switching regulators, always begin with the obvious. Check for input power and output shorts, broken wires, defective connectors, solder bridges, defective solder joints, bad copper traces, scorched components, and so on. It's surprising how often a good visual inspection can uncover a problem.

Make sure you have a data sheet, pinouts of the control IC, and a circuit schematic, preferably with voltages and waveforms. There is such a wide variety of IC's and operating modes that it's difficult to troubleshoot on an intuitive basis. Figure 11 shows a "generic" block diagram, which may help you to think through the circuit function-by-function.

When breadboarding temporary components, remember that switching regulators produce fast, high-current pulses. Conductor size and lead dress are important. The input filter capacitor should be close to the IC, not a foot away. If the main source of power is at a distance, add a several hundred microfarad input bypass capacitor next to the IC.

Even though you may understand the operation of switching regulators, troubleshooting them can be difficult. The IC and its circuitry perform many functions, and the failure of one can cause improper operation of the rest. For example, failure of the feedback circuit may lead to overvoltage, overcurrent, and shutdown by one of the protective features. Is the circuit dead, unstable or out of regulation? That alone may often narrow the search to one particular part of the circuit.

The following hints may help you pinpoint the problem to a specific area of the circuit. After the visual inspection, check the output for shorts or overloads and check the input source, rectifier, filter, and transformer.

TABLE 1—A SUMMARY OF SELECTED SWITCHING REGULATOR IC'S

IC Family	Manufacturers*	Mode V or I	Output (Single or Push-Pull)	Package	Supply	I_{OUT} Max	Reference	Comments
3524/5/7	CS, ERIC, EXAR, GE, IPS, LT, MOT, NAT, SGS, SIL, SLG, TI, UNI	V	P-P	16 Pin	8-35V	100mA	5 or 5.1V	See Article.
3842-7	CS, ERIC, IPS, LT, MOT, SGS, SIG, TI, UNI	I	S	8 Pin	8 (or 16)-25V	1A	5V	See Article.
4191-3	MAX, RAY	V	S	8 Pin	2.4-30V	150mA	1.31V	Micropower for battery applications, 200μA quiescent supply current.
4391	MAX, RAY	V	S	8 Pin	−4 to −30V	100mA	1.25V	Inverting, micropower for battery applications, 250μA supply at 4V.
5560 5562 5561	CS, IPS, SIG	V V	S S	16 Pin 20 Pin 8 Pin	10.5-18V 10-16V 10.5V-18V	40mA 100mA 20mA	3.72V 3.80V 3.75V	Full-featured, flexible. Lower cost, fewer housekeeping functions.
493/4/5 593/4/5	CS, EXAR, GS, IPS, MOT, NAT, TI, UNI	V	P-P	16 or 18 Pin	7-40V	200mA	5V	
μA78S40	MOT, NAT	V	S	16 Pin	2.5-40V	1.5V	1.24V	Universal subsystem IC.
125/7	IPS, SIL	V	P-P	16 Pin	8-35V	100mA	5.1V	
33060/ 34060/ 35060	IPS, MOT	V	S	14 Pin	7-40V	500mA	5V	
1060	IPS, PLES	V	S	16 Pin	20mA into 5V shunt regulator	40mA	3.7V	
LT1070	LT	I	S	5 Pin Power	3-40V	5A	1.24V	Self-contained power IC.

*Manufacturers: CS = Cherry Semiconductor, ERIC = Ericsson, EXAR = Exar, GE = GE/RCA/Harris, GS = Gold Star, IPS = Integrated Power Semiconductor, LT = Linear Technology, MAX = Maxim, MOT = Motorola, NAT = National Semiconductor, RAY = Raytheon, SGS = SGS-Thomson, SIG = Signetics, SIL = Siliconix, SLG = Silicon General, TI = Texas Instruments, UNI = Unitrode

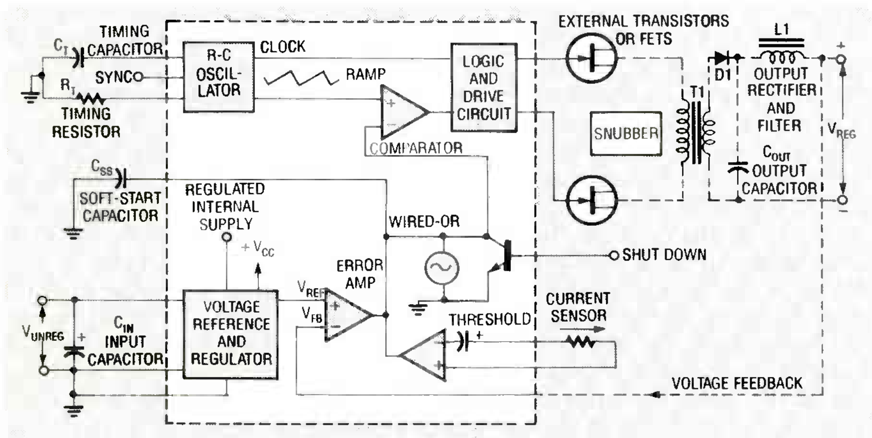


FIG. 11—THIS "GENERIC" BLOCK DIAGRAM of a switching regulator is useful in sorting out the functions which make up the circuit.

Sometimes a failure which looks like it might have been caused by output overload is actually caused by a low input voltage. When the input voltage drops, the regulator's duty cycle increases, raising the input current. The increased current may further drag down the voltage, resulting in even higher current drain, until an input fuse or circuit breaker trips or something burns out.

If the output is dead, check the rectifier and filter, the drive transistors and the output transformer or inductor. Before replacing damaged components check any snubber or surge-suppres-

continued on page 64

Schools and colleges teach many things—but they don't teach electronic-equipment manufacturing. Most of us pick up that type of knowledge through on-the-job experience or through our hobbies. (In fact, hobby magazines like **Radio-Electronics** probably are the most common teachers of practical design and construction.) However, many engineers graduate from school and enter the work force with little or no practical experience.

Recently I had to set up a training center to instruct young engineers at my company in basic manufacturing processes. My task was to create a small manufacturing factory where students would build an electronic product. In the process, they would experience every stage of the manufacturing process: interpreting engineering drawings, buying parts, testing them, building the product, and shipping it to the customer. The project was dubbed the Manufacturing Technology Facility (MTF).

With a limited budget and limited time in which to teach more than 400 people, I searched for automation aids that would speed up the mundane work without attenuating the manufacturing experience we were trying to impart. One area I attacked was incoming inspection. In a normal manufacturing plant, parts are bought from many sources. When they arrive, they are tested to ensure they work, because it can cost more than $10 to find and fix a bad $1 part in a finished product.

The product we built had more than thirty different types of electronic parts, which fell into five groups: resistors, capacitors, diodes, transistors, and IC's. What I needed was a low-cost way for students to inspect the parts quickly, but with minimum chance for error. The result was what we now call the Component Inspection System (CIS). It incorporates a capacitance meter, an IC tester, and a computer-controlled voltmeter used for testing resistors and diode and transistor junctions. The CIS software includes a database containing each component's specifications, complete with pass/fail criteria. In addition, the system contains a data-logging function that allows us to maintain a record of each vendor's quality history, which is useful in selecting vendors.

In future articles, we will describe different components of the CIS hardware and software. This time we'll present a $15 two-IC circuit that lets you use your PC as a capacitance meter. Later installments will include complete details for building sophisticated component and IC testers. When space is available, we'll provide the software listings (all of which are in QuickBASIC); compiled programs and source code are also available.

PC-based capacitance meter

The first project is a capacitance meter. It will be incorporated into the next project, a combined voltmeter, ohmmeter, and capacitance meter on a PC board, but it can also be used as a stand-alone test instrument. First let's discuss the details of hardware operation.

The circuit, shown in Fig. 1, consists of two IC's: a 555 timer (IC1) and a quad bilateral switch (IC2). The 555 is the heart of the circuit. When configured in the astable (one-shot) mode, the length of the pulse generated at pin 3 is directly proportional to the value of the timing resistor (R1) and the timing capacitor (C_X). With a fixed timing resistor, the duration of the output pulse will be directly proportional to the value of the timing capacitor. Thus, by connecting a known resistor and an unknown capacitor to IC1, triggering it, and then measuring the length of the resultant output pulse, we can calculate the value of the capacitor.

We wanted to obtain an effective meter range of 20 pF to 20 μF. To achieve such a wide range, we had to use two different timing resistors—and that's where the 4066 comes in. By driving pin 12 of IC2 high, the IC effectively parallels a second resistor (R2) with the main timing resistor (R1). Doing so makes it easier to measure large-value capacitors. With R2 switched in, the effective range of the meter is 0.1μF to 20 μF. If the value of the unknown capacitor is less than 0.1 μF, R2 can be switched out of the circuit (automatically by the software) and the capacitor can then be remeasured.

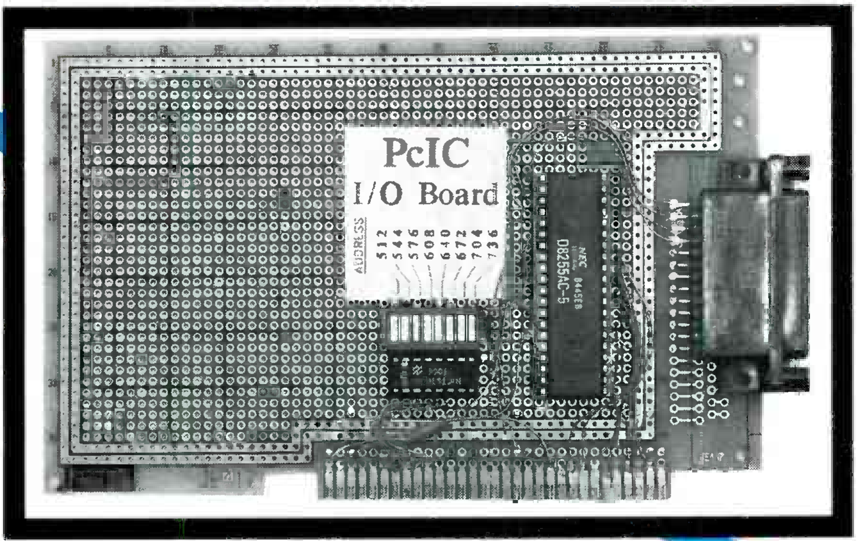
The PC connection

The capacitance meter attaches to your PC via three lines (plus ground) of a standard parallel port. The $\overline{\text{AUTOFD}}$ signal connects to IC1's $\overline{\text{TRIGGER}}$ input (pin 2) to initiate the timing cycle. The $\overline{\text{ACK}}$ line from the port connects to IC1's output (pin 3). In operation, our software drives $\overline{\text{AUTOFD}}$ momentarily low and then high again to trigger IC1. While the PC counts the time interval, the capacitor charges until IC1's internal comparator drives its output from low to high. At that time, $\overline{\text{ACK}}$ senses the end of the timing cycle and alerts the PC to stop counting. The software then converts the elapsed time interval to a capacitance value.

The D6 line from the parallel port drives the bilateral switch. Initially, the switch is on, which places R2 in parallel with R1, and allows you to measure the high range (0.1–20 μF). If the resultant count is less than a specified value, the software switches R2 out of the circuit, obtains a new count, and then scales it for the low range (20 pF–0.1μF).

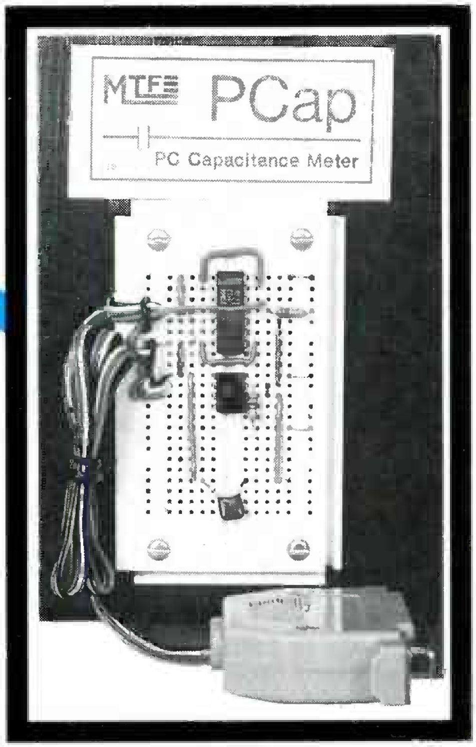
Because the software depends on a timing loop, it must be calibrated before use. Calibration consists of making two readings: one accounts for stray circuit capacitance; the other involves measuring a known capacitor to provide a standard. The circuit

EXPERIMENTING WITH PC-BASED TEST EQUIPMENT



Build your own low-cost PC-based test equipment

JAMES J. BARBARELLO



must be recalibrated if the PC's operating speed changes (e.g., via a turbo mode), or if you connect the meter to another PC.

Software

The simplicity of the hardware is made possible by the software. Although we won't discuss all the details here, there are a few points you should be aware of in the event you wish to modify the software. First, there are two programs, CAP and CAPFAX; CAP is the main program and CAPFAX helps calibrate the software. Both programs are written in Microsoft's QuickBASIC. The software must be compiled; interpreters (including BASICA and GWBASIC) do not run quickly enough to measure capacitors less than 1 µF. If you want to use the software as is, you don't need to own a copy of QuickBASIC; a compiled version is available from the author, as mentioned in the parts list. However, to modify the software, you will need a copy of QuickBASIC.

Now let's talk about CAP. Before doing anything else, the software locates the I/O address of your parallel printer port. That is necessary because some cards don't address their printer ports at the standard location (0378h or 888 decimal). In Listing 1, line 16 locates the address and stores it in variable C. (Note that line numbers are optional in QuickBASIC; they are shown here for reference only.) Variables B and A, which are derived from C, are used to read IC1's output and to operate IC2, respectively.

The measuring function begins in line 18, which switches in the 100K resistor. The next line initializes the counting variable, X. The next line contains two functions. The first, consisting of the OUT statements, generates a negative-going pulse to trigger IC1. The WHILE/WEND loop then continually increments X until pin , of IC1 goes low.

The remainder of the program determines if R2 should be switched in, converts the count to a capacitance value, and displays the value in an appropriate form (pF or µF).

You use the second program, CAPFAX, to create a data file (CAPFAX.DAT) that contains information required by CAP. (CAPFAX is shown in Listing 2.) Five values are required: zero offset, low factor, high factor, picofarad limit, and microfarad limit. Zero offset is the count obtained with no capacitor connected to the circuit. In operation, CAP subtracts this value from the count ob-

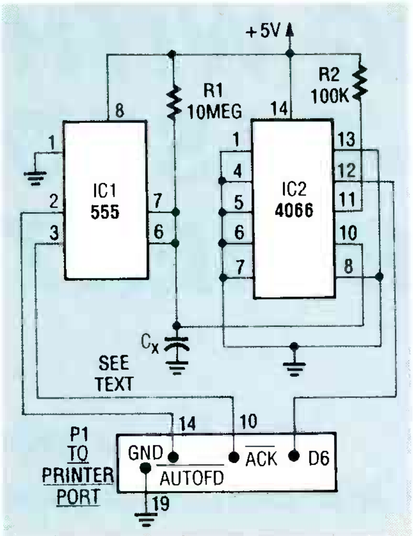


FIG. 1—SCHEMATIC DIAGRAM. The capacitance meter consists of two IC's: a 555 running in the astable mode, and an analog switch that allows the software to perform automatic range switching.

tained during measurement to eliminate the effects of stray circuit capacitance. Low factor and high factor are reference values that tell CAP what the count should be for a 0.100 µF capacitor in the low and high ranges. Using those factors, CAP calculates the value of the unknown capacitor. Picofarad limit and microfarad limit are values that CAP uses to determine when to switch ranges, and how to format the measured value for presentation on the screen. CAPFAX is used during calibration, and any time you change the circuit layout, PC operating speed, or the PC itself.

Construction

The circuit's simplicity allows just about any construction method to be used. The easiest approach is to use a solderless breadboard. You'll also need a source of 5-volt DC power; in a pinch you could power the circuit with three batteries in series (the 4.5 volts produced should be adequate to generate the required TTL logic levels.) If you use a CMOS 555, the batteries will last a long time.

