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Vol. 62 No. 11

BUILD THIS

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TECHNOLOGY

DEPARTMENTS

AND MORE

ON THE COVER

Digital storage oscilloscopes sold in today's market come in such a wide range of features and price tags that it's hard to determine what best suits your needs, while still fitting your budget. We'll help you make that decision by taking the guesswork out of deciphering such important terms as digital bandwidth, sampling rate, A/D conversion techniques, resolution, and accuracy of these unique instruments. You can use our information to find out what type of DSO is best for your testing needs. You'll also find a rundown of 20–500 MHz DSO's currently available in the market place in a comprehensive chart on page 38. Turn to page 31 and dare to venture into the world of DSO's!

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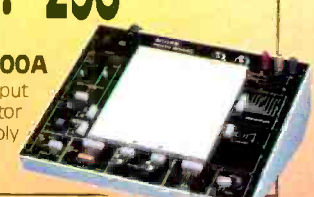

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WHAT'S NEWS

A review of the latest happenings in electronics.

A step toward practical superconducting electronics

A process for making high-temperature superconducting devices, developed by researchers at Bellcore (Livingston, NJ), could help pave the way for ultra-fast telecommunications switches and powerful computer circuits. The technique demonstrates the possibility of layering extremely thin films of superconducting and non-superconducting materials by aligning atoms in a precise and predictable way, which vastly improves the critical electrical connections between the layers. According to Bellcore scientists, the key to the breakthrough lies in their success in making the molecular compounds within each layer stand up vertically and line up end-to-end. Making the planes perpendicular to the surface of the chip allows for the best flow of electrical "supercurrents" through the various layers.

In most conventional superconducting devices, the planes lay flat and are stacked horizontally. The resulting Josephson junctions—the heart of superconducting electronics—suffer from two shortcomings: The junctions between the layers appear to occur randomly, and there is little control over the location of those junctions on a chip. That makes them virtually impossible to use in circuits requiring precisely controlled electrical properties.

THIS EXPERIMENTAL PROTOTYPE of a high-temperature superconducting device, developed by researchers at Bellcore using an experimental process called pulsed excimer laser deposition, could be used to create new generations of powerful computerized switches.

Bellcore's technique has shown the possibility of making Josephson junctions more controllable, with possible applications in IC's as high-speed electronic devices. The next step will be to improve the prototype device's properties, while uncovering the basic physics that govern the behavior of junctions made from the new superconductors.

Measuring thin-film surface area

A highly accurate method to directly measure the surface area of minute samples of porous, thin films has been patented by Sandia National Laboratories (Albuquerque, NM). The technique, an improvement on a decades-old method, has important implications for the microelectronics, optics, gas-separation, and solar-cell industries. The use of a solid-state sensor called a surface acoustic wave (SAW) device, provides measurements 10,000 times more sensitive than existing commercial instruments and can measure samples as small as 0.2 cm^2.

The classic surface-area measurement technique in use since the 1930's, known as the BET method (for its developers, Brunauer, Emmett, and Teller), is based on the premise that a porous material will absorb nitrogen gas in measurable quantities proportional to its surface area. The original method involved placing the material in a flask, weighing it, exposing it to nitrogen at its boiling point, and them measuring the flask again. The surface area of the sample could them be calculated using the weight difference and the surface area for one molecule of nitrogen. The BET technique is still used today for powders with large surface areas, but today's BET-measurement equipment cannot discern the small weight changes that result from materials with low total surface ares, such as most thin films.

SAW devices use transducers lithographically patterned on a piezoelectric substrate to launch and detect acoustic waves that interact with solids, liquids, and gases on the SAW devices surface, providing information about the material's characteristics. When exposed to nitrogen gas, a thin film on the surface of the SAW device absorbs nitrogen and increases in mass, slowing down the acoustic wave as it travels along the surface. The slowing causes the oscillation frequency to decrease, and that change is recorded by a frequency counter. The film is exposed to various concentrations of nitrogen gas to obtain the data required to carry out the BET analysis. The SAW device can measure a mass change as small as 20 picogram (a picogram is one trillionth of a gram), as compared to a standard BET system, which can only measure mass changes of about 1 million picograms.

NARDA opposes universal scrambling of cable signals

The National Association of Retail Dealers of America (NARDA), in response to reports that cable companies in some areas are applying to local boards to be allowed to scramble all stations on their systems except those that can be picked up by regular antennas, passed a resolution opposing the universal scrambling of cable signals. According to NARDA president Ed Knodle, universal scrambling, which would require that all subscribers use cable-supplied boxes to pick up both basic and premium channels, "would render useless our best products, such as cable-ready TV's and VCR's, remote control, and all the new technologies which give consumers enhanced video, sound, and convenience." Knodle, referring to universal scrambling as another way for the cable companies to generate revenues at the expense of manufacturers, retailers, and consumers, urges retailers "to be alert for this kind of attempt in their communities and to be ready to combat any such move." **R-E**

VIDEO NEWS

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

DAVID LACHENBRUCH

• **Super-premium CRT's.** The next TV trend from Japan might be the deluxe or super-premium picture tube. Matsushita, which makes Panasonic TV's, has a major hit on the Japanese domestic market with a tube it calls "Gao," which loosely translates from the Japanese as "king of pictures" (**Radio-Electronics**, September 1991). Gao is available in Japan in 26-, 27-, 31-inch sizes in top-of-the-line Panasonic sets. It is scheduled to appear momentarily on the American market, first in the 31-inch, and then the 27-inch size. The major attribute of this new tube is its flatter faceplate, with sharp reduction in reflections. The front panel's light transmission on the 31-inch set has been reduced to 33.5% from Panasonic's standard 47.5%, and the tube's new electron gun and drive system maintain brightness and result in better focus.

It now turns out that Gao is only the forerunner of a rash of such supertubes. Not to be outdone, Sony has introduced the "Super Trinitron" in Japan, and the company said it will be offered in the U.S. as well. This new tube improves on Sony's vertically flat faceplate by sharply reducing the curvature of the horizontal plane. The tube will be offered in 27- and 32-inch versions, and Sony says that ambient reflections are virtually eliminated in the new tubes.

A third super-deluxe picture tube was introduced in Japan at our deadline by Hitachi. The 27-inch version is claimed to have a 40% flatter screen than the same company's conventional tube. Further information on this and other competitive entries into the high-priced tube field are expected in the next few weeks.

• **Widescreen programs coming?** Widescreen TV sets using the 16:9 ratio, as opposed to the standard 4:3, have now been introduced in France, Germany, Italy, and Spain. As reported here (**Radio-Electronics**, October 1991), they're headed to the U.S. under such brands as JVC, Hitachi, Toshiba, and, later, RCA. But what do you show on them? Well, you can cut the top and bottom off a standard TV picture to squeeze it into the new widescreen proportion, or you can show some of the few readily available letterbox laserdiscs and videotapes. Thomson Consumer Electronics, the parent of RCA and GE in the U.S., has started a campaign to convince movie companies, broadcasters, and cable companies to develop more widescreen programs in anticipation of the arrival to the new sets. For the time being, it is concentrating on the letterbox format, but it is also trying to persuade programmers to produce more shows in widescreen proportions for conversion to upcoming formats. Upcoming formats include Advanced Compatible TV (ACTV), a widescreen transmission system compatible with standard broadcasting, and widescreen VCR's, which are compatible with conventional programs as well as 16:9-aspect pictures (but not HDTV—see below). The latter has already been developed by JVC for the European market, and an American version will be marketed as soon as standards can be set.

It may or may not be the writing on the wall, but widescreen TV receivers suffered a setback this summer, when introduction by Thomson in England was postponed to next year. Among the reasons given were poor economic climate, a disagreement in the European community over standards for satellite broadcasting—specifically whether and when widescreen broadcasting will be required—and the advisability of waiting for the 1992 Olympics (which will be broadcast in widescreen HDTV) to take advantage of the best promotional opportunities.

• **HDTV VCR is set.** Japanese companies have agreed on a standard VCR for recording and playing back high-definition pictures. To the surprise of some, it's not digital, but analog—a new analog system that is incompatible with VHS but resembles it in some respects. Hitachi, Matsushita, and Sony are the originators of this system, which is designed for Japanese HDTV standards, but could also accommodate other HDTV specs. The system, which employs no data compression, uses half-inch metal-particle tape in a dustproof cassette slightly larger than the VHS version, and can record or play back for three hours. The system is said to be capable of storing five to six times the amount of information contained in a standard NTSC signal. However, if the United States adopts a digital HDTV system, you can bet there will be plenty of pressure to move home video recording into the digital age as well.

• **Multimedia confusion.** Interactive video, or multimedia, is the hot new product—at least theoretically. But it may be in for a battle of standards that will make the Beta-VHS debacle look like a friendly debate. For one thing, the two major consumer formats of 1991, Commodore's CDTV and Philips' CD-I, are completely incompatible. Then there are the multimedia systems designed as computer peripheries, such as Intel's DVI, along with other incompatibles.