As shown in Fig. 1, several pins of IC2 must be grounded to ensure proper switching operation. If those pins are not grounded, the meter may operate erratically.

To connect the unknown capacitor, you could insert it directly into the solderless breadboard. For more convenient access, you could use a pair of binding posts connected via short lengths of wire. Although doing so adds stray capacitance to the circuit, it can be canceled during calibration.

After building the circuit, wire a short cable from a standard DB-25 male connector and four lengths of wire. Connect the appropriate pins on the connector to the circuit, and the DB-25 end to your PC's parallel port.

Calibration

Calibration must be performed prior to using the meter. To perform the calibration, you need a

LISTING 1

```
REM************************
REM**      CAP.BAS        *
REM**      V900114        *
REM************************
REM
REM** NOTE: THIS PROGRAM MUST BE COMPLIED WITH QUICKBASIC 4.0 PRIOR TO
USE
REM
DEF SEG = 64: DEFINT A-C, I, K: DEFLNG X
OPEN "r", 1, "capfax.dat", 50
FIELD 1, 10 AS ol$, 10 AS fl$, 10 AS fh$, 10 AS pf$, 10 AS uf$
GET 1, 1
offsetlo = VAL(ol$): FACTORLO! = VAL(fl$): FACTORHI! = VAL(fh$)
apf = VAL(pf$): auf = VAL(uf$)
CLOSE
FACTORLOPF# = FACTORLO! / 1000000: factorhipf# = FACTORHI! / 1000000
GOSUB S1: C = PEEK(8) + 256 * (PEEK(9)) + 2: B = C - 1: A = B - 1
RESTART:
OUT A, 64
X = 0: LOCATE 12, 31: PRINT "    MEASURING...    ";
OUT C, 2: OUT C, 0: WHILE (INP(B) AND 64): X = X + 1: WEND
SELECT CASE X
 CASE IS > auf
  measuredvalue = X / FACTORHI!
  LOCATE 12, 31: PRINT SPACE$(18);
  LOCATE 24, 1: PRINT "Hi - uf";
  LOCATE 12, 36: PRINT USING "####.# uf"; measuredvalue
  GOTO SKIPIT
 CASE ELSE
  OUT A, 0
END SELECT
OUT C, 2: X = 0: OUT C, 0: WHILE (INP(B) AND 64): X = X + 1: WEND
SELECT CASE X
 CASE IS > apf
  measuredvalue = (X - offsetlo) / FACTORLO!
  measuredvalue = INT(measuredvalue * 10000) / 10000
  LOCATE 12, 31: PRINT SPACE$(18);
  LOCATE 24, 1: PRINT "Lo - uf";
  LOCATE 12, 36: PRINT USING "#.### uf"; measuredvalue
  GOTO SKIPIT
 CASE ELSE
  AA = 0: XX = 0
REDO:
  OUT C, 2: X = 0: OUT C, 0: WHILE (INP(B) AND 64): X = X + 1: WEND
  IF AA < 5 THEN AA = AA + 1: XX = X + XX: FOR i = 1 TO 100: NEXT i:
GOTO REDO
  mean = XX / 5: X = mean
  LOCATE 12, 31: PRINT SPACE$(18);
  measuredvalue = (X - offsetlo) / FACTORLOPF#
  LOCATE 24, 1: PRINT "Lo - pf";
  LOCATE 12, 36: PRINT USING "#### pf"; measuredvalue
END SELECT
SKIPIT:
LOCATE 24, 62: PRINT SPACE$(17); : LOCATE 24, 62: PRINT "Count:"; X;
COLOR 7, 0: LOCATE 20, 29
COLOR 0, 7: PRINT " M "; : COLOR 7, 0: PRINT "easure, or ";
COLOR 0, 7: PRINT " E "; : COLOR 7, 0: PRINT "nd ... ";
Tryagain:
Reply$ = UCASE$(INPUT$(1))
SELECT CASE Reply$
 CASE "M"
   LOCATE 12, 37: PRINT SPACE$(6)
   GOTO RESTART
 CASE "E"
   CLOSE : END
 CASE ELSE
   BEEP: GOTO Tryagain
END SELECT
END
S1:
CLS : LOCATE 3, 23: COLOR 0, 7: PRINT SPACE$(35)
LOCATE 4, 23: PRINT "       PC CAPACITANCE METER        "
LOCATE 5, 23: PRINT "     (c) 1990, JJ BARBARELLO       "
LOCATE 6, 23: PRINT SPACE$(35): COLOR 7, 0
LOCATE 11, 30: PRINT CHR$(222); STRING$(19, 223); CHR$(221)
LOCATE 12, 30: PRINT CHR$(222): LOCATE 12, 50: PRINT CHR$(221)
LOCATE 13, 30: PRINT CHR$(222); STRING$(19, 220); CHR$(221)
RETURN
```

LISTING 2

```
REM** CAPFAX.BAS
REM** REVISE CAPFAX.DAT ENTRIES
REM** V900114
CLS : OPEN "r", 1, "capfax.dat", 50
FIELD 1, 10 AS zero$, 10 AS low$, 10 AS high$, 10 AS pf$, 10 AS uf$
GET 1, 1
LOCATE 1, 30: PRINT "REVISE CAPFAX.DAT FILE"
LOCATE 3, 1: PRINT "Zero Offset: "; zero$
LOCATE 4, 1: PRINT "Low Factor : "; low$
LOCATE 5, 1: PRINT "High Factor: "; high$
LOCATE 6, 1: PRINT "pF Limit   : "; pf$
LOCATE 7, 1: PRINT "uF Limit   : "; uf$
LOCATE 9, 10: PRINT "Change (Y/N)? ";
GOSUB yesno: IF a$ = "N" THEN GOTO endit
z$ = zero$: l$ = low$: h$ = high$: p$ = pf$: u$ = uf$
getnewones:
VIEW PRINT 3 TO 23: CLS : VIEW PRINT
LOCATE 3, 1: PRINT "Zero Offset: "; z$
LOCATE 4, 1: PRINT "Low Factor : "; l$
LOCATE 5, 1: PRINT "High Factor: "; h$
LOCATE 6, 1: PRINT "pF Limit   : "; p$
LOCATE 7, 1: PRINT "uF Limit   : "; u$
LOCATE 9, 10: LINE INPUT "New Zero Offset..."; z$
IF z$ = "" THEN z$ = zero$ ELSE LSET zero$ = z$ + "          "
LOCATE 9, 28: PRINT z$
LOCATE 10, 10: LINE INPUT "New Low Factor..."; l$
IF l$ = "" THEN l$ = low$ ELSE LSET low$ = l$ + "          "
 LOCATE 10, 27: PRINT l$
LOCATE 11, 10: LINE INPUT "New High Factor..."; h$
IF h$ = "" THEN h$ = high$ ELSE LSET high$ = h$ + "          "
LOCATE 11, 28: PRINT h$
LOCATE 12, 10: LINE INPUT "New pF Limit......"; p$
IF p$ = "" THEN p$ = pf$ ELSE LSET pf$ = p$ + "          "
LOCATE 12, 28: PRINT p$
LOCATE 13, 10: LINE INPUT "New uF Limit......"; u$
IF u$ = "" THEN u$ = uf$ ELSE LSET uf$ = u$ + "          "
LOCATE 13, 28: PRINT u$
LOCATE 15, 10: PRINT "Change (Y/N)?";
GOSUB yesno: IF a$ = "N" THEN GOTO endit ELSE GOTO getnewones
endit:
VIEW PRINT 3 TO 23: CLS : VIEW PRINT
LOCATE 3, 1: PRINT "Zero Offset: "; zero$
LOCATE 4, 1: PRINT "Low Factor : "; low$
LOCATE 5, 1: PRINT "High Factor: "; high$
LOCATE 6, 1: PRINT "pF Limit   : "; pf$
LOCATE 7, 1: PRINT "uF Limit   : "; uf$
LOCATE 15, 10: PRINT "Save (Y/N)? ";
GOSUB yesno: IF a$ = "N" THEN CLOSE : PRINT "NO SAVE": LOCATE 18, 1:
END
PUT 1, 1: CLOSE : PRINT "New Data Saved.": LOCATE 18, 1: END
yesno:
a$ = UCASE$(INPUT$(1))
SELECT CASE a$
   CASE "Y"
   RETURN
   CASE "N"
   RETURN
   CASE ELSE
   GOTO yesno:
END SELECT
```

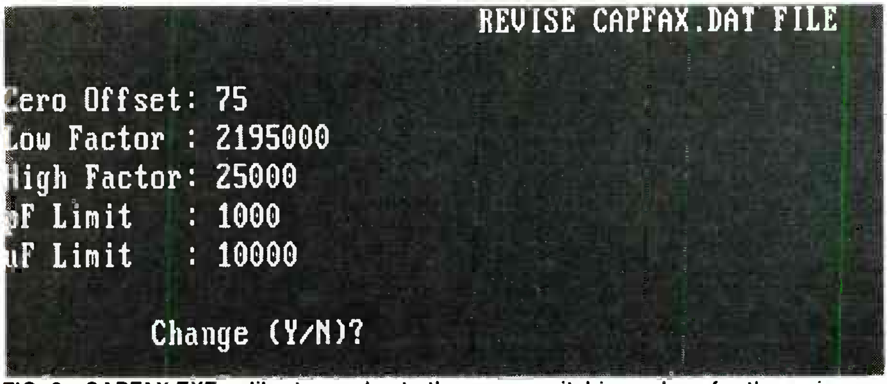


FIG. 2—CAPFAX.EXE calibrates and sets the range-switching values for the main program, CAP.EXE.

0.1 µF capacitor for which you know the exact value. If you don't have one, use a capacitor marked 0.1 µF with the best tolerance you can find (at least 5% or 10%).

Begin by executing CAPFAX.EXE; you'll see a screen like that shown in Fig. 2, except that the five values will all be 0.0. To change values, press Y, and then enter the following values as a starting point.

- Zero Offset: 0
- Low Factor : 1
- High Factor: 1
- pF Limit : 1000
- µF Limit : 10000

After entering those values, respond by pressing N (No) to the Change question. Respond Y (Yes) to the Save question to create the initial CAPFAX.DAT file.

Now connect the circuit to your PC's printer port, but make sure there is no capacitor connected to the test points. Apply power to the circuit and start the software by typing the command CAP at the DOS prompt.

The screen will display some value of capacitance, and a count in the lower right hand corner. Press M to measure again. Disregard the value displayed, but note the count, which should be between 5 and 100, depending on your particular PC and circuit construction). That value is the zero offset.

Next connect the known 0.1 µF capacitor and press M to measure. Again, disregard the value displayed, but note the count. Multiply that number by 10 to obtain the low factor. For example, if the count is 123456, the low factor is 1234560. Leave the 0.1 µF capacitor in the circuit.

Execute CAPFAX again and en-

PARTS LIST

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

R1—10 megohms
R2—100,000 ohms

Semiconductors

IC1—555 timer
IC2—4066 quad bilateral switch

Other components

P1—25-pin male D connector

Miscellaneous: 0.1 µF high-tolerance capacitor for calibration, solderless breadboard, five-volt power source, wire, solder, etc.

Note: The following is available from JJ Barbarello, RD#3, Box 241H, Tennent Road, Manalapan, NJ 07726: Compiled version of the software (CAP and CAPFAX), with datalogging, on 5¼-inch double-density PC diskette, $8.00. The author will be happy to answer any questions. Please include a self-addressed stamped envelope for reply.

ter the appropriate values into the Zero Offset and Low Factor fields. Also, change the μF limit to 1. Save the new data and re-execute CAP. Press M to measure. Disregard the value, but note the count, and multiply it by 10 to obtain the high factor. For example, if the count is 1234, the high factor is 12340. Execute CAPFAX one more time to enter the high factor and change the μF limit back to 10000. Save the revised data.

Use

Using the PC-based capacitance meter is straightforward. With your PC on and the meter connected to the printer port, apply power to the meter. At the DOS prompt, type CAP and press Enter. Insert the capacitor to be measured, and press M. The value appears in the middle of the screen, and the bottom indicates the range (pF, μF low, μF high), along with the timer count. To end the program, press E.

The μF limit and pF limit factors are used to determine how to format the measured value. If you measure a capacitor that displays 0.00 μF, but has a count greater than 0, you are in a "no-man's land" between the two limits. Execute CAPFAX and increase the pF limit factor. Doing so increases the pF formatting range and allows the measured value to be displayed properly.

Remember that if you vary the meter circuit or your PC, you should recalibrate the software to maintain accuracy.

Next Time

In the near future we'll incorporate the capacitance-measurement circuitry into a combination instrument that measures resistance, capacitance, and voltage. The device allows you to measure resistors, capacitors, diodes, and transistors. Because it is computer controlled, it can be the heart of an automated inspection system for your shop or business. You can save a lot of troubleshooting time by ensuring that the IC's you plan to use in a project function properly before you use them. The last project in this series is an IC tester that allows you to verify operation of most 14- and 16-pin TTL and CMOS IC's. **R-E**

DRAM TESTER

continued from page 40

to operate a few minutes for maximum stability, set R5 at 100 ns on the dial, and adjust R19 for a low clock pulse of 200 ns. Measure the pulse at the 1.0-volt DC level. Next turn R5 fully counterclockwise; the low clock pulse should be 150 ns. Turn R5 fully clockwise; the low clock pulse should be 300 ns—if not, adjust R17 for the proper "dial spread."

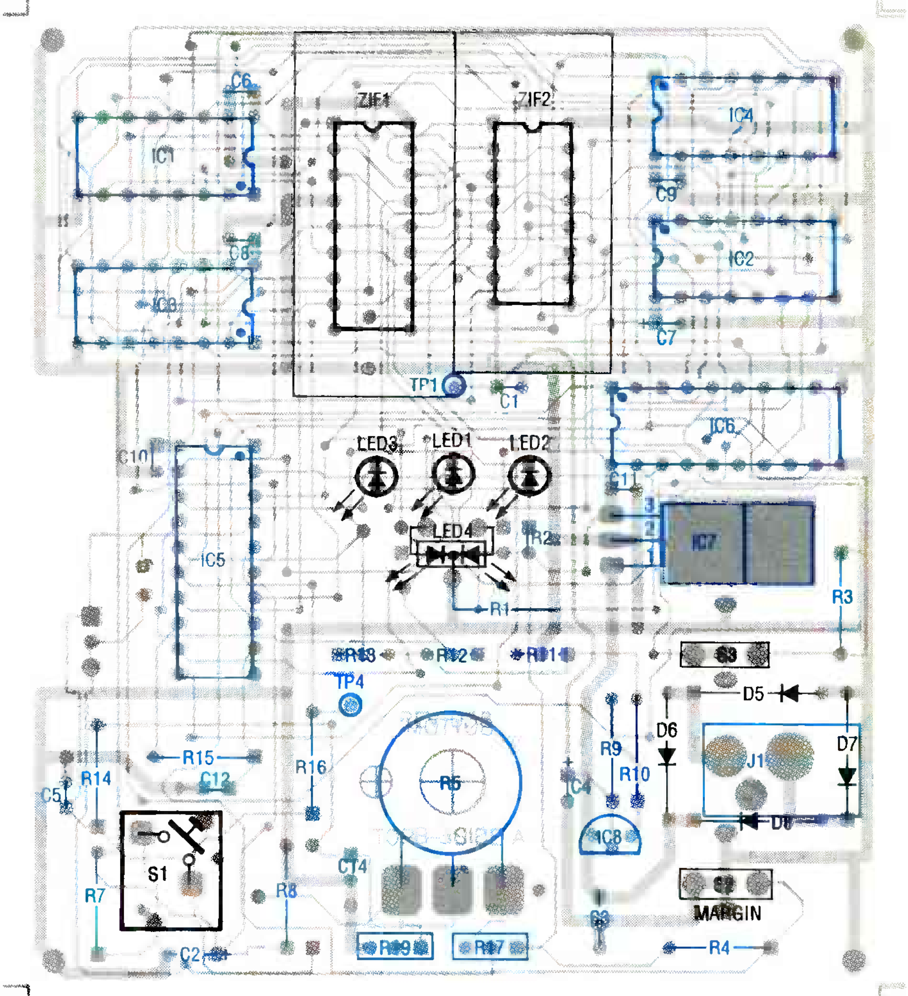


FIG. 9—PARTS-PLACEMENT DIAGRAM. The parts shown in color are installed on the "bottom," or solder side of the board—that is, the side opposite that with the ZIF sockets.