But in the end, consumer multimedia may derive from video games, although there's plenty of confusion there, too. Although Philips will convert some of the hottest Nintendo games to CD-I, and Nintendo will design some more for the system, Sony—as we reported here—will be introducing its own CD-ROM based multimedia game format called Super Disc—incompatible with everything else, of course. Meanwhile, Sega and JVC have signed an agreement for a console combining a CD-ROM player with Sega's Genesis video game. NEC has been marketing a CD-ROM player for its TurboGrafX video game and will soon market a combination player. One software developer said he has already counted 12 mutually incompatible CD-based entertainment and information multimedia systems—and there are certain to be more on the way. **R-E**

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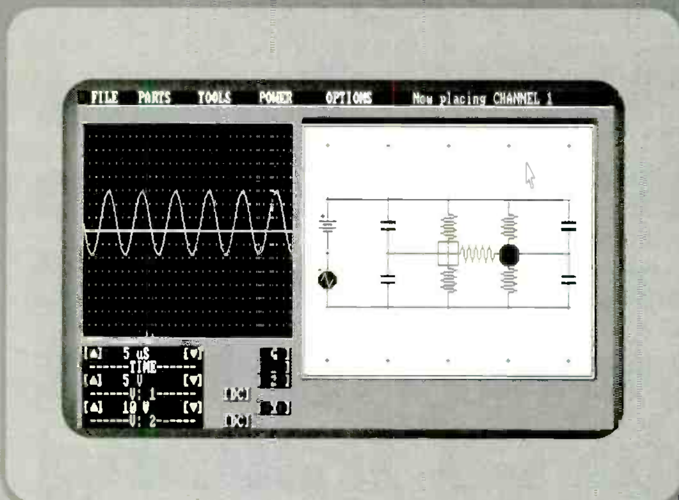

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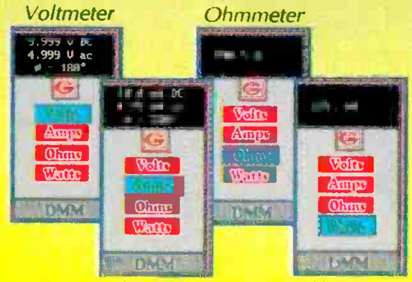

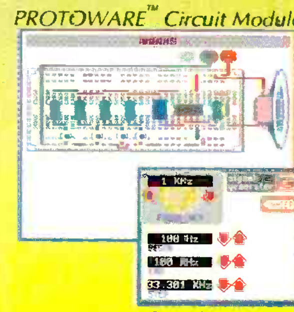

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WIG-WAG CIRCUIT?

I have a 1982 Toyota and would like the hazard lights to light side to side rather than simply on and off. I've been told that the way to do this is with something called a "wig-wag" circuit—also known as a sequencer board. I'm not sure what this is and was wondering if you could help me.—R. Berkey, Seattle, WA

You can take some comfort from the fact that I, too, don't have any idea what a "wig-wag" circuit is and, as far as I'm concerned, sequencer boards are devices for electronic music. I think that the term "wig-wag" refers more to what the circuit has to do rather than specifying a particular collection of components or a particular circuit layout.

There are lots of ways to achieve the effect you're looking for, and which one you use depends on how slick you want it to be and how much work you're willing to do. All of them, however, presuppose that you have some way to isolate the left and right flasher lamps on your car since you have to be able to address each side of the car separately for any wiring scheme to work. If your car, like most other ones, uses the directional filaments for the flashers, you won't have any problem.

The easiest way to do the job is to use a double-pole, double-throw relay as shown in Fig. 1. You can try controlling the relay directly from the output of the flasher unit but I'm not sure whether your car has a mechanical or electronic flasher unit. If the unit is mechanical, you can wire the circuit as shown in Fig. 1—but don't forget to add the switch or you won't be able to turn the bulbs off.

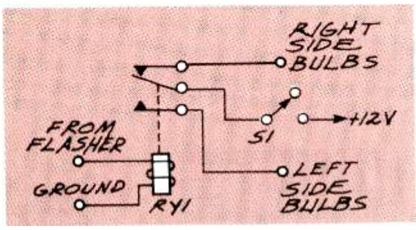

FIG. 1—THE EASIEST WAY to make your flashers blink side-to-side is to use a double-pole, double-throw relay as shown here. You can control the relay directly from the output of the car's flasher unit if the unit is mechanical.

If the flasher unit is electronic, you'll have to take the signal from farther down the line at a point where the existing circuit is designed to drive the filaments of the bulb. Once you find that point, the wiring to the relay will be the same as what is shown in Fig. 1.

A more exotic flashing alternative can be gotten by disregarding the existing flashing unit and controlling the bulbs completely by the electronics shown in Fig. 2. The 4017 is driven by a 555 clock whose frequency can be set with the potentiometer. Since the 4017 has ten outputs, you can assign each of the bulbs to an output and, by picking the output numbers and clock frequency carefully, you can flash the bulbs in pairs, all together, or even individually.

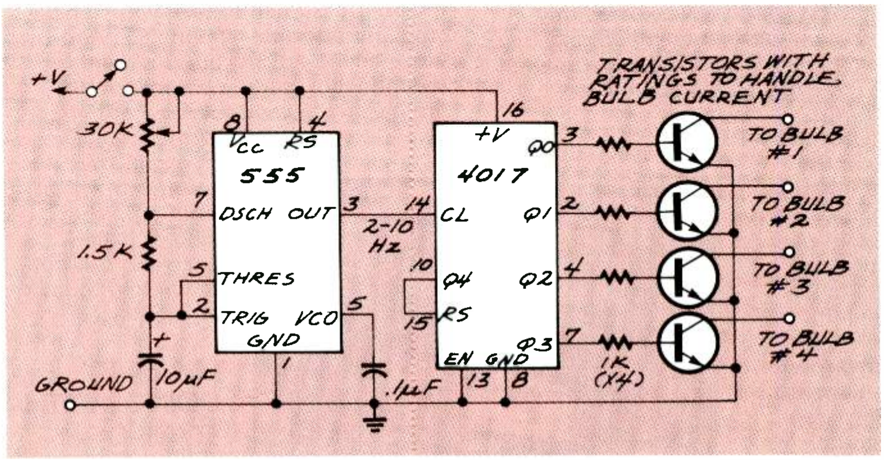

FIG. 2—YOU CAN DISREGARD the existing flashing unit and control the flasher bulbs using this circuit.

BLINKING BLOCKS

I have a PC-compatible computer with both a VGA and monochrome monitor connected to it. I need this setup because some of the software I use was only works on the monochrome screen. The problem I'm having is that when I run programs on the monochrome screen, it often leaves blocks of inverse and blinking video on the screen and the only way I can get rid of it is to reboot the computer. What's causing this and is there anything I can do about it?—F. Geoffrey, New York, NY

The reason you're having a problem like this is due to a combination of things. Any one of them individually won't cause the problem that you are seeing but, when you put them together, the result is messed up video.

You didn't mention your exact video setup in your letter but I'd be willing to bet my new pair of white tennis shoes that you've got a sixteen-bit VGA card and a regular eight-bit mono card. And not only that, but I'll bet you've got your VGA card in a sixteen-bit slot and it's configured to run as a sixteen-bit device. That in itself wouldn't be too much of a problem, but the way the IBM video screen is set up along with how the display memory is organized is what causes your problem with getting the messed up video.

Each position on the screen requires two bytes of memory—one for the character and the other for its attribute. The first byte is what you type at the keyboard and the second is what determines either the color (for your VGA), or the highlighting and underlining (for your monochrome). Also, when you have a VGA card in your system, the computer will address the screen two bytes at a time. The first byte will be put on the

lower eight bits of the bus and the second byte, the one controlling the attribute, will be put on the upper eight bits.

Since the monochrome card is an eight-bit device sitting in an eight-bit bus, it never sees the attribute byte. As a result, when DOS clears the monochrome screen or does some other activities, the data is sent to the monochrome card, but the attributes (sent at the same time as the data but on different data lines) never get there.

Programs that write directly to the monochrome screen can poke any attributes directly, but a more legitimate write to the screen through one of the DOS services won't work properly. The culprit in all this is the VGA card's BIOS since it loads itself in memory at boot up and replaces the standard DOS video handlers. The VGA BIOS checks to see if the VGA card is in a sixteen-bit slot (where it should be for maximum speed), and if it's found there, the data is sent out two bytes at a time. If the VGA card is found in an eight-bit slot, the BIOS will use only the lower eight bits of the bus and the monochrome card will then be addressed properly.

Some VGA cards allow you to use software to have them run as either eight- or sixteen-bit devices. Setting the card as an eight-bit device may solve some problems with particular software, but whether it will solve your problem depends on the nitty gritty of the VGA BIOS. I doubt if it will do anything but, since you can do it without using a screwdriver, it's easy enough to try—always try easy solutions first.

The next thing to do is call the VGA card manufacturer (best of luck on this one if you've got a generic clone card), and find out if they've got a fix for the problem. If they don't, you can eliminate the problem by moving the VGA card to an eight-bit slot. That will make the hassle disappear but you'll pay a price in the speed of screen stuff.

As a last resort, you can run the program "CLR—MONO.COM" which you'll find on the RE-BBS (516) 293-2283, 1200/2400, 8N1. It's a 34-byte program that will reset all the monochrome attribute bytes to 07H, the value needed for non-blinking, non-underlined, low-intensity. You can run it whenever you've got garbage left on the monochrome screen after running your programs and it will clear it right up.

A FULL 360

I'm building a project that requires two potentiometers that can turn a full 360 degrees. The potentiometer has to return to zero resistance after it's been turned through a full rotation. I've checked everywhere but can't find anything like this. Do you know where I can get these or if they even exist at all?—H. Fennel, Bainbridge, NY

I'm sorry to say that I've never run across a potentiometer like the one you've described. However, if you absolutely must have a device like that, and can't find anything like it commercially, you should be able to make your own. You'll have to do some surgery on a standard potentiometer, but certainly nothing that requires years of medical school.

If you bend back the tabs holding a standard potentiometer together, you'll find that there are small pieces of metal that act as the stops for each end of the potentiometer's wiper. If you bend these out of the way, or just grind them off completely, the potentiometer will rotate through a complete 360 degrees. You may still have a problem, however, because the new area being swept by the wiper will be an open circuit since there's nothing that is electrically connected to either end of the potentiometer's resistive material.

You can try painting the area with some conductive paint, India ink, or even gluing down a piece of copper foil. If you do this, be sure to leave a slight gap on one side between the material you add and the end of the potentiometer's original resistive element while making contact on the other end. If you connect it to both ends you'll be putting the new material in parallel with the original material and the value of the potentiometer will change and the sweep will be extremely non-linear. If you use conductive paint or copper foil you'll have a dead short.

Having a small gap will leave you with a dead spot which may be unsuitable for your application. If this is a problem that you can not deal with, you'll have to contact one of the manufacturers and price out the cost of custom parts. **R-E**

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FRANK POLIMENE

VACUUM TUBES DEFENDED

I have seen may letters in this column from readers who are dead-set against vacuum tubes, but the letter from Paul J. Carlson (**Radio-Electronics**, July 1991) really pushed it too far. Mr. Carlson had the audacity to call audiophiles with certain beliefs foolish and gullible, and he went one step further in calling Creation Science illegitimate, which outrages me.

I am sick and tired of people who knock good ol' vacuum tubes. What other electronic component, when used in a well-designed, low-level audio circuit, can offer a greater-than-10-megohm input impedance, high input-overload immunity, static immunity, a 100-dB dynamic range, a 25-volt P-P voltage swing into 600 ohms, negligible distortion, low noise, a flat frequency response from 10 Hz to over 30 kHz—all for under ten dollars? That is not fantasy. I constructed a preamplifier for my electric bass guitar with the above specifications, using a single 12AX7A, and it works! The same goes for high-level audio electronics.

How about RF circuits? I have in my collection of CB radios two Hallicrafter CB-3A's. They are ancient 8-channel crystal-controlled units, and their receivers out-performed a solid-state DX-200, TRC-48, TRC-449, TRC-451, and a Cobra 142-GTL by 30%! Vacuum tubes perform admirably when used as high-power RF amplifiers too. A tube high-frequency linear amplifier is superior to a transistor-type in the following: low harmonic generation, low IMD characteristics, high immunity to a high SWR, and reliability—and it's about ½ to ⅔ the cost of a solid-state linear amp in the same power-output range. Television is another area in which I've found vacuum tubes superior.

Vacuum-tube technology is not yet dead. The *What's News* column in the February 1991 issue of **Radio-Electronics** told of micro-miniature silicon needles that could by used as solid-state cathodes in—what else?—vacuum tubes. That could re-

continued on page 100

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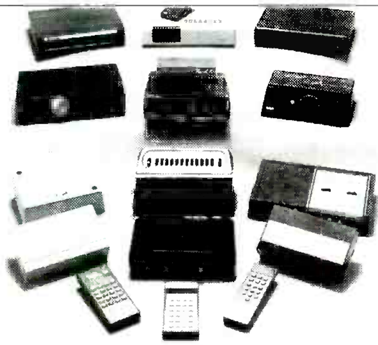

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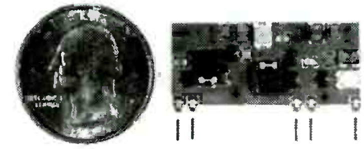

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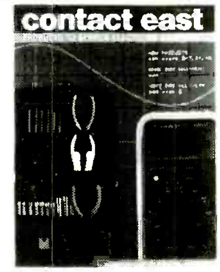

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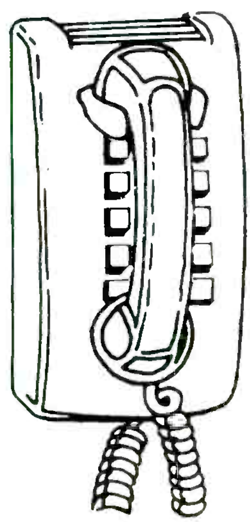

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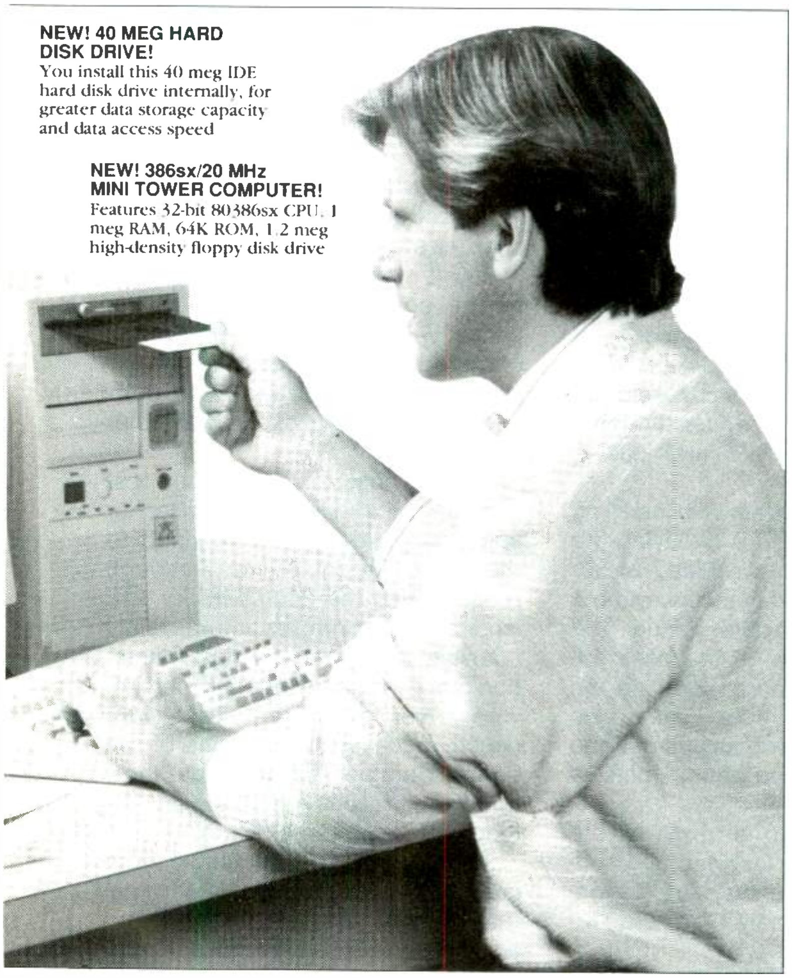

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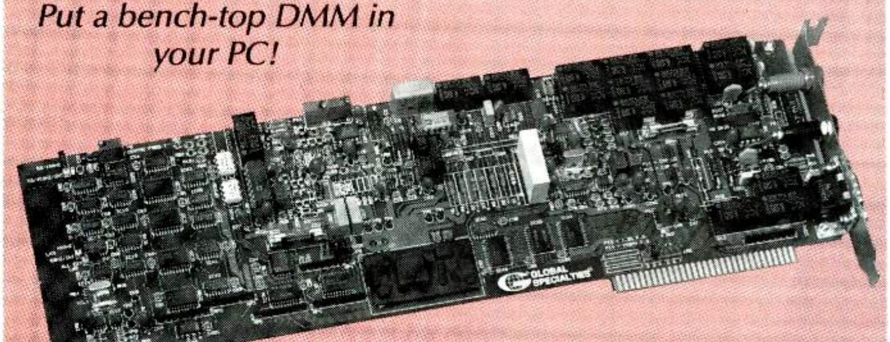

CIRCLE 10 ON FREE INFORMATION CARD

There is no turning back the clock: PC-based test equipment is here to stay. The reason for that is flexibility of the sort available from the PCI-DMM from Global Specialties (70 Fulton Terrace, New Haven, CT 06512).

The PCI-DMM is a plug-in card and software package for your IBM PC or compatible computer. In essence, it turns your PC into a full-featured, configurable DMM with such additional features as data storage and graphics.

The PCI-DMM package consists of the board itself, test leads and probes, a program disk, and a user manual. The board fits into a full-length slot in any PC, XT, AT, or '386 machine. The rear "panel" contains banana jacks for the positive and common test leads, and a 9-pin "D" jack for connection to a "scanner," which we'll discuss later. The test leads are about five feet long, (which is necessary because they have the get around the computer) and include two kinds of probe attachments. The software disk includes executable files and device drivers, but also includes programming examples in the C language to assist those who want to customize the operation of the PCI-DMM. The manual is decidedly low-tech; illustrations hardly exist and pages are printed on one side only. But it's written well enough that its appearance isn't a hindrance.

Installing the PCI-DMM

The basic system requirements for the PCI-DMM are an IBM XT or better running DOS 3.0 or higher, with 640K of RAM, and EGA or VGA graphics (color or monochrome). A mouse is supported, and, although it makes using the DMM much easier, it's not essential

The biggest problem with installing the board in the PC is choosing the right slot—the input cables have to wrap around front somehow, without getting tangled in other wiring. The only other concern is the base address where the board will reside and the interrupt it will use. Jumper pins make it easy to select an address and interrupt that will be free of conflicts with other boards.

Once the board is in place, the software must be installed and configured to your machine. It's a reasonably simple, automated process.

Using the DMM

Once you run the software, the screen of your PC is turned into the front panel of a benchtop DMM with chart recorder. Three-dimensional "buttons" are used to select all functions.

At the top center of the "front panel" is is a 4½-digit (20,000-count) display. Below that is a row of function keys (voltage, current, resistance, capacitance, and decibels relative to 1 mW into 600 ohms). A range selector is located to the display's left. Below that are three toggling mode switches (AC/DC, absolute/relative, and fast/slow). A touch-hold button and "power switch" (which lets you exit the software) round out the DMM controls.