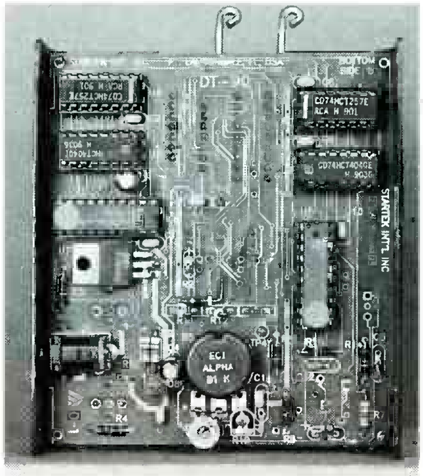


FIG. 10—THE FINISHED BOARD is neat and compact—and, of course, quite useful.

The R17 and R19 adjustments will interact somewhat, so adjust by small increments, and again calibrate R19 at the 100-ns dial setting with R5 after each change to R17. This adjustment should be easy; both potentiometers should end up somewhere near midrange.

If you do not have a scope immediately available to calibrate the access-time control, set R17 and R19 to midrange, which should be near calibration, and use the speed test for a relative indication; the function and voltage margin tests should work fine. All you have to do now is install the unit in an appropriate case and put it to good use. **R-E**

ROGER P. NEWELL*

PERSONAL COMMUNICATION NETWORKS

Can microcell technology of PCN's make mobile communications truly affordable for everyone?

A NEW ERA OF PERSONAL COMMUNICATIONS may be just over the horizon. Imagine the freedom and mobility of making and receiving calls away from your desk and home—in the street, roaming around your office, or even on the golf course. This new service will be provided by Personal Communications Networks (PCN's), which are radio-telephone networks designed to run parallel to, and compete with, the Public Switched Telephone Network (PSTN) that we are all familiar with.

PCN's are intended to provide mobile telephone service with quality and reliability equivalent to wireline. The handset is a digital radio designed to permit privacy and security that meet the standards of a fixed network, with usage rates that are comparable, or only slightly higher, than those charged by wireline services. Those advantages can come only if there is a large number of subscribers. A further objective of PCN's is to make efficient use of the radio spectrum in order to have as large a capacity as possible.

What is a PCN?

A generally accepted definition of a PCN is that it is a complete telephone system, running parallel to (and competing with) the traditional fixed telephone system. A PCN consists of pocket radio telephones communicating with fixed base stations in the street or in buildings. PCN's will permit any person to make or receive telephone calls, no matter where he or she might be—at home, on the street, or in the office. Using digital radio techniques in combination with a low-cost pocket-sized handset, the PCN will provide a fully mobile service with enhanced quality and all the features and functions of a standard telephone system. The underlying idea is that calls should be made to a person, not a place. By assigning a personal telephone number to an individual (rather than a line from the phone company's central office) the PCN will be able to ensure that the customer is always able to be reached in an instant.

A more basic system, called Telepoint, operates as a radio pocket payphone, allowing calls to be placed whenever the user is within radio range of a base station installed by the Telepoint operator. When a subscriber wants to make a call, he or she goes within radio range of a public base station installed by the Telepoint operator, opens the handset and punches in a personal identification number (PIN). The base station will validate the PIN, and accept the dial information. The call is then extended through the public telephone network. The base station collects information on the caller's identity (transmitted by the handset) and the duration and distance of the call. The Telepoint company will send a bill to the customer for all calls that happen to have been made during the month.

Market demand

The desire for communications mobility is strong. A.D. Little, a respected marketing consultant firm, has done market research that indicates that a large fraction of the nation's households would gladly subscribe to a PCN. Although market demand depended on the price of the handset and the monthly charges for the service, 40% of all households surveyed were likely to subscribe to PCN's, assuming monthly service charges of $10 per month over the consumer's current telephone bill, and a handset price of $100. When the service premium increased to $40 per month, and handset prices to $250, 14% of all households indicated the willingness to buy PCN service—and that's only the residential market. Between 25 and 35% of all businesses were likely to subscribe to PCN's.

A.D. Little concluded that the interest in PCN's is nearly double that of most other new services. It also found that annual revenues from personal communications will range from $10 billion in the first year or two to over $30 billion as the service matures. That's enough to make even a telephone company's mouth water, and explains the current high interest in personal communication networks.

How it works

In some ways PCN's are similar to cellular telephones. In each case, the radio telephone transmits signals to a fixed base station, which then connects the call to another subscriber, or the public-switched telephone network. The fundamental difference is that PCN's use ex-

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tremely low power for the radio link between the handset and the base station—about 10 milliwatts peak power compared with 600 milliwatts for cellular portables, and 3 watts for a car telephone. Low power means short range, which would seem to be a severe drawback for a radio telephone, but is actually the reason for the current intense interest in PCN's. With a short range, it is necessary to have very large numbers of base stations, each covering a microcell whose radius is from 200 meters to perhaps half a kilometer. In comparison, cellular cells are usually several miles wide.

Since the spectrum can be reused in each of those microcells, PCN's are more spectrum efficient than cellular phones, and can provide service to many more people. With such a large capacity, the investment cost per subscriber can be kept extremely low. The initial cost of a PCN is expected to be about $300 per subscriber, compared with $800 for cellular and $1,600 for wireline networks.

In addition, the use of low power also brings manufacturing advantages into play. If the handsets broadcast at low power, less power is needed in the battery, which means smaller batteries, and therefore, smaller terminals and micro-miniaturized components are used. All that translates into longer talk time, with lower prices available to the public.

Spectrum scarcity

Microcell technology has the potential to change the way we communicate, and to be a prodigious revenue-producer for those supplying the equipment and service. Yet PCN's are not springing up all over the landscape. The reason is that an essential element is in short supply—the radio spectrum for handset-to-base transmissions. Virtually all of the technically appropriate spectrum has been allocated to users who guard it with the intensity of a bear protecting her cubs. The Federal Communications Commission (FCC) and industry are attempting to find a path through the spectrum thicket. The FCC could, in theory, clear spectrum for a PCN service simply by reallocating a slice away from current users; but past experience has shown that trying to remove a slice of the spectrum is like walking into a buzzsaw.

As an alternative, spectrum could be assigned to PCN on a co-primary (sharing) basis, or on a secondary basis, requiring PCN operators to defer to the primary users of the spectrum. But sharing leaves the operators unsure of whether their spectrum is sufficiently solid to warrant the high investments needed to set up their systems. Either method would involve bloody battles in the halls of the FCC between the spectrum haves and have-nots, and would take several years to resolve.

So companies throughout the telecommunications industry are exploring ways to bring to consumers the benefits of low-cost mobile phones, despite the shortage of frequencies. Over 50 applications for experimental licenses for PCN's and Telepoints have been filed in the U.S., and 13 in Canada, seeking to test a variety of technologies. For example, one company which owns a network of interbuilding microwave systems in New York City, will test its use as the backbone distribution network for a PCN. Many applicants, especially the Bell Operating Companies, plan to hedge their bets by testing everything in sight. At this time, most of the testers are still in the preparatory stage, and that is the reason why few results have been publicly reported.

CT2 systems

One system, called Cordless Telecommunications, 2nd Generation (CT2), is drawing interest because it uses comparatively little spectrum. It can be used for Telepoint, residential cordless phones, and wireless PBX's for use in offices. The technique uses frequency-division multiple access (FDMA) to divide four megahertz of spectrum into 40 channels of 100 kilohertz each. The handset checks each of the 40 channels at 750 millisecond intervals, and if it finds another channel with less interference, it will switch to the new channel. When used for residential cordless telephones, CT2 has marketing advantages over current analog cordless telephones, since CT2 telephones tend to be smaller, have a greater range, and are more difficult to be overheard by one's neighbors.

CT2 operates in the 800–1000 MHz range, but only three megahertz of spectrum remain unassigned in that range, and those frequencies were promised to

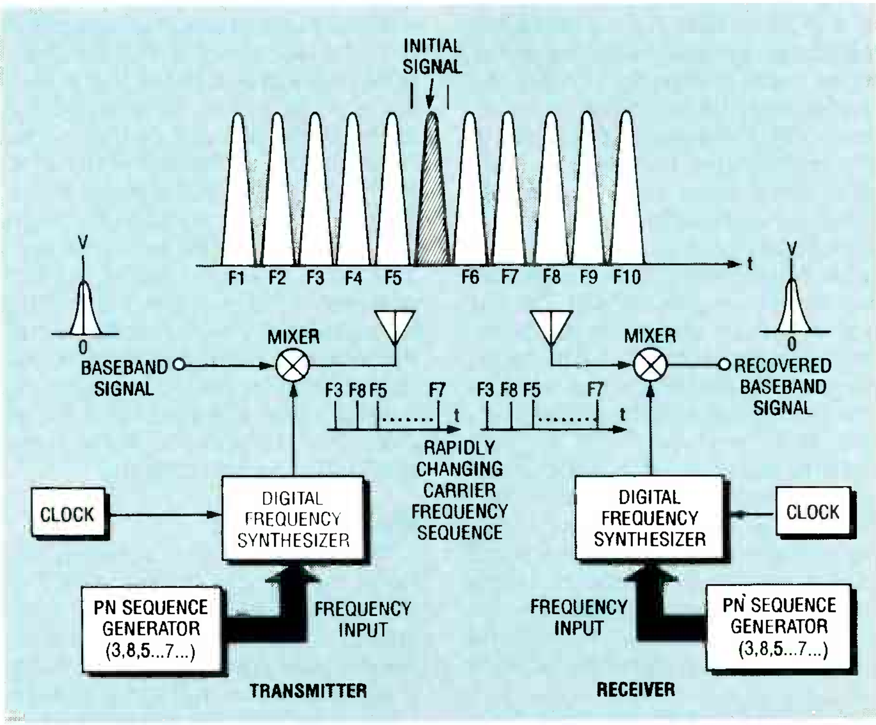

FIG. 1—A FREQUENCY HOPPING SYSTEM. Pseudorandom noise sequence generators in the transmitter and receiver are used to output the same frequency-hopping sequence.

other mobile phone users. An assignment to a Telepoint service would, however, run into intense opposition from companies already in the market that had hoped to use the spectrum for other mobile uses.

CT2 plus

Another possibility lies in the use of a more spectrum efficient version of CT. Northern Telecom has proposed that the 3-MHz slices in the 900-MHz band be used for control channels, while actual communication will take place over a 30-MHz band, occupying parts of the spectrum not being used by point-to-point microwave operators in any particular location. Interference with microwave operators would be avoided by use of "smart" base stations which would have the ability to sense which frequencies are being used by microwave channels and would block those frequencies off from the handsets.

The FCC's Chief Engineer, Dr. Thomas Stanley, presented the possibility that the 4 MHz being considered for allocation to the air/ground telephone service could be shared by microcell users. That may be feasible since the air/ground use is not likely to be heavy in any one location at any given time.

Cellular frequencies

Dr. Stanley also pointed out that under a recent FCC order, cellular operators are free to use their allotted spectrum for auxiliary services, providing the primary service of cellular telephony is not affected. Up to 50 MHz of cellular spectrum could be used for a PCN-type service, assuming that a cellular operator would take precious spectrum away from the higher-priced cellular services. The hitch is that frequencies used for PCN's would have to be taken away from the profitable cellular service. Nevertheless, NYNEX has announced that it would use a portion of its cellular frequencies to build PCN's in New York and Boston, and is expected to be operational by 1992.

Spread spectrum

Vast numbers of radio devices operate today with no license at all under the FCC's Part 15 regulations for low-powered devices, including such things as garage-door openers and existing analog cordless telephones. A personal communications system operating at 10 milliwatts or less of radiated power would fall under the power limitations of Part 15, and would be allowed to operate at any frequency, but would have to accept interference from existing and future licensed operations, as well as any other Part 15 devices. That's a very uncertain foundation for a large investment.

One potential solution is to share spectrum through "spread-spectrum" technology. Several experimental PCN's have been set up to explore that option, including PCN's to be built in Houston and New Orleans by a subsidiary of Millicom, Inc. If successful, they will pave the way to establish a personal communications service despite the frequency crunch. Results are expected by the end of 1991. Although spread spectrum has been criticized as expensive, and untried in public telephony, it may offer the only hope in the U.S. of getting a PCN service off the ground.

Spread-spectrum modulation was originally developed by the military to permit jam-proof and undetectable radio communications. Those are the qualities that permit low-power radio links without interference to or from other radio transmissions. By spreading signal strength over a wide bandwidth, the energy transmitted at any one frequency in the band is low, which effectively reduces the chance of harmful interference.

Using spread-spectrum tech-

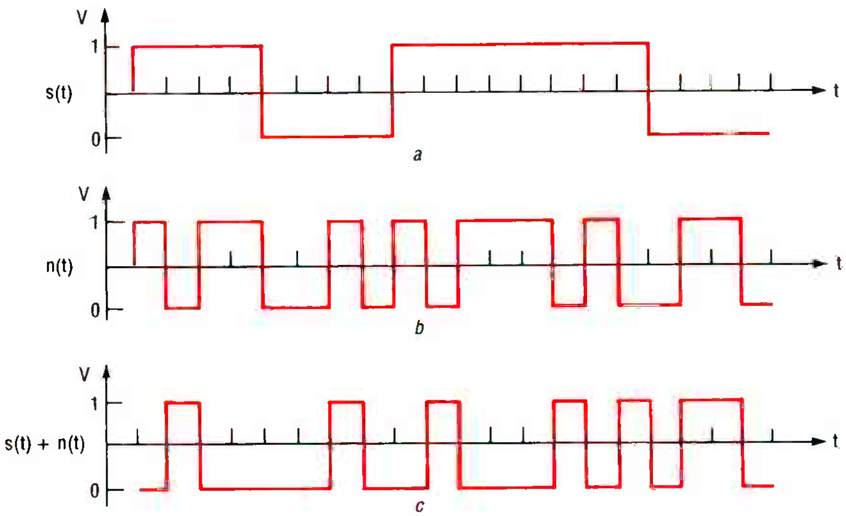

FIG. 2—SPREAD-SPECTRUM SIGNAL. The carrier signal (*a*) is modulated by a noise signal (*b*), resulting in a summed signal, with an expanded bandwidth.

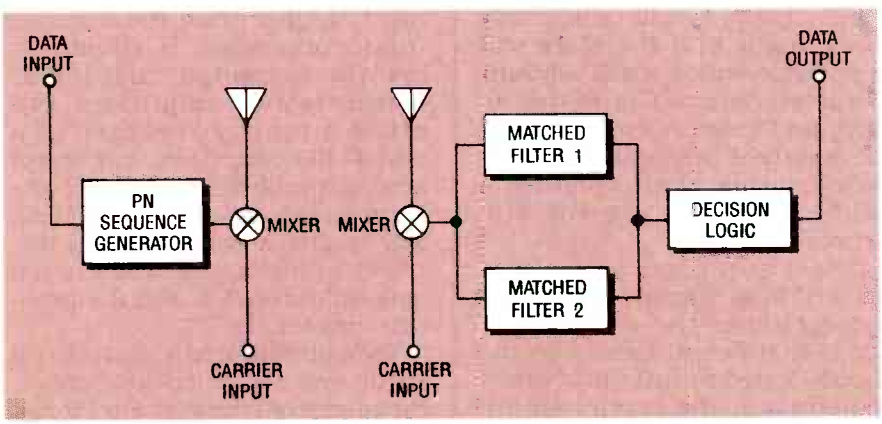

FIG. 3—DIRECT SEQUENCE uses multiple matched filters to reduce noise and increase successful correlation between the receiver and transmitter. Decision logic selects the filter output that is most likely to be correct.

niques, information is transmitted over a wide bandwidth using a pseudorandom pattern. User-specific codes are transmitted by each sender to permit the intended receiver to select out the relevant transmission. There are two primary methods that are traditionally used to do that; they are frequency hopping and direct sequence.

Frequency hopping is conceptually very simple. In transmitting a traditional narrow-band signal, the carrier frequency is changed, or "hopped," to one of a great many frequency slots many times per second over a large number of channels. The resulting signal has an expanded hopped bandwidth, which is often in the order of a few hundred MHz.

The hopping pattern may seem to be an unpredictable sequence, but is actually controlled by a predetermined pseudorandom noise (PN) generator. The PN sequence generator is used to determine the varying hop slot. The intended receiver and the transmitter simultaneously hop to the same pattern and thus can hear one another. A block diagram of a typical frequency-hopper system is shown in Fig. 1.

The pseudorandom nature of the hops has several benefits. Some of those benefits include

1. An eavesdropper will have a difficult time listening unless he has the code which determines the hop pattern.
2. A deliberate jammer will not know where to put his transmitter on the band of frequencies since the frequency hopper dodges the jammer.
3. Multiple, uncoordinated frequency hoppers will collide only occasionally and therefore will experience only a small amount of interference. Therefore, as more and more users come on, the quality of the signal degrades slowly rather than creating a hard limit on the capacity of a network.

Direct sequence, sometimes referred to as "signal shredding," accomplishes the same goals, but uses different tactics. In the sophisticated technique of direct sequencing, the carrier (information) signal is digitally modulated by the noise signal. Figures

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SWITCHING SUPPLIES

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sion components. Failure of those will allow high voltage spikes, possibly destroying switching transistors or rectifier diodes. Incidentally, always use identical or approved replacement parts for diodes and switching transistors. Slow "garden variety" components will fail quickly, possibly taking other components with them.

Before replacing the IC, go through the circuit function-by-function. Try to narrow the problem to one area of the circuit and see if any external components have failed. Is the IC's internal regulated voltage correct? If not, the failure almost certainly is in the IC. Is the oscillator running? If not, check the resistor and capacitor before replacing the IC. Check the soft-start capacitor and the external shutdown input, if your circuit has them. Check any compensation components, especially if the output is oscillating or unstable.

If all of the above are working but the output is incorrect, the problem is most likely either the IC or the voltage feedback circuitry. A malfunctioning feedback circuit is always tricky to troubleshoot, especially in a device as complex as a switching regulator.

The best advice is to start at the output and go step-by-step through the feedback circuit. The voltage divider's input-to-output ratio should be correct, even if the voltage isn't. An op-amp or comparator's output should be high if the positive input is higher than the negative input; otherwise, it should be low. (Note, though, that the IC connects two amplifiers and other circuitry together in a wired-OR connection. Any one of several problems can bring the error amp's output low.) Check any feedback windings and rectifiers, optocouplers, and so on. If you still haven't found the problem, replace the IC.

Troubleshooting switching regulators can be tricky. Just remember to go through the circuit step-by step, and keep the basics in mind when you encounter problems. **R-E**

HARDWARE HACKER

More on toner-cartridge reloading and Santa Claus machines, and some VHF and Microwave resources.

DON LANCASTER

Every now and then, it seems a good idea to go back over some of our older *Hardware Hacker* subjects and bring them up to date. Certainly one of the most popular topics ever found on our helpline involves...

Toner cartridge reloading

PostScript and other laser printers are fast becoming a major industry. There are many millions of units now in use. By far the best and the most popular versions use several styles of laser engines made by *Canon*. These engines were originally intended to accept a throwaway plug-in cartridge. Inside the cartridge is a source of toner, a photosensitive drum, and a spent-toner holding tank.

Played according to the rules, you buy these cartridges for $120, use them for 4000 copies, and end up with a per-page toner cost of three cents.

As we have seen before, you can easily reload these cartridges yourself dozens of times. Today, you can do so in two minutes for a cost of $6.50 or less, and can easily reduce your per-page toner costs to 0.2 cents per page, a whopping 15:1 cost improvement.

Besides saving big bucks on your own printer, you could also resell recharged cartridges for as much as $15 or even $19 each, as part of an ongoing neighborhood service.

There's lots of exciting new things happening in the toner recharging industry, so I thought we might pick up some fundamentals and then bring you up to date on the newest and the best insider secrets.

What is toner? Well, it is a mixture of (usually) black stuff and hot glue. Specifically, toner is a fine powder which has very precisely controlled magnetic, electrostatic, thermal, and visual properties. Most toners are basically a mixture of ferric oxides, polyethylene, and lubricants.

Toner starts out in the cartridge's *fresh toner tank*. A magnetized roller then picks up a very uniform layer of toner. Meanwhile, a nearby photosensitive drum gets flooded with light and then electrostatically charged. It next gets selectively discharged by a laser beam, leaving a charge pattern on the drum. As the drum rotates, it passes very near the magnetic roller and the toner selectively jumps onto the drum, sticking by electrostatic forces only where you want an image.

As your drum rotates further, it passes very close to a highly charged piece of paper, and the toner particles then jump onto the paper. Any remaining toner that was left on the drum gets scraped off and routed to a *spent-toner holding tank*. The photosensitive drum then continues on its way for another cycle.

Meanwhile, you now have your image on the paper. But it is only held there by gravity and by rather weak electrostatic forces. It will easily smear if you touch it. The paper then goes on to a *fusion roller* assembly. Heat and pressure will melt the toner and force it into the paper, giving you a fairly durable final hard copy.

One very important part of most fuser assemblies is the *wiper pad*. The wiper pad has a small amount of silicon oil on it that both lubricates and cleans up any remaining toner on the pressure rollers. Wiper pads are usually replaced whenever a cartridge is recharged. Note that just washing a wiper pad is a no-no.

Our first rule: Toners vary from machine to machine. Most *Canon* laser printers use what is known as a *black write* system, since laser diodes will last much longer this way. On the other hand, all but the newest and most expensive copiers use a *white write* system so that light ends up as white and dark as black.

Thus: *Copier and Laser-Printing toners must NEVER be interchanged or substituted for each other!* There are usually mechanical interlocks that prevent you from plugging a copier cartridge into a laser printer and vice versa. If you attempt to defeat those interlocks, you will end up using the wrong toner. At the very least, that gives you useless copies, and at worst, it can cause serious damage.

Similarly, toner chemistry varies from printer to printer, especially between manufacturers. Our second rule: *The refill toner you use must be pretested in and rated for the exact cartridge you are refilling.*

So where do you get refill toner and the wiper pads? My two favorite sources are *Don Thompson* and *Lazer Products*. There is also one outfit called *Black Lightning* that stocks specialty toners for T-shirt and fabric printing uses.

The toner industry has its own trade journal. It is called *Recharger*, and is chock full of supplier ads and useful industry info. There are also at least a dozen recharging associations who do have lots of seminars and conventions. Details on those usually appear in *Recharger*.

The big news today in toner refilling involves new third-party hard coated drums. For some reason or another, the factory stock drums are made needlessly soft. The third-party drums instead are ultra-hard and can easily be used for dozens of reloads. One leading importer of hard drums is *CopyMate Products*.

Let's look at some specific refilling details. Certainly the most popular cartridges are those used in the *Canon* CX, SX, and LX engines. Figure 1 lists many popular laser printers

NEED HELP?

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

HP MANUAL	HP PRINTER	APPLE PRINTER	QMS PRINTER
02686-90920 (CX Engine)	LaserJet I	LaserWriter LaserWriter Plus	PS800
33449-90906 (SX Engine)	LaserJet II LaserJet III	LaserWriter NT LaserWriter NTX	PS810 & Turbo PS820 & Turbo
33459-90906 (SX Engine)	LaserJet IID LaserJet IIID	----	----
33471-90904 (LX Engine)	LaserJet IIP	Personal LW NT	PS410

FIG. 1—HERE'S A LIST of all the most popular PostScript laser printers, their equivalent service manuals, and the style of toner cartridges they use.

and the specific engine used in each one. Figure 1 also reveals to you the outstanding *Hewlett-Packard* repair and service manuals involved. The manuals, and all major parts, can be had overnight via VISA/800.

For some reason which I simply cannot fathom, *Apple Computer* absolutely insists that you use the HP service manuals to keep your Apple LaserWriter printers alive. As near as I can tell, this is some sort of a top-secret rebate policy.

At any rate, you can recognize the older CX cartridges by their large three-inch drums, their red-yellow-green end dial, and their obvious lunchbox handle. While the original LaserWriter and all similar printers using them are rather dated, they do remain useful, especially when printing lots of heavier stock. Many used bargains are now cropping up involving these machines. Two sources are *Don Thompson* and *The Printer Works*.

Non-PostScript laser printers, of course, are an utterly useless ripoff, so be absolutely certain that your used machine can speak genuine Adobe PostScript.

Before we begin, note that the photosensitive drums must *never* be exposed to strong light, or to *any* light at all over any long period of time. Never get fingerprints on the drum. Cotton gloves are a good idea.

Toner is an ultra fine powder that can end up all over everything. It is sometimes best to work outside, possibly wearing a mask. Toner can, in theory, explode a vacuum cleaner, but that rarely will happen. But do be careful.

The general steps in refilling any cartridge are fivefold:

(1) Remove and discard any waste toner from the spent toner holding tank. Do not reuse the spent toner.
(2) Refill your fresh-toner supply tank with a new bottle.
(3) Lubricate the drum with a light dusting of *Pixie Dust* (see below).
(4) Replace the oiled wiper felt on the fusion assembly elsewhere in the printer.
(5) Update accurate life and service records on a suitable label.

Figure 2 shows you those CX refilling details. There is really never any

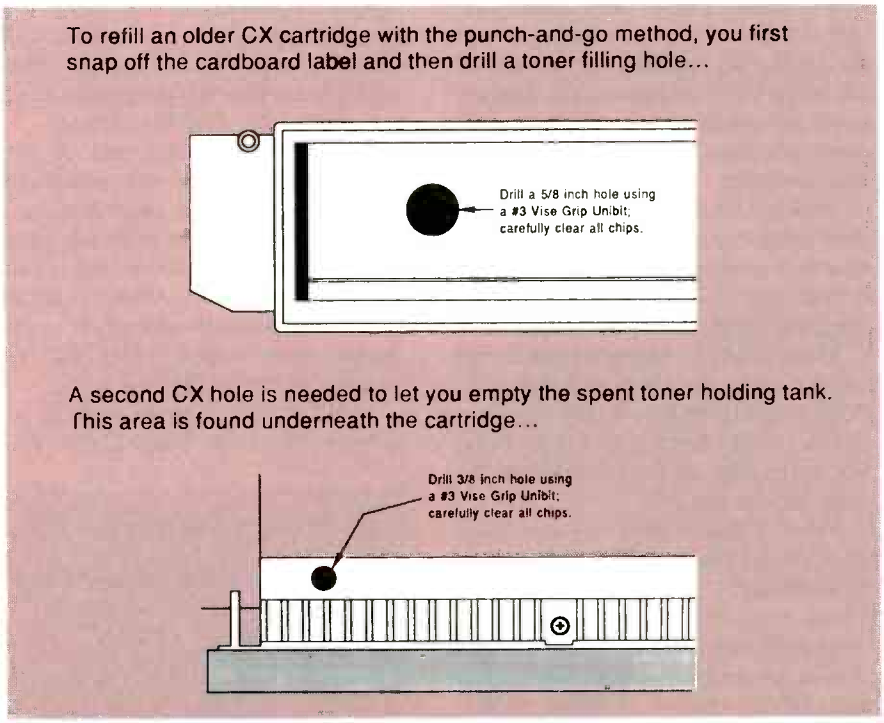


FIG. 2—THE CX CARTRIDGE is easily recognized by its large drum and its obvious "lunchbox" handle. Here are my "punch-and-go" refilling secrets.

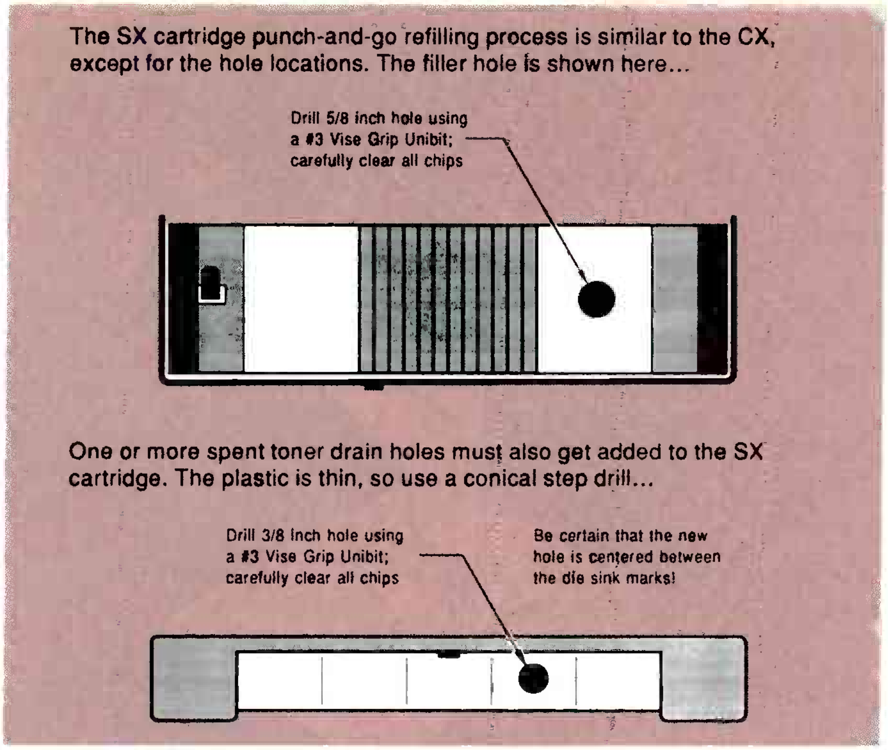


FIG. 3—THE SX CARTRIDGE is wider than it is high, has a small drum, and is the most popular cartridge for the larger 8-PPM PostScript laser printers.

reason to tear down a CX cartridge, except to substitute a hard drum. The original factory drums are big enough that you can often get four or five refills as is. For most people most of the time, a total teardown will cause many more problems than it will solve. Remember that your ultimate goal should be minimizing all of your per-page toner costs, not maximizing the number of recharges for each drum. An extra recharge is pointless if it costs the end user more per page to do so.

If you absolutely have your heart set on taking a CX cartridge apart, you'll need two special tools. One is a special tamperproof *Torx* bit. This is *EVCO* part number #945B700 and is available from *Jensen Tools* as well as most refilling supply houses. The second is a special pin-pulling tool called a *CX Glompenstractor* and available once again through *Don Thompson*.

Should you use my *punch and go* method, you will have to drill two holes in the cartridge on your first reload. That is best done using a rather unusual step-drill called a #3 *Vise Grip Unibit*. They are available from *Jensen Tools* or from any larger electrical contracting supply house. When used with a variable-speed hand drill, the Unibit cleanly cuts a perfectly round hole in brittle plastic, while producing a single and easily grabbed chip.

After drilling the holes, the spent toner is shaken or vacuumed out. You can reseal the hole with plain old Scotch Tape (be VERY careful to get a secure seal!), or else use a nickel *Caplug*. Your fresh-toner hole is similarly used to accept a bottle of new toner and then resealed.

Figure 3 shows you the SX cartridge recharging. The LaserWriter NTX is a typical machine that uses this cartridge. The SX cartridges have a one-inch drum and are rather flat looking, being much wider than thick. Should you decide to tear down the cartridge or upgrade to a hard drum, a different glompenstractor is needed having a narrower snout.

The details of my punch-and-go refill method remain pretty much the same. First time around, you drill a suitable filling and emptying hole. Once again, the #3 *Vise-Grip* Unibit in a variable-speed hand drill is ideal for this. To refill, drain and discard the spent toner and reseal. Then fill the fresh toner tank and reseal.