The other controls on the virtual front panel are not commonly found on DMM's; they're used to control the chart-recorder functions. Eight pens are available to plot data to the "roll paper," and the time between samples can be varied from 0.5 seconds to almost ten hours.

The chart paper isn't there just to add a bit of pizzaz to the DMM. It's actually where the real benefits of PC-based instruments show up. Each chart is stored on disk, and can be replayed at a user-selectable speed to the screen or to a dot-matrix printer. Stored data is also available in delimited ASCII files that can be imported into databases, spreadsheets, word processors, and other software.

For low cost ATE (automatic test equipment), a multi-channel scanner unit is available to provide 8 inputs to the main system board. Although programming the PCI-DMM for ATE isn't a simple matter, it's certainly possible thanks to the documentation that's included. The supplied device driver lets external software directly access the functions of the board. Sample "C" routines show how to control and switch the DMM's functions and internal relays.

The PCI-DMM is protected from overload by self-resetting thermal fuses; conventional fuses protect against worst-case overloads. Your computer is isolated from inputs up to 500 volts.

We experienced no problems or difficulties with the PCI-DMM, and found it to operate as claimed by Global Specialties. The software is simple to use—at least with a mouse.

Since the Windows environment is starting to become the *de facto* standard for PC-based instrumentation, we would have preferred to see software that ran under Windows. Despite that shortcoming, we think that the PCI-DMM is a strong product. Its $795 price should make it attractive to engineers and technicians involved in quality assurance and automatic test. **R-E**

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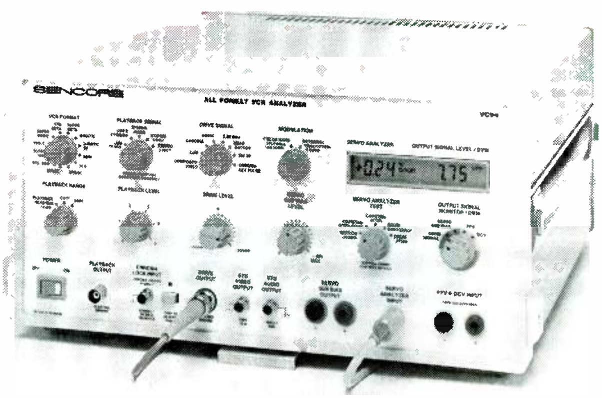
ALL-FORMAT VCR ANALYZER. A companion to *Sencore's VA62A Universal Video Analyzer*, the *VC93 All Format VCR Analyzer* is designed to isolate all video, audio, and servo problems in the playback and record circuits of VCR's and camcorders. Together, the two instruments completely analyze VCR's from antenna to line output. The *VC93*'s servo tests allow the user to automatically check out a VCR without removing the VCR' cover. Those tests eliminate the confusion of whether a bad playback symptom is luminance or servo related, and isolate servo problems to the capstan or cylinder. Head-substitution signals positively isolate video-head defects from other circuit problems. Phase- and chroma-locked drive signals troubleshoot all VCR stages from the heads to the outputs; and the *VC93* even troubleshoots defects in stereo hi-fi audio circuits. It supports VHS, Super VHS, VHS-C, Super VHS-C, Beta, Super Beta, 8mm, Hi-8, U-Matic, and U-Matic SP VCR and camcorder formats.



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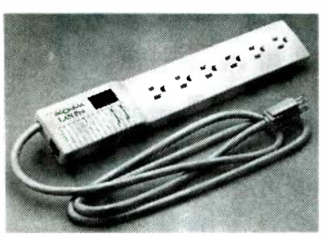

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LAN Pro S20LP from *Proxima* supplies such protection by eliminating high-frequency noise and high-energy surges and spikes. A special filter removes 99% of all EMI/RFI noise from 500 kHz to 100 MHz, which is particularly important for LAN communications that run between 2.5 and 20-plus MHz. A "super high energy dissipation" (SHED) circuit provides an energy dissipation capability of 480 joules and can withstand three times the number of high-energy (IEEE 587 1980 category-B) surges as ordinary computer-grade surge suppressors. The *LAN Pro S20LP* also features a polarity/ground fault indication for additional security, since LAN's are particularly vulnerable to ground faults. A Lifetime Equipment Protection Policy guarantees the replacement or repair of any computer equipment that is damaged due to power transients while properly connected to the *S20LP*.

The *LAN Pro S20LP* has a list price of $79.95.—**Proxima Corporation**, 6610 Nancy Ridge Drive, San Diego, CA 92121; Phone: 619-457-5500.

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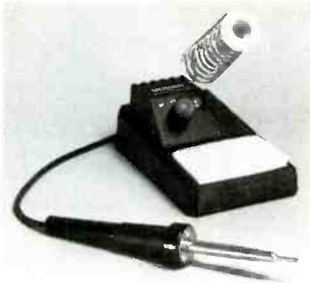
CIRCLE 18 ON FREE INFORMATION CARD

The *3500* frequency counter costs $250.—**Startek International Inc.**, 398 NE 38th Street, Fort Lauderdale, FL 33334; Phone: 305-561-2211 (for orders only: 800-638-8050); Fax: 305-561-9133.

DUAL-WATTAGE SOLDERING STATION. Delivering professional results at a hobbyist price, *Ungar's UTC SS* soldering station is well suited for electronic-kit assembly and the repair of electronic devices. Its dual-wattage control allows the user to select the proper heat for the job: The low setting, 21 watts, heats to 650°F and the high setting, 35-watts, heats to 850°F. A fully grounded tip ensures safe use with sensitive components on printed cir-



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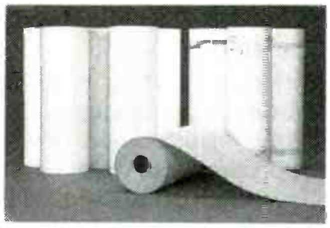
cuit boards, including surface-mount devices. The all-in-one unit includes a power base with built-in controller, a dual-wattage soldering iron with cool, anti-slip handle; and a coil-spring iron holder with a ceramic mouthpiece that provides a safe standby position for the hot iron. The *UTC SS* also features a conveniently located, contamination-free sponge that allows the user to maintain a clean, well-tinned tip. The unit comes with a general-purpose soldering tip, and can be used with 12 different standard-line, ¼-inch, thread-in tips from Ungar. An optional adapter (model *100*) allows the use of a wide selection of Ungar's 1-8-inch tips.

The *UTC SS* soldering station has a suggested list price below $60.—**Ungar**, Division of Eldon Industries, Inc., 5620 Knott Avenue, Buena Park, CA 90621; Phone: 714-994-2510; Fax: 714-523-7790.

CONTINUOUS-ROLL COMPUTER PAPER. Anyone who's ever printed out a computer-generated "Happy Birthday" banner, only to have it tear along the perforations when trying to hang it up, will appreciate *Banner Band* continuous-roll computer paper from *Micro Format*. The paper, manufactured from high-grade 20-pound bond, has ½-inch micro-perf margins and no cross perfora-



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tions. It is available in white and in assorted pastels and fluorescent colors, with borders or over-all designs (hot-air balloons and holiday motifs), and in "BannerBrite" parchment. It comes in two widths to accommodate both standard- and wide-carriage printers, and in 45- and 150-foot lengths.

BannerBrite continuous-roll computer paper costs between $11.95 and $19.95.—**Micro Format, Inc.**, 533 North Wolf Road, Wheeling, IL 60090; Phone: 1-800-333-0549 or 708-520-4699; Fax: 708-520-0197.

VIDEO-AMPLIFIER TRANSISTOR ARRAY. Designed for use as an output device in very fast video-amplifier circuits, *Motorola's CR820* transistor array consists of a complementary pair of silicon bipolar transistors connected as emitter followers. Their primary use will be in black and white CRT video monitors, with other applications where discrete steps of brightness are required. The array consists of a high-voltage, high-cutoff frequency NPN chip mounted along with a similar PNP chip in a common SOE-type package. Collector-base breakdown voltage is 120 volts for the NPN transistor and −80 volts for the PNP. Cutoff for each chip is typically 1 GHz. Junction-to-case thermal resistance is 20°C/W.

The *CR820* costs $8.00 for quantities of 25 and up; samples and small quan-

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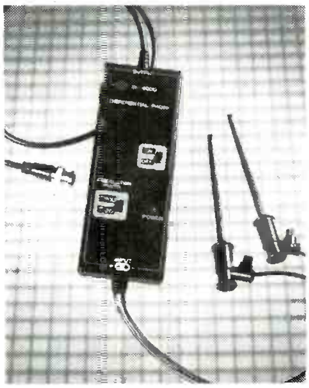
tities are available from stock.—**Motorola Semiconductor Products**, Media Relations MD 56-102, P.O. Box 52073, Phoenix, AZ 85072.

ACTIVE DIFFERENTIAL PROBE. The *API SI-9000* differential probe comes out of the box ready to use. Its built-in, precision differential amplifier is internally powered and requires no adjustment. The *SI-9000* can be used in the lab, in the field, and for education; and for monitoring, testing, designing, and troubleshooting in such areas as balanced data-transmission lines, power converters, inverters, switching-mode power supplies, robotics, HVAC, machine/tool control, and controlled lighting systems. The unit uses one input channel of any general-purpose oscilloscope. It has convenient switch-selectable gains, DC to 15 MHz bandwidth, and a constant input impedance of 2 megohm and 2.5 pF. The *SI-9000* can be used with inputs as high as ±700 volts and provides 2% accuracy for outputs as high as ±3.5 volts across loads as low as 1 kilohm.



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The *SI-9000* active differential probe costs $399.—**Avex Probes Inc.**, 1683 Winchester Road, Bensalem, PA 19020; Phone: 800-877-7623.

PCXI COLOR VGA MONITOR. *Rapid System's PX1490* is a 7.5-inch, VGA color monitor for the "PC Extended for Industry" (PCXI) system. PCXI is a modular, industrial PC based on a 13-slot passive backplane. Each part of the PC is enclosed in a metal, shielded, cooled, modular enclosure. The *PX1490* monitor, a Sony Trinitron with 0.26mm dot pitch and 720×480 maximum resolution, is completely integrated into the PCXI chassis, connecting directly to the PCXI video module. Depending on configuration, a complete system leaves two or three slots open. It can be used for rack-mount applications requiring built-in, eye-level monitoring, in such fields as production testing, factory automation, process control, and data acquisition.

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The *PX1490* monitor costs $1699.—**Rapid Systems Inc.**, 433 North 34th Street, Seattle, WA 98103; Phone: 206-547-8311; Fax: 206-548-0322. **R-E**

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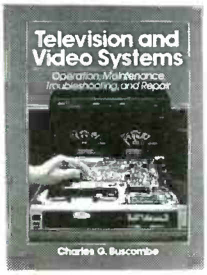
TELEVISION AND VIDEO SYSTEMS: OPERATION, MAINTENANCE, TROUBLESHOOTING, AND REPAIR; by Charles G. Buscombe. Prentice Hall, Englewood Cliffs, NJ 07632; $45.80.



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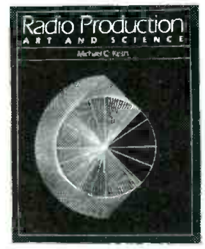
The most popular category of consumer electronics is video—encompassing televisions, monitors, projection TV's, and VCR's—so there are ever-expanding opportunities in servicing such equipment. This book, intended as a training tool for tomorrow's technician's and a reference source for those working in the field today, explores all facets of modern electronic consumer product servicing.

The book assumes a basic knowledge of electronics on the part of the reader, and concentrates instead on theory and troubleshooting. Divided into sections by equipment category, each section contains a straightforward presentation of theory, containing almost no engineering concepts or mathematics, followed by detailed explanations of troubleshooting techniques, accompanied by block diagrams, partial schematics, and other illustrations. At the end of each chapter are questions designed to make the reader ponder what has been taught, and to promote understanding the material. Also included is a full schematic of a late-model color TV that serves as an exercise in schematic reading and circuit tracing.

RADIO PRODUCTION: ART AND SCIENCE; by Michael C. Keith. Focal Press, 80 Montvale Avenue, Stoneham, MA 02180; $29.95.

Taking a fully integrated approach to the subject of radio production, this book examines the effects of station programming formats on the production process, with the belief that the two are inseparable. The first section of the book provides a brief history of radio production followed by a depiction of a



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day in the life of a production director in a modern studio. The skills and qualities required to meet the responsibilities of the job are discussed. The second part of the book begins with an analysis of studio design characteristics, including size, layout, and acoustics, and evaluates the latest audio equipment, including MIDI, synthesizers, digital processors, and computers, in the context of their roles in the production studio. Part III covers the basics of copy preparation, good announcer delivery, and the techniques used in tape editing. A dozen of radio's most popular formats are analyzed in Part IV, along with a look at how the format affects the way that commercials, features, promos, and public-service announcements are produced. The book's final section takes a look at several aspects of the production experience in noncommercial formats. As a whole, the book is intended to provide the reader with a taste of what working in radio production is really like, along with an understanding of how the equipment works and how programming influences the entire radio production process.

INFRARED OPTOELECTRONICS 1991 PRODUCT SELECTION GUIDE; from Quality Technologies, 610 North Mary Avenue, Sunnyvale, CA 94086; Phone: 800-LED-OPTO; free.

CIRCLE 38 ON FREE INFORMATION CARD

This 16-page booklet describes a comprehensive line-up of infrared LED's and phototransistors. Packaging options include metal can, plastic T-34, T-1, T-1¾, and a three-lead T-1-¾ phototransistor. User-friendly specifications provide guaranteed min-max parameters. The book also includes two technical papers for design engineers: "Testing Output Irradiance of Infrared LED's" and "Understanding Light Sources When Measuring On-State Collector Current in Phototransistors."

SOLDERING TOOLS FOR ELECTRONIC PRODUCTION; from Ungar, Division of Eldon Industries, 5620 Knott Avenue, Buena Park, CA 90621; Phone: 714-994-2510; free.

CIRCLE 37 ON FREE INFORMATION CARD

Ungar's updated lines of soldering and desoldering equipment and electronic production aids are described in this 25-page illustrated color catalog. Included are surface-mount rework systems, desoldering service centers, soldering systems, soldering/desoldering irons, heat guns, and rechargeable cordless tools. Highlighted is a new line of electronic manufacturing aids, including flushcutters, pliers, and other hand tools; masking devices; dispensers; thermal wire strippers; and assembly devices. The catalog provides product descriptions, specifications, MIL-SPEC compliance, and selection guidelines. **R-E**

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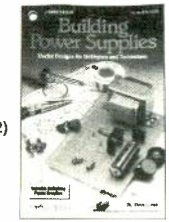
(2) 

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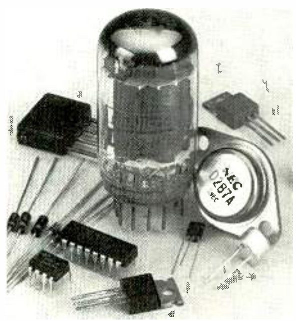

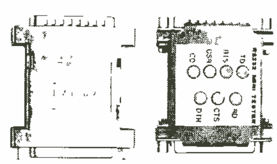

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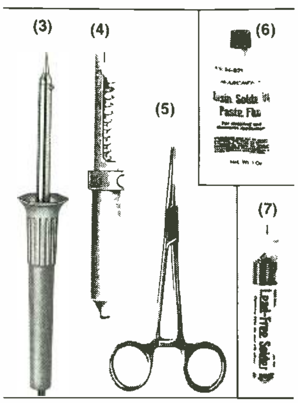

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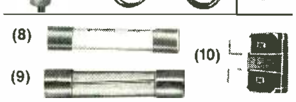

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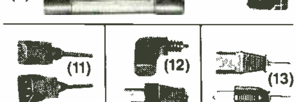

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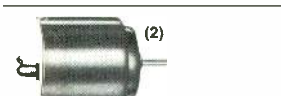
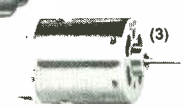
(2) 

(3) 

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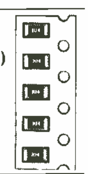
(5) 

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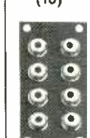
(10) 

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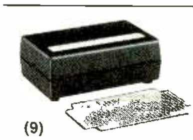
(9) 

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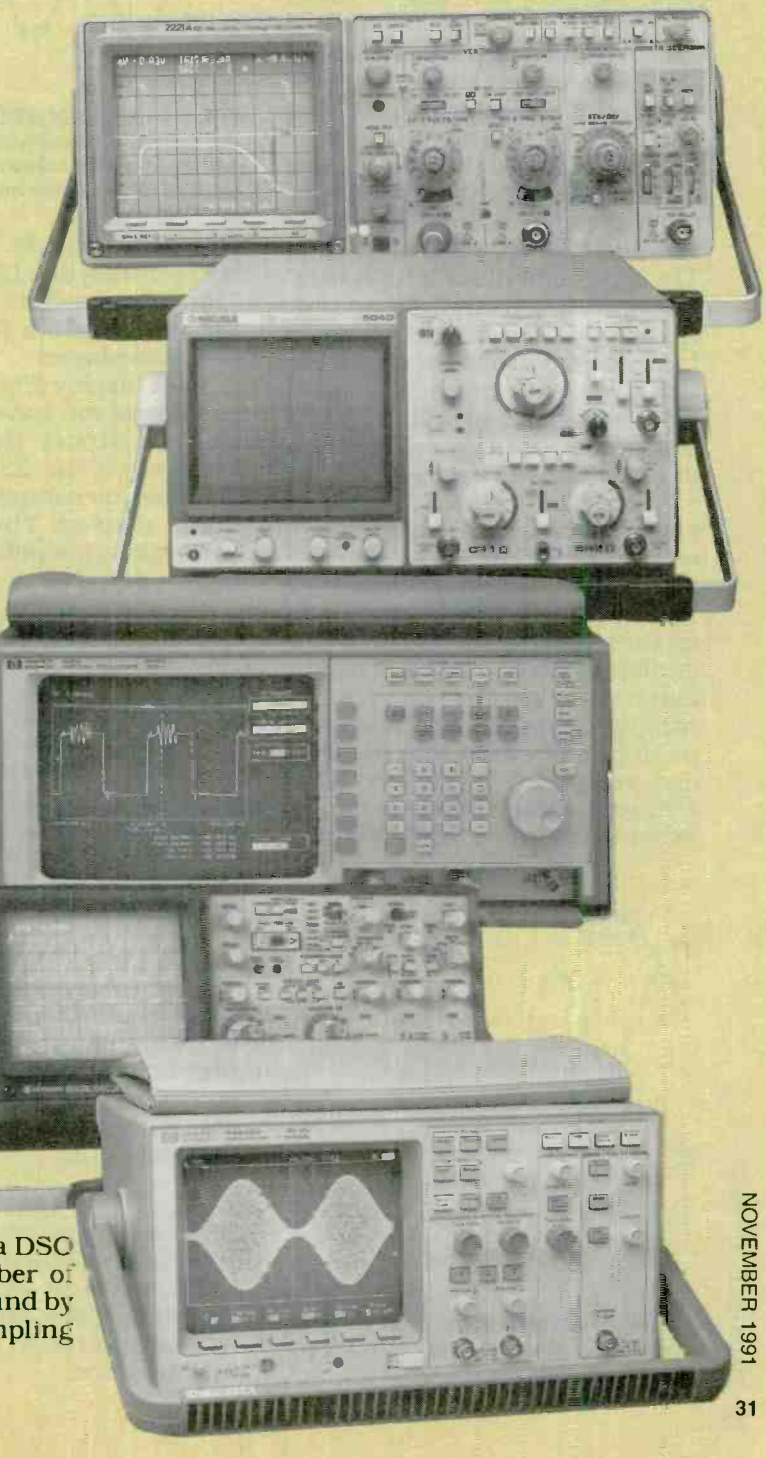
A BUYER'S GUIDE TO:

DIGITAL STORAGE OSCILLOSCOPES

Our in-depth approach to understanding digital storage oscilloscopes will shed new light on these sophisticated test instruments.