Figure 4 shows you the newest LX cartridge recharging. The personal laser printers, such as the *QMS* PS-410, use this cartridge. The LX cartridge is recognized by its small size, an obvious spring, and its "white trim" gears and bearings.

No holes are required. To access the tank, pull the two pins by using *ChannelLock* #357 end pliers. The tank can then be refilled through the existing *Caplug*. To change the drum or drain the spent toner, remove the four *Phillips* screws on those nylon drum bearings and pull the drum.

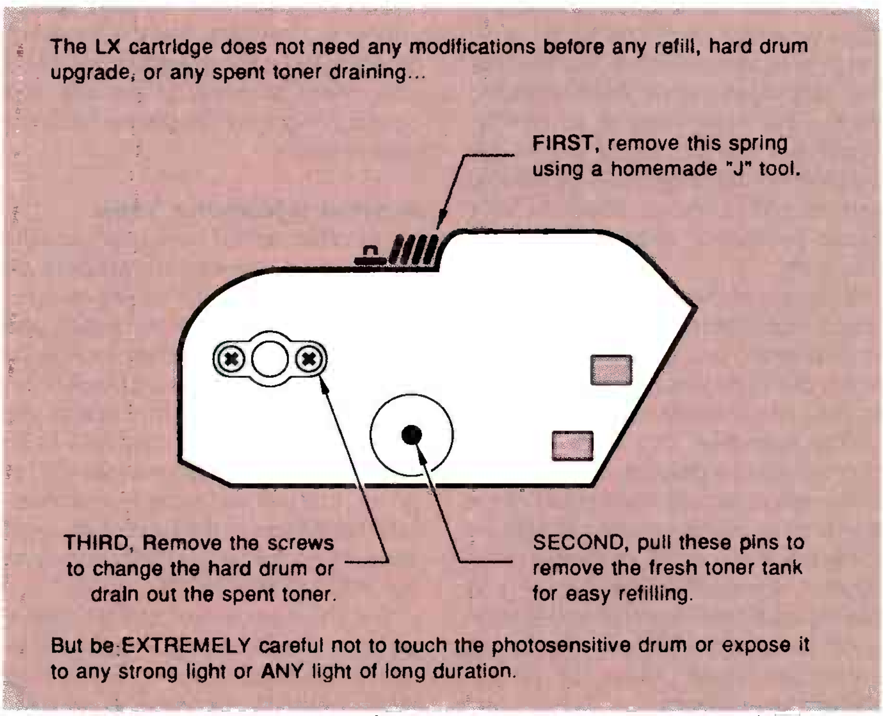


FIG. 4—THE SMALLER LX CARTRIDGE is used in the "personal" 4-PPM printers and is easily spotted by its obvious spring and the "white trim." NEVER use copier toner in a laser printer.

Spent toner can be simply vacuumed or shaken out.

After a recharge, it's a good idea to *very lightly* dust any drum with a suitable lubricant. Many of them are based on plain old zinc sterate. Only don't substitute baby powder since the perfume and oils will do you in. The usual name here is *Pixie Dust*. Pixie dust is available through most recharging supply houses at very low cost. You can make a "duster" from the toe of a child's athletic sock and a rubber band.

Once again, the wiper pad on the fusion assembly should get replaced every time you change the cartridge. You normally keep the old wiper wand and drop a new peel-and-stick oiled nomex felt strip in place.

While you can obtain toner-tank resealing strips, travel of any kind is extremely rough on toner cartridges. I do not recommend ever moving a cartridge further than you can gently and personally hand carry it. Nor do I recommend ever swapping your own cartridges for unknown outsiders. I strictly limit my personal recycling service to a six-mile radius. Yours also should be.

Reuse of toner removed from spent-toner holding tanks is not in the least recommended, nor is recycling your own wiper pads.

There does remain plenty of "zoo" aspects to toner recycling. Certain irresponsible manufacturers have begun some high-profile national "recycling" programs which in fact destroy the cartridges rather than recycling them. The hope here is to permanently get the cartridges out of circulation before they could be refilled and reused. Only an absolute idiot would participate in any program of this sort.

If you do nothing else, you can sell your empty cartridges locally for $5 to $10 each, and then contribute as much of the proceeds as you care to to your favorite environmental group.

Any salesman that tells you that normal use of a properly recycled cartridge automatically voids your printer warranty is telling you an outright lie for which they can be criminally prosecuted. Some others are literally gold plating stuff that does not in the least need to be gold plated. Yet others substitute shoe polish for proper hard-drum recoating.

Those recharge/repair schools run the gamut from outstanding high-quality bargains down to outright ripoffs. To tell one from another, ask the school for a list of all previous students in your area. Then call one or two of them.

So, you will have to pay careful attention to details. But the toner recharging industry is fast maturing and now offers all sorts of exciting and cost-saving new hardware-hacking opportunities.

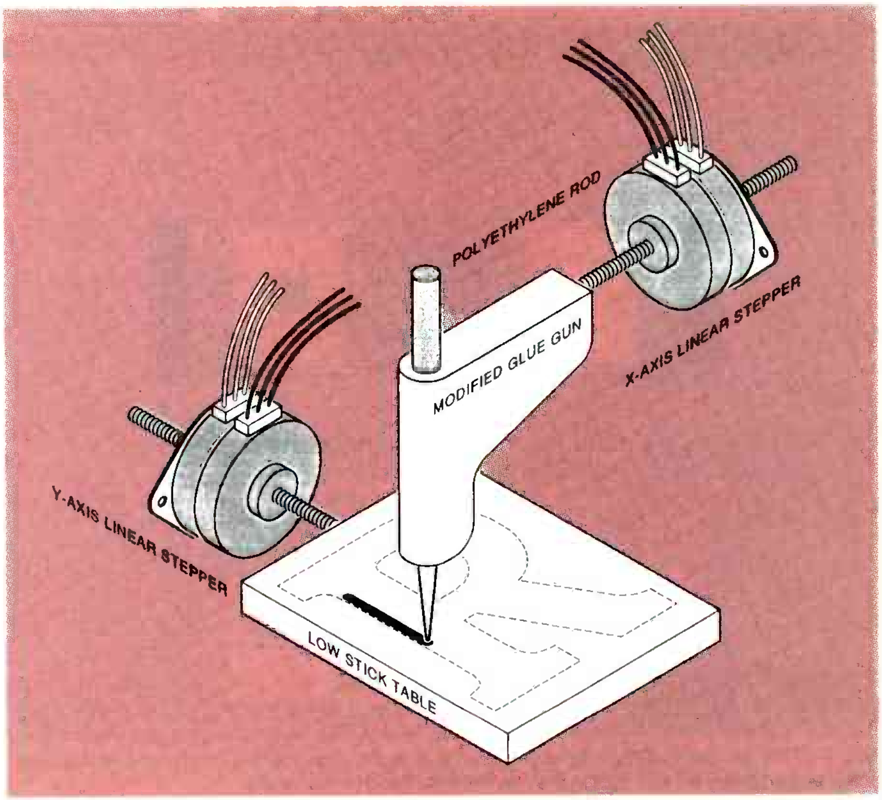


FIG. 5—A "SANTA CLAUS" MACHINE for producing large display letters. The polyethylene bead from the glue gun is programmed to build up the entire letter one strand at a time. While slow, there are no mold charges and the size and style can be instantly changed. Logos and custom characters are a snap.

A great telephone book

I'm often asked how I can usually find helpline names and numbers so fast. Well, I have built up my own resource data base over the years, and that is where I will often look first. Physically, this is just a big black notebook with lots of stuff that keeps falling out of it. Most of this data base appears in the *Hardware Hacker* reprints, and a downloadable and annotated selection of the best of the best appears on my *GEnie* PSRT library as file #80 MYFAVOR.TXT.

But the number-two place I always go to is the *Electronic Industry Telephone Book* from *Harris Publishing*. While it lists for around $50 per year, sometimes you can get a free one or promo copy from a sales rep.

This national coverage gem works just like any other phone book, with alphabetical white pages and by-topic yellow classifieds. Their listings are very thorough, and I am continually amazed by how often this one volume can solve so many problems.

Santa Claus again

Several times now, we've taken a look at the new Santa Claus machines that create instant desktop prototypes at a tiny fraction of the time and cost of traditional methods. As we have seen, all the stuff out there so far is primitive, klutzy, and horrendously priced. At least so far.

We've also seen some outstanding new hacker opportunities here, that range from low-cost desktop prototyping alternatives to offering your own prototyping service bureaus using the commercial systems.

While the best possible desktop prototyping solution remains "none of the above," let's look at a pair of new alternatives.

Have you ever played around with your glue gun? While not readily available, you can get polyethylene rods to use as glue sticks. That gives you a method for encapsulating compo-

NAMES AND NUMBERS

Anderson Power Products
145 Newton Street
Boston, MA 02135
(617) 787-5880
CIRCLE 301 ON FREE INFORMATION CARD

Black Lightning
RR 1-87 Depot Road
Hartland, VT 05048
(800) BLACK99
CIRCLE 302 ON FREE INFORMATION CARD

Caplug
2150 Elmwood Avenue
Buffalo, NY 14207
(716) 876-9855
CIRCLE 303 ON FREE INFORMATION CARD

CopyMate Products
20F Robert Pitt Drive
Monsey, NY 10952
(800) 457-0074
CIRCLE 304 ON FREE INFORMATION CARD

Cory Laboratories
Box 261, 823 5th Street
Menominee, MI 49858
(906) 863-9336
CIRCLE 305 ON FREE INFORMATION CARD

Crystek
2351/2371 Crystal Drive
Ft Myers, FL 33907
(813) 936-2109
CIRCLE 306 ON FREE INFORMATION CARD

EVCO
PO Box 36339
Birmingham, AL 35236
(205) 822-5381
CIRCLE 307 ON FREE INFORMATION CARD

GEnie
401 North Washington Street
Rockville, MD 20850
(800) 638-9636
CIRCLE 308 ON FREE INFORMATION CARD

Harris Publishing/EITD
2057-2 Aurora Road
Twinsburg, OH 44087
(216) 425-9000
CIRCLE 309 ON FREE INFORMATION CARD

Hewlett-Packard/Manuals
19310 Pruneridge Avenue
Cupertino, CA 94014
(800) 752-0900
CIRCLE 310 ON FREE INFORMATION CARD

Lazer Products
12741 E Caley Avenue #130
Englewood, CO 80155
(303) 792-5277
CIRCLE 311 ON FREE INFORMATION CARD

LSI Logic
1551 McCarthy Blvd
Milpitas, CA 95035
(408) 433-8000
CIRCLE 312 ON FREE INFORMATION CARD

Maxim
120 San Gabriel Drive
Sunnyvale, CA 94086
(408) 737-7600
CIRCLE 313 ON FREE INFORMATION CARD

National Sandblast
4421 Prospect NE
Albuquerque, NM 87110
(505) 883-1151
CIRCLE 314 ON FREE INFORMATION CARD

Printer Works
3431 Arden Road
Hayward, CA 94545
(800) 235-6116
CIRCLE 315 ON FREE INFORMATION CARD

Recharger
3870 La Sierra Avenue S266
Riverside, CA 92505
(714) 359-8570
CIRCLE 316 ON FREE INFORMATION CARD

Rohm
8 Whatney
Irvine, CA 92718
(714) 855-2131
CIRCLE 317 ON FREE INFORMATION CARD

Rotary Flight International
5555 Zuni SE, Ste 281
Albuquerque, NM 87108
(505) 298-9362
CIRCLE 318 ON FREE INFORMATION CARD

Sony Semiconductor
10833 Valley View Street
Cypress, CA 90630
(714) 229-4195
CIRCLE 319 ON FREE INFORMATION CARD

Statek
512 N Main Street
Orange, CA 92668
(714) 639-7810
CIRCLE 320 ON FREE INFORMATION CARD

Stratasys
7411 Washington Avenue S
Minneapolis, MN 55439
(612) 941-5607
CIRCLE 321 ON FREE INFORMATION CARD

Don Thompson
23072 Lake Center Drive #100
El Toro, CA 92630
(714) 855-3838
CIRCLE 322 ON FREE INFORMATION CARD

nents in high-quality plastic or making your own custom connectors. Or of doing plastic casting at a tiny fraction of the usual mold costs.

Let's carry this one step further as shown in the crude system of Fig. 5. Say you wanted to produce some large display letters in various styles and sizes. Just take a modified glue gun on a linear stepper and a no-stick base on a second linear stepper, and you should be able to put a plastic bead down that follows the shape of the letter. Repeat the process until the entire letter is created. The host computer traces out the proper path to build up the letter one bead at a time.

Admittedly, this is a rather crude system which is limited to thin two dimensional objects. And we haven't properly addressed the third dimension at all. But it is a good starting point that could lead to some exciting new developments.

One suitable stepper would be the *Hurst model SLS*. I've been meaning to work up some more details on this and on Hurst's new EPC-015 controller. Maybe in a future column.

There is a commercial variation of the "hot glue gun" desktop prototyping method. This is the brand new *Stratasys 3-D Modeler*. They refer to their process as *Fused Deposition Modeling*, or FDM.

The system starts with a large roll of .020 or .050 diameter plastic or wax filament. The filament is heated just enough to make its outside tacky. The filament is then laid down into an existing pattern in the same way you can do artsy-craftsy stuff with string soaked in glue.

A three dimensional object is then built up, literally one string at a time. While they have an elaborate CAD software system based upon NURBS splines, the *PostScript* language and any old word processor should be able to do a vastly better job far faster and much cheaper.

The FDM method seems especially well-suited for modeling containers and other hollow packaging products. But sharp edges appear tricky to do, especially gear teeth. Ultimate costs should be low, since no lasers, fumes, high temperatures, costly materials, or exotic chemicals are involved. The typical speeds approach 1000 inches per minute.

One big problem with the system: Some prototypes can end up looking like something that missed hitting the reject bin in the arts and crafts class. Finer filaments can cure this, but build more slowly.

I'm wondering if a better prototyping solution might not involve two steps. Homes are usually built in a "rough" and "finish" stage. And machinists often work with *near net* stock to try and minimize their total production time. And modelers will often build their model first and then *superdetail* it later.

So perhaps the solution is some system that gets the shape pretty near the way you want it quickly and crudely. A second step would then measure and modify what you have to give for your final precision fit and finish. Let's have your thoughts on this.

VHF AND MICROWAVE RE-SOURCES

ARRL Handbook
225 Main Street
Newington, CT 06111
CIRCLE 323 ON FREE INFORMATION CARD

Defense Electronics
6300 South Syracuse Way, Ste 650
Englewood, CO 80111
(303) 220-0600
CIRCLE 324 ON FREE INFORMATION CARD

Fair Radio Sales
PO Box 1105
Lima, OH 45802
(419) 227-6573
CIRCLE 325 ON FREE INFORMATION CARD

Hewlett-Packard
PO Box 10301
Palo Alto, CA 94303
(415) 857-1501
CIRCLE 326 ON FREE INFORMATION CARD

M/ACom Semiconductor
43 South Avenue
Burlington, MA 01803
(617) 272-3000
CIRCLE 327 ON FREE INFORMATION CARD

Microwave Journal
685 Canton Street
Norwood, MA 02062
(617) 769-9750
CIRCLE 328 ON FREE INFORMATION CARD

Microwave Product Digest
34 Evergreen Place
Tenafly, NJ 07670
(201) 568-5835
CIRCLE 329 ON FREE INFORMATION CARD

Microwaves & RF
611 Route #46 West
Hasbrouck Heights, NJ 07604
(201) 393-6286
CIRCLE 330 ON FREE INFORMATION CARD

Mini-Circuits Labs
PO Box 350166
Brooklyn, NY 11235
(718) 934-4500
CIRCLE 331 ON FREE INFORMATION CARD

Motorola
5005 E McDowell Road
Phoenix, AZ 85008
(800) 521-6274
CIRCLE 332 ON FREE INFORMATION CARD

Nuts & Volts
Box 1111
Placentia, CA 92670
(714) 632-7721
CIRCLE 333 ON FREE INFORMATION CARD

Plessey Semiconductor
13900 Alton Pkwy, Ste 123
Irvine, CA 92718
(714) 455-2950
CIRCLE 334 ON FREE INFORMATION CARD

Radio Research Instruments
584 North Main Street
Waterbury, CT 06704
(203) 792-6666
CIRCLE 335 ON FREE INFORMATION CARD

Rogers
100 S Roosevelt Avenue
Chandler, AZ 85226
(602) 961-1382
CIRCLE 336 ON FREE INFORMATION CARD

SGS-Thomson Microelectronics
211 Commerce Drive
Montgomeryville, PA 18936
(215) 362-8500
CIRCLE 337 ON FREE INFORMATION CARD

Surplus Trader
Winters Lane Box 276
Alburg, VT 05440
(514) 739-9328
CIRCLE 338 ON FREE INFORMATION CARD

VHF and microwave resources

There are all sorts of interesting things going on in those VHF and microwave frequencies found above several hundred megahertz. Amateur television, weather fax reception, cable services, satellite downlinks, cellular phones, sports radar, remote controls, radio astronomy, emergency services, garage doors, altimeters, instrumentation, microwave ovens, and video links are a few examples of hackable opportunities in the VHF and microwave frequency areas.