STAN PRENTISS



IF YOU'VE EVER USED A DIGITAL STORAGE OSCILLOSCOPE (DSO), you know what an invaluable tool it can be. DSO's are designed specifically to receive, store, and process a variety of signals, including one-shot events, pre-trigger actions and various fast- or low-frequency signals that would normally escape detection by ordinary analog scopes. Unlike analog storage oscilloscopes, DSO's can store transients as well as repetitive waveforms permanently in digital memory for later viewing or record keeping.

DSO's are unsurpassed in their ability to record characteristic waveforms for individual analysis or for comparison with other waveforms at a later time. Binary data captured in a DSO's memory can be transmitted to a central computer, sent to an X-Y recorder for hard copies, or permanently stored on tape or disc.

We will begin with some basics on how a DSO operates, then we'll discuss resolution, accuracy, bandwidth and risetime considerations as well as some specialized features which have made DSO's so popular. After laying out the groundwork on critical DSO characteristics, we'll give you a round up of some units ranging in price from about $1700 all the way up to $9900!

Digital bandwidth

One of the most important operating specifications of a DSO is its maximum sampling rate. The sampling rate of a DSO is usually specified in megasamples per second (Ms/s). The quality of a displayed waveform depends on the number of dots, or samples, that are taken for each cycle. With a high number of samples for each cycle, the waveform will be displayed in great detail. When fewer samples are taken, important details may be lost.

Digital bandwidth can best be illustrated with a simple example. If a relatively low input signal of 500 kHz is displayed on a DSO that can sample at a rate of 50 Ms/s, the number of samples that are taken during one cycle can be found by dividing the signal frequency into the scope's sampling rate. Therefore, the number of samples equals

$$50 \text{ Ms/s} \div 500 \text{ kHz} = 100.$$

One cycle of the displayed 500-kHz signal is made up of 100 dots. That sampling rate may be fine for lower frequencies, but if you have a much higher frequency of 10 MHz, the sampling rate reduces to only 5 dots per cycle, which will not give a clear picture of the actual waveform.

When a signal is sampled less often than it should be, a phenomenon known as *aliasing* occurs. An under-sampled signal, and the resulting aliased signal is shown in Fig. 1-a and -b, respectively. To avoid aliasing error, more samples per second must be taken.

According to the Nyquist criterion, to completely reconstruct a waveform, sampling must occur at a frequency greater than twice the rate of the highest frequency for ordinary information, and often greater than 10 times for rise and fall time measurements. The requirement for a high sampling rate means that the analog-to-digital converter (ADC) must have a fast conversion rate. That usually requires an expensive flash converter, or a less expensive analog storage device, both of which we will discuss further.

A commonly used "figure of merit" is the useful storage bandwidth (USB). The USB describes the maximum signal frequency a DSO can store, and is dependent on the sampling rate and the type of display used. The USB can be calculated as the (maximum sampling rate)/25, and is the upper-frequency limit that the DSO can adequately reproduce. That frequency limit, however, can be extended by using different interpolation methods. Interpolation is essentially the DSO's ability to "connect-the-dots," smoothing the image into a fairly continuous waveshape.

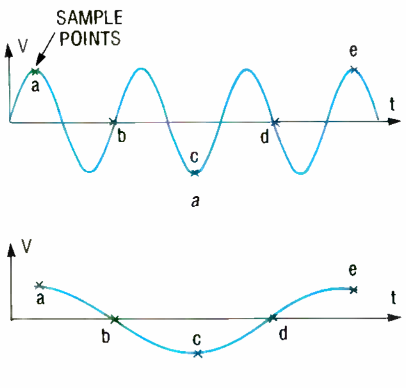


FIG. 1—AN ALIASED SIGNAL; an input signal with a low sampling frequency (*a*), and the resulting aliased signal (*b*).

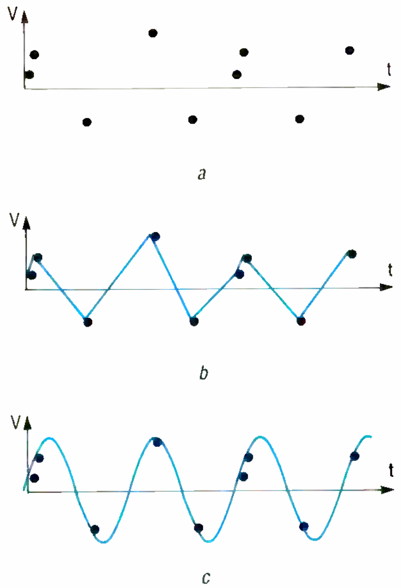


FIG. 2—INTERPOLATION METHODS; a dot display (*a*) has no interpolation, a linear interpolator connects the dots with vectors (*b*), and sine interpolation (*c*).

A dot display (Fig. 2-a) is useful as long as you have enough dots to reconstruct the waveform. Generally, about 25 points per cycle must be sampled for an adequate display. Therefore, for a full-scale sinusoidal display, the USB is equal to

$$\text{maximum sampling rate (Ms/s)/25.}$$

Linear interpolation (Fig. 2-b), or vector display uses a vector generator to draw lines between the data points on the screen. When that type of interpolation is used to display a sine wave, only 10 lines per cycle are needed to reconstruct the waveform. The USB for a linear interpolator is therefore

$$\text{(Ms/s)/10.}$$

Sine interpolation (Fig. 2-c) can even further extend the USB by introducing a sinusoidal function between the dots. Only 2.5 points per cycle are needed to display a signal. The USB of a sine interpolator is

$$\text{(Ms/s)/2.5.}$$

Not all measurements involve sine waves. When dealing with pulse waves, it is the rise time that determines the scope's ability to display such waveforms, as we'll now see.

Rise time

One of the most important parameters involved in reproducing pulse waveforms is the rise time (T_r). In analog oscilloscopes, the rise time can be calculated simply by the equation

$$T_r(\text{ns}) = 0.35/\text{bandwidth (MHz)}.$$

A 100-MHz scope, for instance, would have a rise time of

$$0.35/100 \times 10^6 = 3.5 \times 10^{-9} = 3.5 \text{ ns}.$$

With digital scopes, however, minimum instrument T_r varies between 0.8 to 1.6 of the sample intervals. If you measure between 10% and 90% of the pulse amplitude, the maximum possible rise time is

$$T_r = 0.8 \times 2(\text{sample interval})$$
$$T_r = 1.6/(\text{sampling rate}).$$

Because the most limiting measurement errors occur when a 1.6 sample interval is used, the useful rise time (UT_r) can be deined as

$$UT_r = 1.6/(\text{sampling rate}) \text{or}$$
$$UT_r = (\text{minimum sample interval}) \times 1.6.$$

So in a worst case situation where digitizing rates were 100 Ms/s, the minimum sample interval would become 0.01 μs and

$$T_{rDSO} = 0.01 \times 1.6 = 16 \text{ ns}.$$

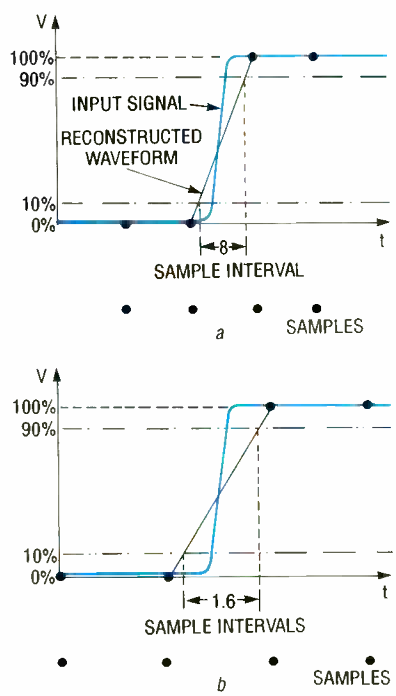
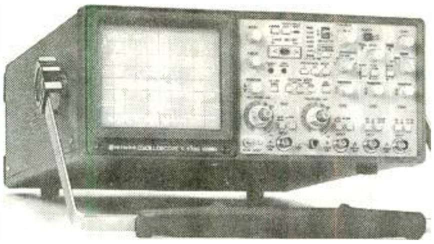


FIG. 3—RISE TIME IS AN IMPORTANT parameter in recording pulses. Errors in rise time made by a DSO depend on sample placement. The displayed signal can vary from 0.8 (*a*) to 1,6 (*b*) sample intervals.



HITACHI PRESENTS EIGHT MODELS of DSO's with attractive specifications, some even have four inputs.

That calculation is based on pulses, not on dots, which are said to have further error conditions, and sine waves may appear faster than the actual input signals due to induced preshoots and overshoots resulting from a small number of input samples.

In Fig. 3-a, the step is exactly between two sample intervals, with a rise time of the resulting display of 0.8 × (sample interval). While viewing the same signal in Fig. 3-b, a sample acquisition is taken in the middle of the step. This is the worst case where the rise time shown in the display is equal to 1.6 × (sample interval).

The real-time resolution between samples can also be calculated easily by dividing the sampling rate by 10 and then taking the reciprocal of that value.

$$\text{Res} = 100\ (\text{Ms/s})/10 = 10\ \text{MHz}$$
$$1/10\ \text{MHz} = 100\ \text{ns}$$

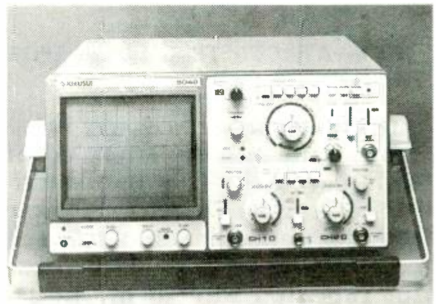
As a practical example, a 100-Ms/s scope would sample every 10 nanoseconds ($1/100f \times 10^6$). Faster sampling would require a higher input-amplifier frequency response. A 500-Ms/s instrument would need a rise time of 1.17 ns since it samples every 2 ns. Be aware of such parameters at all times when undertaking rise time and glitch measurements since bandwidth limitations cause both amplitude and sample timing errors. Unlike an analog scope, you cannot use the useful rise time to work back and calculate the rise time of the original pulse. UT_r is a measure of the upper limits of performance of a DSO.

Now that we've covered some critical aspects of DSO bandwith and rise time, let's look a little deeper into the process of waveform digitization.

Digitizing basics

The primary difference between DSO's and analog storage scopes is their method of storing waveforms. DSO's digitize waveform data, which is then stored in digital memory, while analog storage scopes store waveforms in the CRT by either bistable or mesh storage techniques.

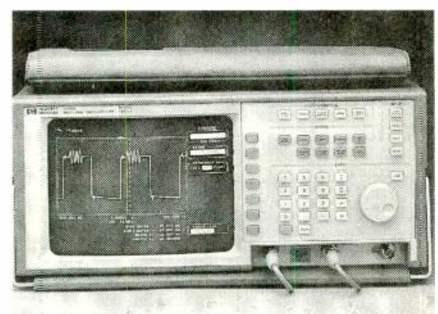
There are three stages involved in digitizing; sampling, quantizing, storage, and readout. Sampling obtains a value of an input signal at specific points in time. Quantizing uses analog-to-digital conversion to transform the sampled values into binary numbers for storage. The digitizing rate is determined by the time base, which is a very precise digital clock. The time base provides discrete points in time to reference the quantized values of the input signal. The digitizing rate is usually specified in megasamples per second (Ms/s), or points per second, as we mentioned earlier. This digitizing normally occurs in the more modestly priced DSO's with an 8-bit (2^8) converter producing 256 voltage levels. The digitized samples are then stored in memory, and converted back to analog form using a digital-to-analog converter (DAC). A block diagram of a DSO is shown in Fig. 4.



KIKUSUI MODEL 5040 is a 400-MHz, 25-Ms/s dual-channel scope with 1K per channel of memory storage.

Sampling

DSO's use two types of sampling techniques—real time (or one-shot) and equivalent time sampling. Random events, or one-shots, are every-day phe-



HEWLETT PACKARD'S SPECIAL—a dual channel, large screen digital (only) 54510A scope that digitizes 2 channels at 1 gigasample per second (Gs/s) with 8-bit vertical resolution.

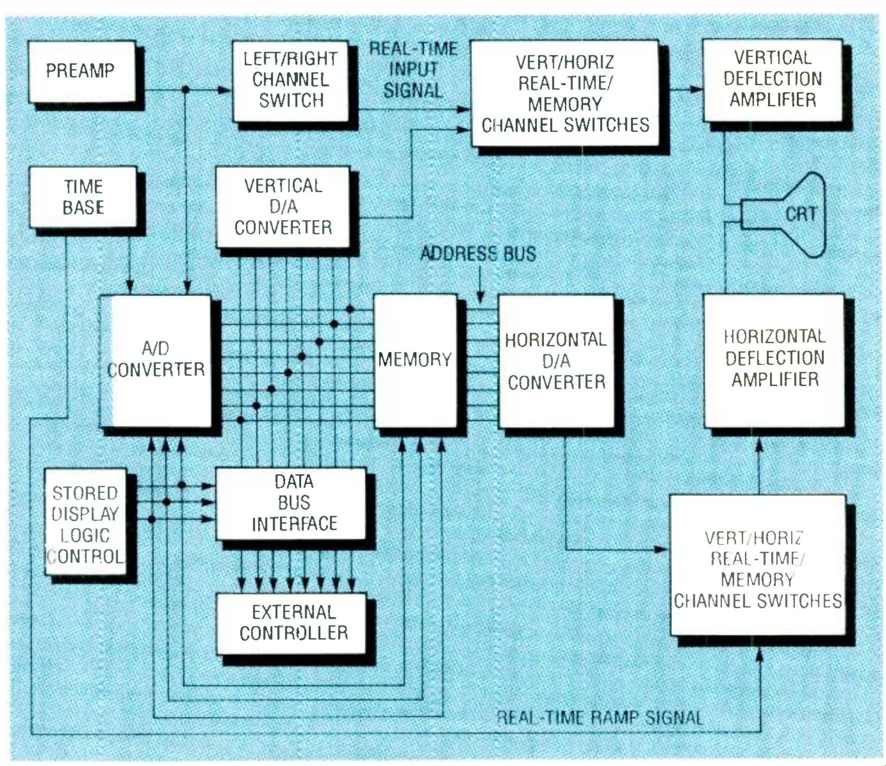


FIG. 4—BLOCK DIAGRAM OF A DSO. The input signal is digitized by an A/D converter and stored in memory in digital form. To view the waveform on the CRT the data from memory is reconstructed in analog form using a D/A converter.

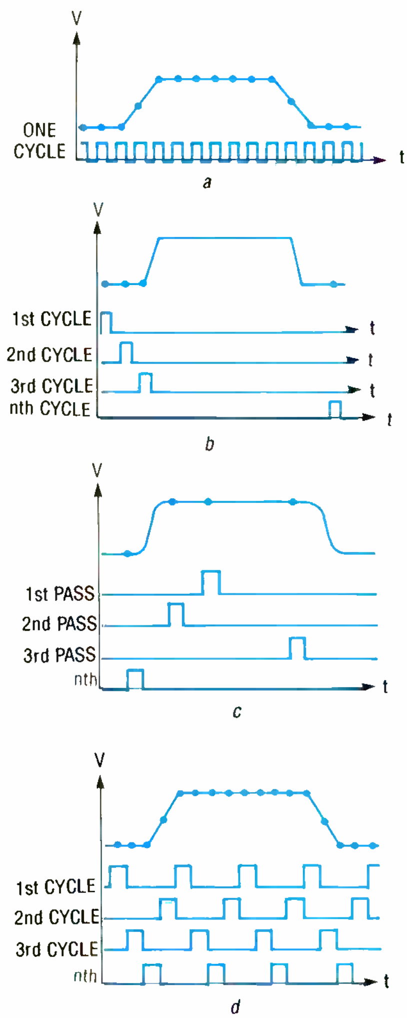


FIG. 5—SAMPLING TECHNIQUES of a DSO in real time(*a*) and equivalent times (*b–d*); sequential sampling (*b*) samples one point of the waveform or every cycle, random sampling (*c*) takes signals in a random sequence. Pre- and post-triggering capabilities are retained with random sampling. Multiple point random sampling (*d*) takes several points of a waveform in one cycle, thereby reducing acquisition considerably.

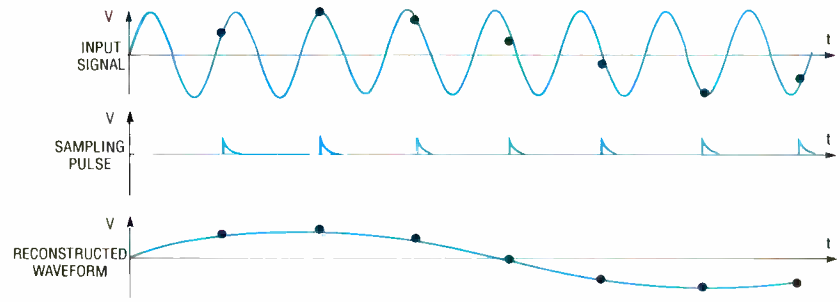


FIG. 6—A RECONSTRUCTED WAVEFORM is shown from an input signal that has been sequentially sampled.

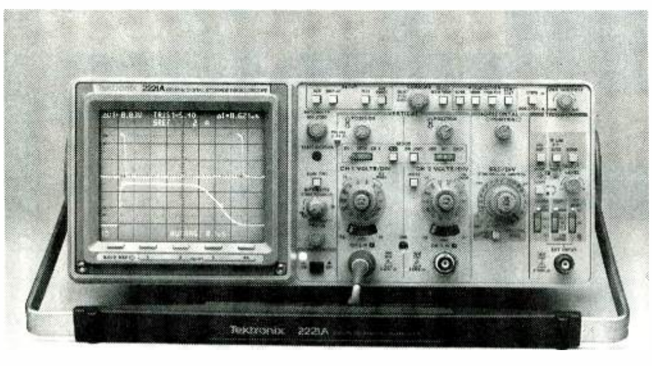
nomena occurring naturally under almost every conceivable circumstance. Repetitive or recurrent events are usually man-made and may be sampled at some part of the information during each cycle. Therefore, sample rates for a one-shot event must be comparatively faster than those for repeated waveforms in sequence. Consequently, any DSO capable of repetitive sampling can accumulate and digitize considerably more high speed intelligence than one designed solely for one-shots, also called real time.