Unfortunately, all of the hacking rules change in the VHF and microwave range. First, you no longer have individual resistors, capacitors, and inductors.

Instead, the individual resistance, capacitance, and inductance of each component has to be uniquely taken into account, and often done so in a distributed manner. Circuit strays can quickly become totally intolerable. Tolerances of a few thousandths of an inch can make or break a circuit's performance.

Second, testing and measurement often has to be indirect, because many attempts to directly measure a microwave circuit could severely disrupt what you are trying to measure. Not to mention the high frequencies and weak signal levels involved. Most suitable test equipment also tends to be very specialized, arcane, and quite expensive, and hard to justify.

Third, VHF and microwave parts can be ridiculously costly, since most of them are aimed at gold-plated low-volume military uses.

Fourth, the math, the field theory, and the advanced technical skills needed to do anything useful at these frequencies goes way beyond electronic fundamentals. A lot of useful microwave information tends to require advanced skills, can be hard to find, and is often classified.

And finally, much of microwave design work is far more art than science. To this day, black magic can be involved, and you either have the right feel for what you are doing, or your circuits simply will not work.

For this month's resource sidebar, I have tried to gather together some VHF and microwave stuff you might find of interest. Obviously, you'll want to start with that *Radio Amateur's Handbook* published by the *ARRL*. Many of the ham magazines and club activities will also involve the VHF and microwave frequencies. Per a recent rule change, certain new ham licenses don't require Morse code.

By far the leading surplus house carrying microwave radar goodies is *Radio Research Instruments*. However, these folks tend to concentrate on whole systems and refuse to show prices in their flyers. Alternate places to look include *Fair Radio Sales*, *Surplus Traders*, and in the *Nuts and Volts* shopper.

While utterly ancient, McGraw Hill's *MIT Rad-Lab* series should still be scrounging around on the dusty back shelves of the larger technical libraries. Volume One in particular, Ridenour's *Radar System Engineering* has been reprinted a number of times and remains highly useful to this day. Another more recent classic is Merrill Skolnik's *Introduction to Radar Systems*

As with any field, the free trade journals are your foremost day-to-day resource. While there are several dozen, four I've found useful include *Microwaves and RF*, the *Microwave Journal*, *Microwave Product Digest*, and *Defense Electronics*.

Be sure to check out *Mini-Circuits Labs* for their low-cost broadband amplifier chips, and *Plessey* for their unusual *Satellite Cable and TV Integrated Circuit Handbook*. They also have lots of info on frequency synthesis and high-speed dividers.

Hewlett Packard, of course, makes all kinds of microwave components, as well as high-performance microwave and VHF test instruments. And *Motorola* has a wide variety of high-frequency semiconductors and application notes available.

Two other chip sources include *SGS* and *M/A Com*, while *Rogers* supplies printed-circuit materials and dielectrics useful for microwaves.

Well, that should be enough to get you started. Please let me know what else you think should be added to our resource files.

New tech literature

From *Sony*, there's a new *Memory Data Book*. They also have lots of great stuff on A/D and D/A converters. From *Rohm*, there's an *Electronic Components Catalog* which includes details on their FM stereo broadcasters and lots of other goodies.

From *LSI Logic*, there's a new group of LR64700 video-compression chips that should revolutionize both still- and moving-picture image storage and transmission.

I get lots of calls asking about hacker-friendly sources for custom crystals. Two of my favorite sources are *Statek* for low frequencies and *Crystek* for higher frequencies. Both have catalogs, data sheets, and ap notes available.

A new detailed bibliography on magnetic refrigeration is available through Jerry Hagen at his *Cory Laboratories*. Our unusual hacker magazine for the month is *Homebuilt Rotorcraft* from the *Rotary Flight International* folks, while that free *Maxim Engineering Journal* has all sorts of semiconductor goodies in it. Especially for audio/video switches and power supplies that work off a single AA cell.

Free samples of *Powerpole* connectors are available from *Anderson Power Products Inc*. These are both snap-together modular and sexless. They should be ideal for such things as solar panels.

An interesting sandblasting catalog is available from *National Sandblast*. This is one quick way to spruce up any metal on your prototypes.

Turning to my own products, for the fundamentals of digital integrated circuits, do check into my *TTL Cookbook* and *CMOS Cookbook*. Or to pick up all the goodies at once, try my *Lancaster Classics Library*.

We also now have the *Hardware Hacker III* reprints available, which has the latest and best of all these columns in them. All edited, revised, corrected, and indexed.

Finally, I do have a new and free mailer for you which includes dozens of insider hardware hacking secret resources. Write or call for info. Our usual reminder here that most of the items mentioned appear either in the *Names and Numbers* or in the *Microwave Resources* sidebars.

As always, this is your column and you can get technical help and off-the-wall networking per that *Need Help?* box. The best calling times are weekdays 8–5, *Mountain Standard Time*. Let's hear from you. **R-E**

AUDIO UPDATE

Japan: The Evolution of an Audio Colossus

LARRY KLEIN

It may seem strange to audio newcomers, but in the early days of hi-fi—the 1950's—there were no Japanese components in the U.S. There was, however, a Japanese domestic audio market. I remember reading about the hi-fi coffee houses with sophisticated sound systems that dotted Tokyo. As further evidence, *Audio* magazine ran intermittent ads from a Tokyo company called Fukuin Electric. Their Pioneer brand products included various drivers plus "An Ideal All-Purpose Amplifier for Home High Fidelity Systems" that was actually an AM/FM shortwave receiver. Neither a price nor a U.S. source was mentioned in any of the ads, so one can assume that Fukuin was trying to attract distributors rather than mail-order customers. True, there was a line of Japanese open-reel tape recorders being sold by a California distributor called Superscope; few knew or cared that they were being made by Sony, another unknown Japanese company. And so things went for several years.

The Japanese invasion

The Japanese entry into the audio market started relatively slowly. In 1966, as Technical Editor of *Stereo Review*, I arranged for the first lab test of a Japanese receiver. Made by Kenwood, it appeared to have nothing terribly innovative about its circuitry, but it was a fine performer and very well made by U.S. standards. We judged it to be an excellent value. Within six months of our report, an upgraded model appeared with four times the power and greatly improved FM performance. The kicker was that it sold for exactly the same price ($239.95) as the earlier unit! If I had been an American audio manufacturer at the time, I would have become very nervous!

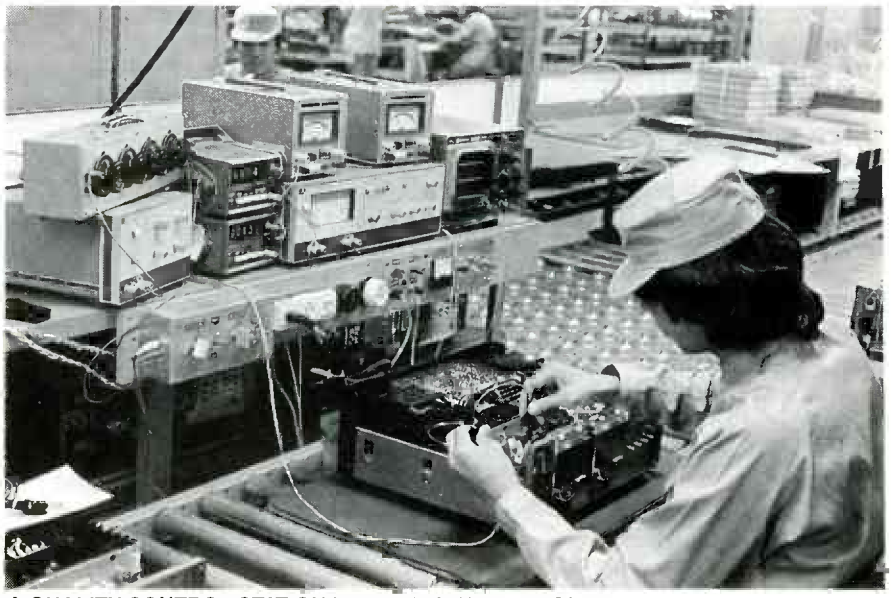
There was another aspect of the Kenwood review worth mentioning. Bear in mind that this all took place long before the FTC became involved in amplifier specifications, and most audio manufacturers were, let us say, somewhat "optimistic" when reporting their specs. When Mr. Kasuga of Kenwood called to ask how the report was coming, I told him that it was fine and the unit easily met all its specs except for a slight rise in distortion below 50 Hz.

To my surprise, Kasuga became upset and stated that his receiver was free of such problems. I asked our lab to retest the unit; the results were the same. After a great deal of back-and-forthing it turned out that one of our lab meters had developed a fault that caused the spurious large distortion reading. I hadn't originally given the out-of-spec distortion a second thought because virtually all previously tested U.S.-made receivers showed far higher distortion at the same frequencies.

Quality control

A quality-control engineer once said to me that quality is not something you inspect into a product after it's built—it should be designed in right from the outset. I later learned that this was one of the prime precepts of W. Edwards Deming, who is generally regarded as the father of quality-control methodology. Comparatively unknown in the U.S., in the early 1950's Deming started teaching Japanese managers and engineers how to manufacture quality components. Deming was subsequently awarded a medal and a citation by Emperor Hirohito that credited him for the rebirth and worldwide success of Japan's industry.

The quality concept was one that the Japanese obviously took to heart early on in all aspects of their audio (and camera) manufacturing careers. For example, during my first visit to Japan in the early 1970's, I bought, among other items, a prerecorded cassette from a street display outside a Ginza department store. The cassette was chosen simply because I was amused by its jacket showing what appeared to be a Japanese country-and-western rock group. When I went to play the cassette at home I immediately noticed two things: (1) It was not Dolby encoded,



A QUALITY-CONTROL STATION in Yamaha's Hamatsu Plant.

and (2) it was quieter than most of my prerecorded cassettes that included Dolby noise reduction.

My subsequent experiences with Japanese LP's and prerecorded open-reel tapes were similar. The Japanese tapes were quieter, the records were flatter and had better surfaces, and both had lower distortion and a wider frequency range than the usual U.S. products. And when I first visited Japan, I was so impressed by the clarity, detail, and color of their TV transmissions that I assumed that they were using some system other than the U.S.-standard NTSC. However when some U.S.-made programs were broadcast, it became apparent that the superiority of the Japanese picture was due solely to the care exercised in its production. So, too, with the records and tapes. It was evident that Japanese engineers and production people gave a damn about their products, an attitude that apparently was and is somewhat rare in the U.S. In short, Deming's quality-control methodology provided the tools, the Japanese workers and management provided the attitude—and the rest is history.

Japanese marketing

When Japanese audio products began to appear in the U.S., they were mostly brought in by U.S. distributors, such as Superscope mentioned before. Some American marketeers did a creditable job; others didn't seem to realize exactly what they had. For example, I remember a company called Nivico whose product line included several models of German fake fireplaces complete with a bar, glasses, and a "hi-fi" system. This less-than-high-tech company also distributed JVC's top-of-the-line audio equipment. I remember seeing a JVC preamplifier with pink-noise source and multiband equalizer on sale in Macy's radio department. I have no idea how many were sold—and whether the buyers were told that they would also need a power amplifier, speakers, and a tuner in order to hear music.

In any case, most Japanese manufacturers ultimately bought themselves back from their distributors, some came over on their own, and a few bought U.S. hi-fi companies such as Fisher—via Emerson Radio—and proceeded to design and manufacturer the products in Japan. Some brands, Sansui for one, in effect came to the U.S. via Vietnam, where they were best sellers in the military PX's. At some point in time, the Japanese began to emulate U.S. auto makers by bringing out new models every year. Their self-imposed rules demanded that each new model include some spec improvement—however minor—and/or a new circuit with wondrous properties. For example, during a visit to the Osaka Technics factory, the engineers showed me a chart on which they had listed their upcoming "breakthrough" improvements for each of the next 5 years!

Audio today

One aspect of the Far-Eastern audio scene that I've not mentioned is their extensive private-labeling enterprises. A friend who owns a U.S. company and manufacturing plant based in Washington state produces a wide range of audio equipment, some of which is built in the Far East. I asked him what determines which is made here and which is made there. His answer was simple: When he expected to sell large numbers of a product—such as his medium-priced receiver—"economies of scale" made it far cheaper to have it manufactured overseas. On the other hand, limited-production components such as his very high-powered amplifiers can profitably be made in his U.S. plant.

That explains why the limited production, "esoteric" audio products are mostly built in the U.S. or Great Britain, while high-volume products are made in the Far East. Of course, there are still a few American manufacturers who put out quality components at both affordable and somewhat high-end prices. So if you are the type of person who insists on buying American, you still can. However, it cannot be denied that the bulk of the electronics industry now belongs to the Far East. I guess all of this has worked out pretty well for the U.S. audio consumer, in that you can get more bang for your audio buck than ever before. But for the American manufacturers, or ex-manufacturers, of audio components (and television sets, cars, and dozens of other categories), the Japanese manufacturing juggernaut has been an economic disaster. **R-E**

PCN

continued from page 64

2-a–c show how a modulated spread-spectrum signal used in direct sequencing is generated. When a carrier signal (a) is mixed with a noise signal (b), a broadening of the RF carrier occurs, resulting in a modulated spread spectrum (c). Modulation is accomplished using the exclusive OR logic operation. The effect of modulation is to reverse blocks of the wideband noise bits. Because the noise signal is much higher in frequency than the information signal, the resulting bit sequence still appears to be random. The modulated signal is actually the sum of the noise and signal bandwidths.

You're probably wondering how the original information can be decoded at the receiving end. The information signal can be recovered by modulating (exclusive OR) a second time with the same noise waveform. Instead of modulating the information signal with random noise, a PN generator is used, which possesses many properties of wideband noise, but is exactly reproducible at remote locations. In order to remove unintentional noise in the receiver, multiple matched filters are normally used. A block diagram of a typical direct sequence is shown in Fig. 3.

Even though signal spreading appears to be an inefficient use of spectrum for a single user, the theory suggests that many such transmitters can operate at the same time, on the same wide band, and in the same area, since each transmitter's intended receiver will see only its code and ignore all others. In essence, this is code-division multiple access (CDMA).

A spread-spectrum signal looks like low-level noise to a traditional narrowband receiver, and can be designed so that it doesn't interfere with the traditional receiver. In turn, a spread-spectrum receiver can be designed to ignore the interference of even multiple transmitters operating within its broad bandwidth. That resistance to interference can apply to intentional interferers, such as other users of the spectrum, as well as spurious RF emissions created by many common household and office appliances.

The technique can be viewed as similar to a concert hall with a hundred pianos, each playing a different tune, and each member of the audience listening for one particular tune. As long as the listener can isolate that melody, it doesn't matter how many pianos there are (until the listener is deafened).

Transmit power would generally be at 1 milliwatt, but by using a technique called adaptive power control (APC), each base could monitor and adjust power levels of handsets to the minimum necessary to achieve communication without interference. A reduction in emitted power through APC will permit a far larger number of simultaneous users, so that at one milliwatt, one hundred simultaneous calls can be handled in a microcell within a 600-foot radius.

TDMA

Another technique being considered is time-division multiple access (TDMA). TDMA works by dividing each second into 100 ten-millisecond slots (as an example), and dividing each time slot into a number of frames, typically 24. Half of those frames are then allocated for transmission from base stations to mobile units; and the other half are devoted to transmission in the return direction. Therefore, 12 handsets could broadcast at the same time and place using the same frequency. That technique is used by PCN's in the United Kingdom, and is a technique that has been adopted for the cellular telephone systems in the United States when they become digital over the next few years. The disadvantage of the technique is that it requires extremely precise timing and sophisticated electronics.

The FCC is now considering what action to take. Last June it launched an inquiry into whether PCN's are needed, what they will accomplish, what spectrum should be allotted, if any, and how the new phenomenon should be regulated. Comments poured in from 110 companies,

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DRAWING BOARD

Let's build a simple, inexpensive logic probe for the home workbench.

ROBERT GROSSBLATT

Even though the main reason for spending time at the bench is to wind up with a working circuit, there are other good reasons for spending hours and hours hunched over a breadboard. Nothing ever works out the way you want it to, and that's especially true at the test bench. Dealing with unexpected (or perhaps expected) design glitches is what makes bench time a great way to stretch your brain.

Working your way through a project is a good learning experience, but only if you have the right equipment. For instance, a logic analyzer can instantly give you a window into the nitty gritty of a complex design. But there aren't many of us that can justify parting with the kind of cash that's necessary to get your hands on a logic analyzer—or any other kind of exotic test equipment for that matter. That's especially true when the project has nothing to do with generating income.

While there's no argument that high-tech designs can really be debugged only with high-tech equipment, you can do a lot of work with much simpler and less expensive test gear if you're willing to do a bit more work with your brain. High-speed circuitry can be slowed down, gated latches can be added to catch pulses, and other similar tricks can be pulled to snoop around a circuit.

An extremely useful, but relatively inexpensive addition to any test bench is a logic probe. Now there are all sorts of different logic probes, and just how useful it can be depends on how many bells and whistles it has. A simple two-LED probe is about the bottom line, and the sort of information it can give you is just basic, bottom-line information.

When designing a logic probe, you have to provide a way for the probe to operate with different logic families. That can complicate things slightly because each family—TTL, CMOS, etc.—has its own idea of what voltages constitute a high or low. Not only that, but some of them, such as TTL, also have about a one-volt dead band in which the whole idea of logic levels gets a bit murky.

When you get right down to it, a logic probe is simply a circuit with the ability to detect and react to particular voltage levels. Anytime you're designing something like this and you plan on building it out of parts that are cheap and easily available (as we are), your mind should immediately turn to voltage comparators.

A voltage comparator is really nothing more than an op-amp with a built-in hysteresis that makes it react sharply to voltages that cross a particular threshold. You can build one out of any standard op-amp, but its a lot easier to use a part like an LM339.

The pinouts for the chip are shown in Fig. 1, and you should be struck by how much they look like op-amps. Just about the only pins that are missing are the ones for frequency compensation and offset adjustments. Those aren't needed in a comparator since the chip is designed to operate more like a switch than an op-amp. The gain is extremely high, the chip can be driven by a single-ended supply, and the output can typically sink as much as 16 mA.

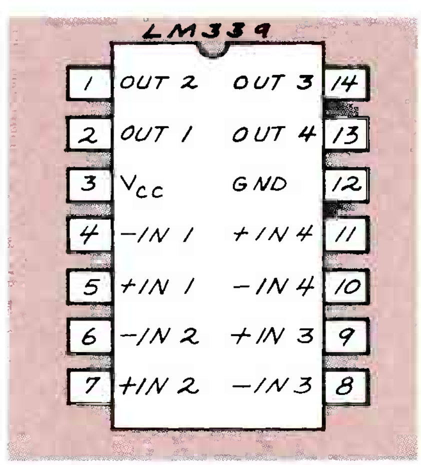

FIG. 1—THE LM339 VOLTAGE-comparator IC contains four comparators on the same substrate. We need only two comparators for a logic probe, so we'll have an extra pair.

The simplest circuit for a logic probe is shown in Fig. 2. As you can see, we've tied together two of the pins; one on each of the comparators. Those are the pins that are going to receive the input voltage from the probe. Since we want the output of both the high and low detectors to go high when they're turned on, we have to make the low detector inverting and set the high detector to be non-inverting. That's why we've connected the non-inverting input of IC1-a, the high detector, to the inverting input of IC1-b, the low detector.

Now that we've decided where we want to put the input signal, the next step in the design is to work out the reference voltages that are going to be applied to the other input pins of the comparators. The easiest way to do that is by building a resistor voltage divider—and that brings us to our first real problem.

If we were going to use the logic probe only with CMOS, the design of the divider would be relatively simple. Since CMOS changes state halfway up the power rail, we could use two equal-value resistors for the divider. But that would seriously affect the versatility of the design so I'm only mentioning it as an aside. We have to do more than that because we also want it to be able to work with the standard TTL levels of below 0.8 volts for a low and above 2 volts for a high.

The way to do that is to use three resistors in the divider chain, as shown in Fig. 2. By separating the high and low reference inputs of the comparators with a resistor, we can have our design account for the TTL deadband voltage range between 0.8 and 2 volts. In Fig. 2, the output of IC1-a will go high if the applied voltage at pin 6 is more than the reference voltage at pin 7, and the output of IC1-b will go high if the applied voltage at pin 5 is lower than the reference voltage at pin 4.

Now that we've got the basic configuration worked out, the next step is to calculate the values for the resistors. As we go through this, we'll be aiming for the 0.8- and 2-volt thresholds but, since we're going to be using standard-value resistors (things have to be cheap and available, remember?), we'll probably miss the exact numbers by a little bit.

Since we want the reference voltage for IC1-a to be 2 volts (assuming a system voltage of 5 volts), we're aiming for a 3-volt drop across R1—a final ratio of 3/5. That means the value for R1 has to be 60% of the total value of R1 + R2 + R3. Things are a more complex when we calculate the individual values for R2 and R3 since those two resistors don't see the 5-volt system voltage. The voltage division has to be based on the voltage appearing at pin 7 of IC1-a.

Let's be a bit more rigorous about working this out. The voltage drop across the entire resistive chain is about equal to the system voltage. I'm saying "about" because there is a slight drop due to presence of the comparator, but the impedance of the inputs is so high that we can forget about it for all practical purposes. Since the three resistors are in series, the sum of the voltage drops is equal to the system voltage.

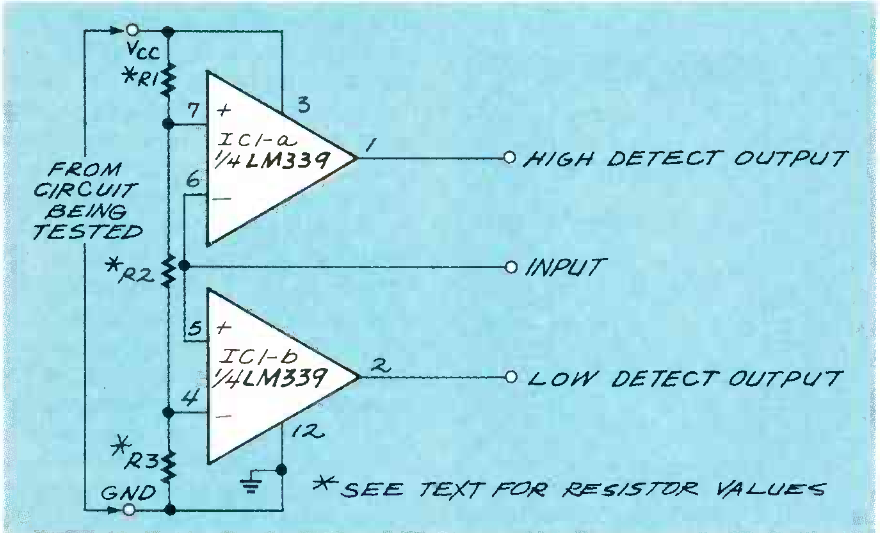

FIG. 2—IN THIS LOGIC-PROBE CIRCUIT we've tied together one pin from each comparator. Those pins will receive the input voltage from the probe. The low detector is inverting and the high detector is non-inverting.

Since we know that the voltage drop across R1 has to be 3V, the combined voltage drop across the other two resistors will be 2V. We also know that we want the drop across R3 to be 0.8V since that's the value of the reference voltage we're aiming toward. Some simple arithmetic tells us that the R2 drop has to be 1.2V.

Once we've taken the analysis this far, we've also calculated the relative values of the resistors. Since the resistors are in series, the same current is flowing through all of them and that means the resistor values are going to be directly proportional to the voltage drops. R1 is going to be ⅗ of the total, R2 is going to be 1.2/5 of the total, and R3 is going to be 0.8/5 of the total. Putting things in simpler terms, if R_T is the total value of the three resistors, R1 has to be $0.60R_T$, R2 has to be $0.24R_T$, and R3 has to be $0.16R_T$.

Knowing the resistor ratios is only part of the answer since it's still short of knowing the actual values. In theory, any combination of resistors in the correct ratio will work for us but there are some other things we have to take into consideration to come up with the final resistor values.

When we get together next time, we'll take care of that, add a few surprises to the circuit, and get to talking about some other test gear you can build yourself. **R-E**

Video standards

JEFF HOLTZMAN

My first video terminal consisted of a 4800-baud MicroTerm terminal, with ASCII keyboard, driving a 5" Sony black-and-white portable TV, through a custom video interface suggested in a book by a guy named Don Lancaster. Resolution was 16 lines by 64 characters; needless to say, bit-mapped graphics were not even a dream.

Today, about 12 years later, I have a 19" NEC MultiSync XL with a non-interlaced graphics resolution of 768 lines × 1024 rows, in an essentially infinite variety of colors.

What happened in the interim? And what's coming up next?

Memory vs. I/O mapped

Back in the early days of personal computers, user interaction was considered peripheral to the main function, computation. (By contrast, today some heretics believe that computation is peripheral to user interaction.) In line with that type of thinking, user input and output was handled a byte at a time, usually through an RS-232 interface that communicated with the CPU via a single I/O port.

Of course, there were early exceptions from Apple and Commodore. Those companies built memory-mapped displays for the Apple II, the C64, and their successors. However, resolution was so low that sustained professional use produced eye strain. So most business machines centered around Z80's and serial ASCII terminals running under the CP/M operating system.

In August of 1981, IBM introduced its version of the personal computer. The IBM PC was based on a relatively new microprocessor, the 8088, that had 16 times the memory space of the Z80 machines prevalent at the time.

In that seemingly boundless address space, IBM chose to implement a memory-mapped video system, including both a character-based black-and-white system with resolution sufficient for sustained use in word processors, spreadsheets, and database managers, as well as a bit-mapped color system for entertainment. The two systems were assigned different memory addresses and I/O ports for control, so they could coexist in the same machine simultaneously, a feature useful for programmers who use one screen for program output and the other for debugging. Some CAD systems also put drawings on one screen and menus on another.

In one of the greatest ironies of this industry, and one that we continue to pay for every day, even though the PC was designed with memory-mapped video hardware, IBM's BIOS implemented an interface that mimicked the old ASCII terminal approach. Performance was truly lousy; early PC word processors ran more slowly on a PC than via a 19,200-baud terminal.

Programmers eventually devised more efficient interfaces to the video hardware, but created the problems of portability and compatibility that haunt us to this day, and that will continue to haunt us until the PC architecture has been laid to rest. But that's another story.

Color and pixels

The first bit-mapped graphics system for the PC was called the Color/Graphics array, or CGA for short. In addition to several fuzzy text modes, CGA has two graphics modes: a "high-res" 640 × 200 in black and white, and a "low-res" 320 × 200 in four colors. (Table 1 summarizes important video modes and resolutions.) The primary market for CGA adapters was game and educational software.

Business users working in 1-2-3 could display graphs on a CGA monitor, but not on the text-only monochrome display adapter (MDA). IBM missed a marketing opportunity and in stepped Hercules, whose monochrome graphics adapter quickly became a pseudo-standard whose reign lasted until very recently, when VGA became king of the hill.

The Hercules card brilliantly solved several problems, including support of decent text-mode resolution, a separate graphics mode with resolution exceeding that of the CGA, and the ability to work with standard monochrome monitors, which cost about 20–25% of CGA monitors at the time.

But IBM did not sit still. In 1984, the company introduced the Enhanced Graphics Adapter (EGA), which maintained backward compatibility with the CGA, and added new text and graphics modes. The text mode ran in 16 colors, and had resolution sufficient for day-in and day-out usage. The new graphics modes allowed more colors (16) as well as more resolution (350 lines; columns remained constant at 640 pixels). Although still relatively expensive, the EGA proved that bit-mapped color displays could be useful for things other than arcade games.

(For purposes of this discussion, I'm ignoring several IBM offerings that never took off, including the Professional Graphics Controller (PGC).)

Then, in the spring of 1987, IBM introduced the PS/2 series, which included a new bus (the Micro Channel), a new version of DOS (3.3), 1.44MB floppy disks, and the next video standard, the Video Graphics Array (VGA). DOS 3.3 quickly became standard. It took a little longer, but eventually the new disk format became widespread. The jury is still out on the ultimate acceptance of the Micro Channel architecture. However, in recent years VGA has taken off faster than a stream of electrons inside a CRT. VGA maintains compatibility with CGA and EGA, and adds several more higher-resolution text and graphics modes. In addition, from the beginning VGA included

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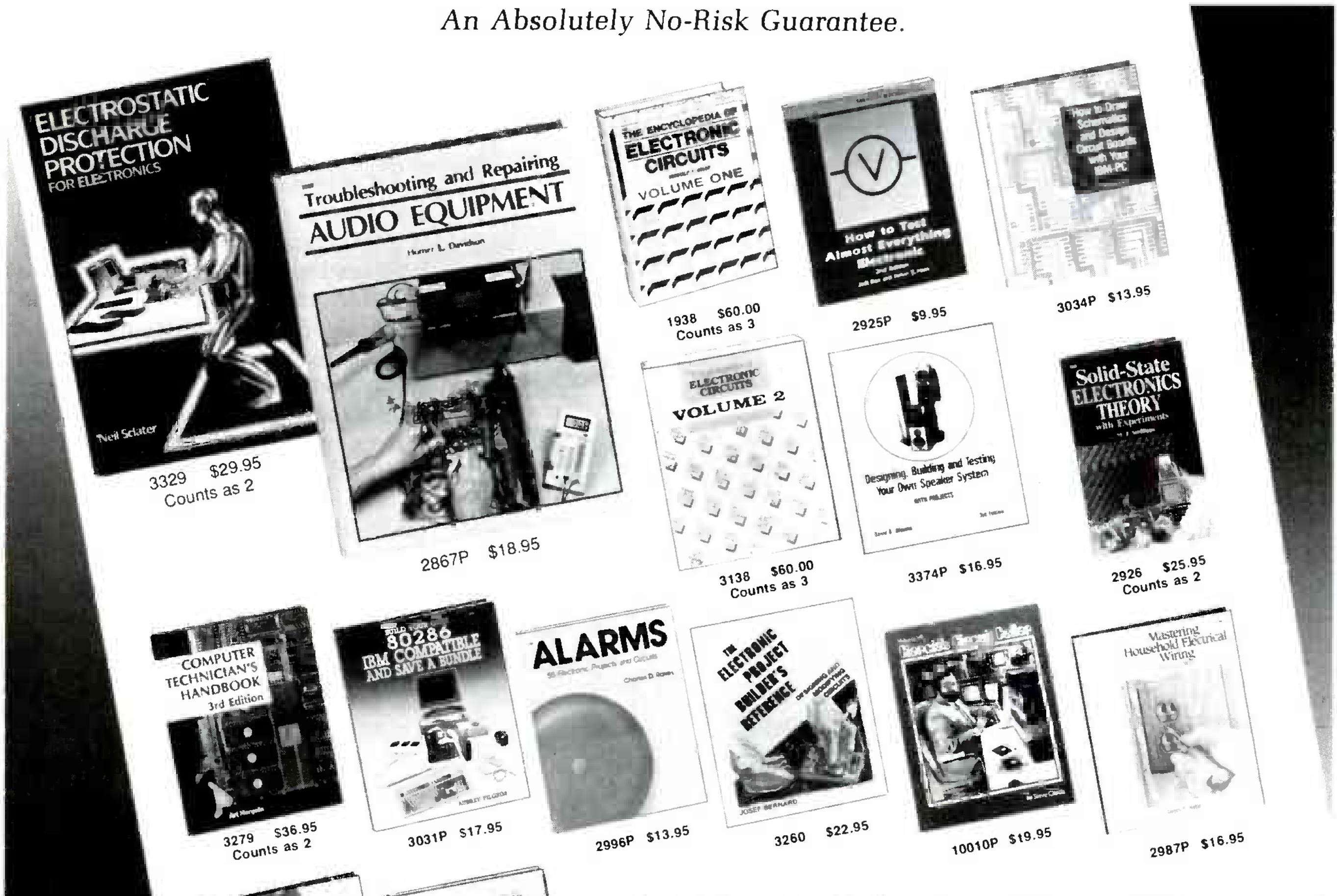

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TABLE 1—PC VIDEO MODES

Mode No.*	Mode Type**	Adapter***	Horiz. Res.	Vert. Res.	Max. Colors
0	T/G	CEVS	40	25	16
1	T/G	CEVS	40	25	16
2	T/G	CEVS	80	25	16
3	T/G	CEVS	80	25	16
4	G	CEVS	320	200	4
5	G	CEVS	320	200	4
6	G	CEVS	640	200	2
7	T	CEVSHM	80	25	2
D	G	EVS	320	200	16
E	G	EVS	640	200	16
F	G	EVS	640	350	2
10	G	E/VS	640	350	4/16
11	G	VS	640	480	2
12	G	VS	640	480	16
13	G	VS	320	200	256
6A	G	S	800	600	16
100	G	S	640	400	256
101	G	S	640	480	256
102	G	S	800	600	16
103	G	S	800	600	256
104	G	S	1024	768	16
105	G	S	1024	768	256
106	G	S	1280	1024	16
107	G	S	1280	1024	256

* In hexadecimal
** T = Text only, G = Graphics only, T/G = Bit-mapped text
*** C = CGA, E = EGA, V = VGA, S = Super VGA, M = MDA, H = Hercules

built-in gray-scaling capabilities, so you can plug either a monochrome or a color monitor into a given adapter, and your software will run unchanged.

Beyond VGA

VGA is nice, but it's not the end of the story. As soon as IBM introduces a product to the PC market, other vendors quickly seek to improve it, and VGA was no exception. Third-party vendors quickly pushed resolution up to 800 × 600, 1024 × 768, and other intermediate resolutions. At first, each vendor implemented its hardware and software in different ways. Soon, however, the industry realized it was headed for chaos, so the Video Electronics Standards Association (VESA) formed to define standards for beyond-VGA modes. VESA membership includes virtually all manufacturers of monitors and video adapters—except IBM, Hercules, Compaq, and a few others.

What VESA has done is standardize horizontal and vertical sweep frequencies, and assign BIOS mode numbers for standard resolutions, as shown in the bottom half of Table 1. These standards should make it easier to write software drivers and assure customers of compatibility.

Beyond Super VGA

Super VGA is *really* nice—but it's not the end of the story either. The reason is that the VGA architecture is dumb, dumb, dumb. It requires the host CPU to do all of its bit twiddling. To draw a line, the host CPU must write directly to memory, often a single memory location for each affected pixel. At low resolution, performance may not be affected much by letting the host CPU do everything. But as resolution increases, the host CPU must spend an increasing proportion of its time tending to the screen, which slows down the rest of the system.

Wouldn't it be nice if the host CPU could delegate some responsibility and free itself up for other types of tasks? Well, it can. The trick is to put some intelligence on the video adapter card itself. Then the host CPU can tell it, "Draw a line from (X1,Y1) to (X2,Y2), and let me know when you're done," and meanwhile go on and do something else like tend to a background print spooler, recalculate a spreadsheet, reformat or spell-check a document, or accept characters from a modem.

IBM's first entry in the world of intelligent graphics adapters was the 8514/A, introduced shortly after the VGA in 1987. Unfortunately (for IBM), the company shrouded the 8514/A in a veil of secrecy by not publishing hardware-level specs, as the company had for all previous adapters. So third-party vendors had to reverse-engineer on-board IC's, which slowed development of clones and software support, hence acceptance in the market. In addition, the 8514/A is really a half-breed that provides only partially intelligent control over the video buffer. Further, IBM's 8514/A produces an interlaced display that many people (including me) find visually straining. The main justification for interlaced monitors is that they are slower, hence cheaper, than non-interlaced monitors. Although the 8514/A provides comparable resolution and better performance than the better Super VGA boards, it seems unlikely that it will ever attain the importance of VGA.

Beyond beyond-Super-VGA

While IBM floundered, Texas Instruments released the 34010 graphics coprocessor and a robust, general-purpose software interface to it. The 34010 is a full-fledged microprocessor with a powerful instruction set containing many graphics-specific commands. At first, support for the 34010 was sparse, but with the increasing popularity of graphical user interfaces, support is increasing, competition is heating up, and board prices are falling. (See the sidebar for a discussion of Hercules' new 34010 board.)

Of course, IBM doesn't give up without a fight. In the fall of 1990, Big Blue introduced its next-generation video controller, the Extended Graphics Array (XGA). XGA differs from 8514/A in several significant respects. First, it's 100% VGA-compatible. Second, it's more intelligent than the 8514/A, so it should be faster. Third, it runs only on Micro Channel PS/2's, which limits its potential market. Fourth, it requires a 386 or 486 to run, which also limits its potential market. Fifth, like the 8514/A, the XGA produces an interlaced display, so it's subject to flicker.

At present it's hard to see, given the falling prices of 34010 boards, how the XGA is going to have any significant impact on the market. (For a technical overview of the XGA, see Jake Richter's article in the February issue of *Byte*.)

Color and resolution

In this discussion so far, I've mostly ignored the issue of color. CGA allowed a maximum of four in its low-res mode; EGA increased the maximum to 16; and VGA increased the maximum to 256, but with that many colors the resolution dropped back to the low-res CGA level. (Even so, 256-color images at that resolution are much more realistic than 16-color images at much higher resolutions.) In the meantime, the Super VGA boards developed support for 256 colors at all resolutions up to 1024 × 768.

256 colors are nice—but it really takes about 16 million (2^{24}) colors for true photo-realistic imaging. Special workstations have had that type of imaging for awhile, as have high-end Macintoshes. But now these "true-color" boards are drifting over to the PC environment. However, they're very expensive ($4000 and up).

HERCULES' GRAPHICS STATION CARD

You can sum up the 34010-based Hercules Graphics Station card in three words: speed, speed, speed. I tested it in a 33-MHz 386 under Windows 3.0, and it roughly doubled screen redraw speed. For example, Word for Windows ran about as fast as a text-mode word processor under DOS. The card provides full hardware-level VGA emulation, a 512 × 480 true-color mode, and a 1024 × 768 256-color mode. Sample true-color images included with the board are breathtaking. The board is well-built, and comes with drivers for Windows 3.0, AutoCAD 11, and others.

Installation and documentation are a bit rough, and I encountered the rudest technical-support person I've run across in years while ironing out a driver upgrade problem. But after overcoming those hurdles, I really enjoyed using the Hercules Graphics Station Card. It really puts some zing into Windows, and the company expects to improve performance as Windows learns how to take advantage of intelligent graphics subsystems.

The card lists for about $1000, but is available through mail-order channels for about $700. Highly recommended for heavy Windows and AutoCAD users. Hercules Computer Technology, Inc., 921 Parker Street, Berkeley, CA 94710. (415) 540-6000.

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What's ahead

HDTV continues to loom just beyond the horizon. In terms of the way I spend my time, I don't much care about it for entertainment, but I do care about it in the way it could affect computer-monitor pricing if the technologies converged. The least-expensive 19" 1024 × 768 monitors now go for about $1500, but if the same technology were used in HDTV displays, that price could easily drop by two thirds. Of course, a strong U.S. presence in HDTV would do much for our economy, the trade deficit, semiconductor manufacturing,... you name it. Let's hear it for a strong U.S. presence in HDTV!

What to buy

There is no reason not to buy VGA. During the past year the price of a plain VGA adapter card has dropped to about $100, and monochrome VGA monitors are available for under $150. Color VGA monitors now go for about $350, Super VGA monitors for about $500, and Super VGA board/monitor combinations can also be had for about $500. Bought as part of a system, color VGA typically adds about $300 to the overall cost. Don't buy anything less than monochrome VGA, and if you run Windows, aim for 800 × 600 Super VGA as a minimum. **R-E**

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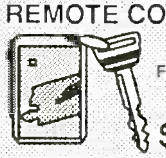

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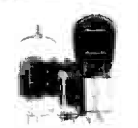

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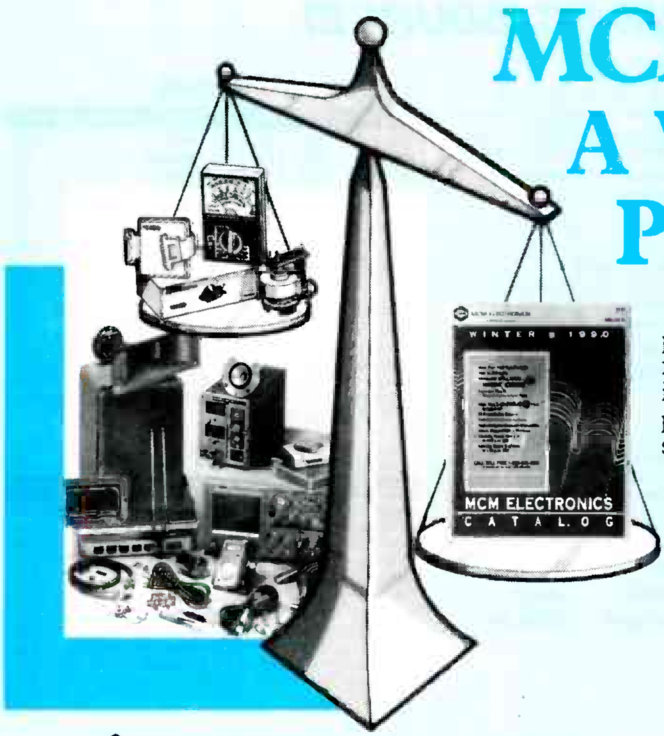

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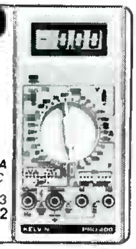

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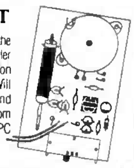

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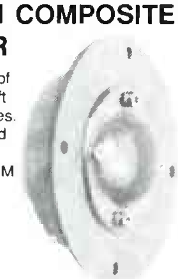

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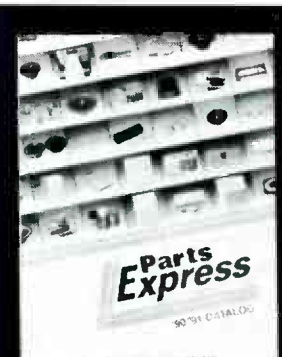

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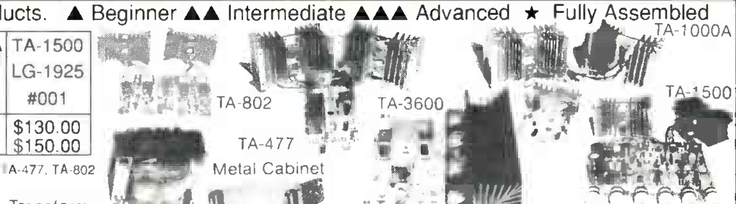

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SM-49	3½ Multi-Functional LCD D.M.P (w/Hold Function) ▲▲	36.00	44 50
SM-100	150MC Digital Frequency Counter ▲▲▲	79.00	90.00
FC-1000A	1 GHz Frequency Counter ★		179.00

MISCELLANEOUS

MODEL	DESCRIPTION	KIT	ASSEMB.
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TY-35	FM Wireless Microphone ▲	11.25	
TY-36	AC/DC Quartz Digital Clock ▲	19 00	26.20
TY-38	Sound / Touch Control Switch ▲	12.00	
TY-41MK V	Infrared Remote Control Unit (w/Case) ▲▲▲	22 00	35.00
TY-42	Bar / Dot Level Meter ▲▲	24.15	33.81
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10.000u/f	80 V Capacitor (Suggested for TA-3600, TA-477, TA-1000A & TA-802)		23.00

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MODEL	DESCRIPTION	KIT	ASSEMB.
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TR-355B	0-30V 3A Regulated DC Power Supply (no case & x'former) ▲	15.65	21.76
TR-503	0-50V 3A Regulated DC Power Supply (no case & x'former) ▲ ▲	16.75	23.65

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MODEL	H"	x W"	x D"	MATCHING	PRICE
LG-1273	3"	12"	7"	TA-2800, TA-377A, TA-2200	$ 22.85
LG-1684	4"	16"	8"	TA-323A, TA-377A, TA-2200	27.50
LG-1924	4"	19"	11½	TA-802, TA-1500, TA120MK 2, TA-800 MK2, TA-1000A	32.80
LG-1925	5"	19"	11½	TA-477, TA-800, MK2, TA-1500, TA-1000A, TA-3600	35.80
LG-1983	2¾"	19"	8"	TA-377A., TA-2800, TA-2200, TA-120MK 2	29.25

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MODEL	DESCRIPTION	MATCHING	PRICE
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004	24V x 2 6A	TA-120 MK 2	22.00
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PCN

continued from page 74

for the most part favoring the set-aside of spectrum for PCN's (providing it comes from someone else's allocation). It will take at least three to four years (and that's optimistic) until the dust settles and permanent allocations to PCN's are made. If the tests show that spread spectrum is indeed a feasible way of introducing PCN's without treading on the toes of the current spectrum users, the FCC's problem will be largely solved. Otherwise, it will have to clear spread spectrum by ordering occupants to move to a higher band. After that, the FCC then has to consider the rather large—and perhaps overwhelming— problem of how to license PCN's.

One possibility of licensing PCN's is the cellular paradigm. The FCC divided the country up into over 700 markets, urban and rural, and allotted two licensees to each, one for the telephone company in the area, and one awarded by lottery. While the process led to a lot of people getting extremely rich, especially those involved in preparing applications for licenses, results were less than satisfactory, since two cellular companies have not provided adequate competition (cellular usage prices have not fallen since services were inaugurated in the mid-80's). Another possibility is to have two to four national licensees or, alternatively, licenses could be granted on a regional basis with two or three licensees in each region. If the FCC chooses that approach, there will be a feverish scramble for whatever licenses are offered and there will certainly be several sore losers.

The upshot of all this is that many of America's largest companies will be scurrying frantically in the next few years to ensure that when the dawn arrives, they will have secured their share. The ultimate beneficiary will be the communications user, who will have a new-found freedom to go anywhere without sacrificing the ability to keep in touch with anybody at any time. **R-E**

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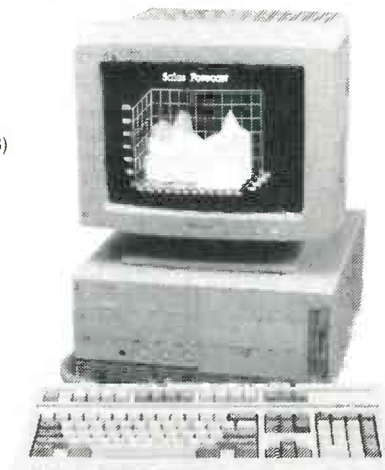

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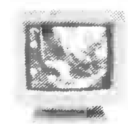

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7411	.35	.25	7490	.49	.39
7414	.35	.25	7493	.45	.35
7417	.35	.25	74116	1.19	1.09
7420	.29	.19	74121	.39	.29
7427	.29	.19	74123	.49	.39
7430	.29	.19	74125	.49	.39
7432	.39	.29	74151	.39	.29
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