In real-time sampling, all samples for a signal are taken during a single pass. When a transient event occurs, such as a mechanical failure/shock, power-supply surge, or a biophysical response, it is usually short-lived and may not be repeated. A transient event must be captured while occurring, and sampled sequentially, from start to finish in one single sweep by real-time sampling. Figure 5-a shows how real-time sampling is used to reconstruct a sloping rectangular wave in a single cycle.

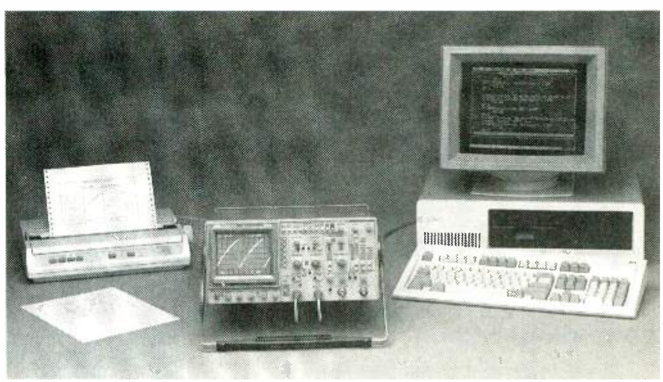
Equivalent-time sampling constructs a picture of a waveform by capturing a small bit of information from each signal repetition. That type of sampling is useful only for capturing repetitive signals. There are two types of equivalent-time sampling; sequential and random sampling. Figure 5-b shows how sequential sampling takes one point of the waveform for every cycle. That process is repeated sequentially until the digital memory is filled. A reconstructed waveform using sequential sampling is shown in Fig. 6.

In addition to real time and repetitive events for DSO display, there is random sampling of information (Fig. 5-c) related directly to the scope's trigger point which also permits pre- and post-triggering waveform evaluations, which sequential sampling cannot do. Multiple-point random sampling (Fig. 5-d) produces one coordinated output from a number of inputs. Some analyzers also have several storage banks where one display can be compared with another, especially triggering actions and preceding or following bytes of serial or related information.

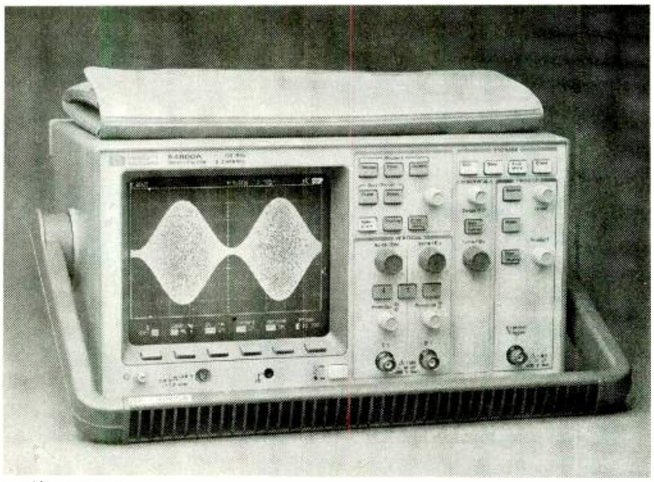
Real-time sampling of a DSO requires as many as 10 samples per period to accurately reconstruct a single-shot waveform. Repetitive sequential signal acquisition, however, is not determined by digital bandwidth restrictions, but by the oscilloscope's vertical (analog) am-



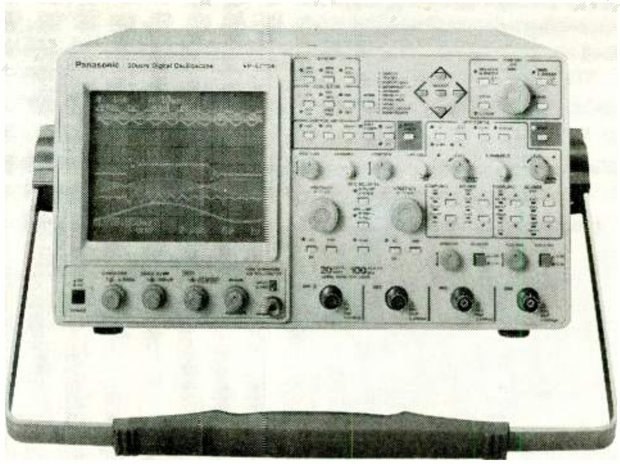
THE NEW TEKTRONIX 2221A 100-Ms/s analog and digital storage scope offers advanced digital processing capabilities in an economical 100 MHz bandwidth DSO.



TEKTRONIX' ANALOG 2252 4-channel scope with a 12-bit A/D converter, an Epson FX-series printer, and an IBM remote PC all combined to form a complete recording package.



HEWLETT PACKARD'S MODELS 54600 and 54601 combine the convenience and display responsiveness of analog instruments with the measurement power of digital architecture. Both models feature 100-MHz repetitive bandwidth, 2-MHz single-shot bandwidth, 20 Ms/s, and a pushbutton hardcopy output.



PANASONIC'S VP-5710A is a menu-driven, 4-channel DSO with a large 64K memory. A unique display position lets you view a large part of the signal on the top of the screen, with a small portion of the waveform below it.

plifiers since there is no mutual time relation between the digitizers internal clock and incoming signal, even though such sampling occurs at fixed intervals. Often, the clock rate is considerably lower than that of the sampled signal. That means that a 100-MHz analog/digital oscilloscope can reasonably display 100 MHz analog and repetitive signals, and only 10 MHz real-time information. That's a significant statistic in evaluating DSO's, although that 10:1 ratio can increase to 6:1 and even 2.5:1 in some of the higher bandwidth instruments with generous interpolation, as we have already discussed.

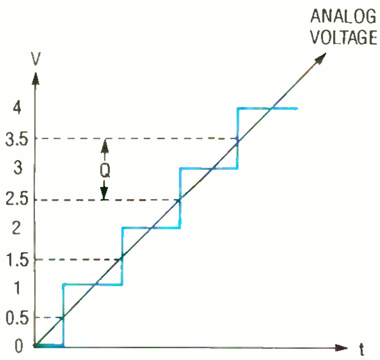


FIG. 7—QUANTIZING BY A/D converters transforms analog voltages into digital binary bits at selected levels.

Quantizing

Quantizing develops as the next step, and is simply defined as a staircase of discrete levels identifying logic bit assignments of analog values to the variously sampled points. As shown in Fig. 7, when the analog voltage increases, decision levels are reached causing the ADC to change states adding additional "1's" and "0's" to the binary output. As always, there's a small measure of uncertainty in any digital electronic processing, and that quantity is usually expressed as ± the least significant bit (LSB). Here, however, quantizing uncertainty registers as noise and the fewer AD bits the more noise. Larger AD's have proportionally less noise, as you might expect.

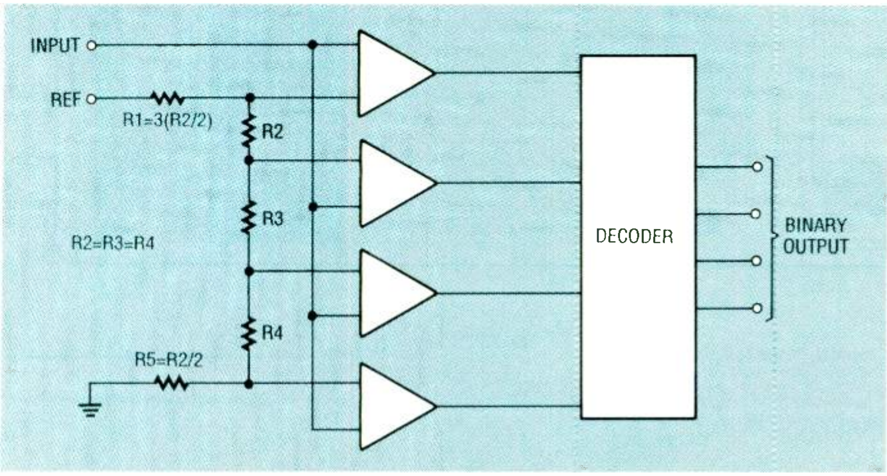


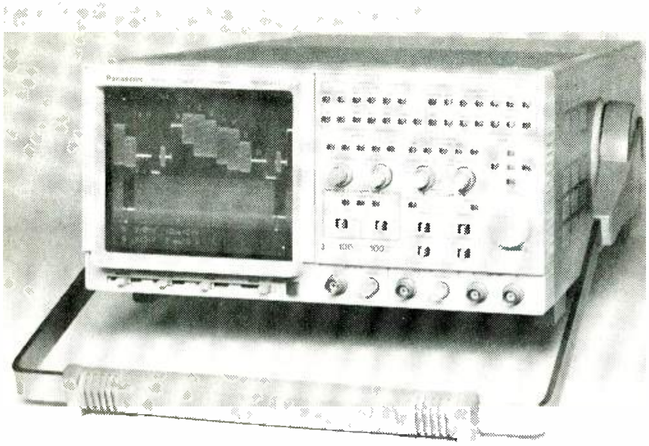
FIG. 8—A FLASH CONVERTER is used to quickly convert analog signals to digital output. Resistors, comparators, and their quantizing decoder are shown.

A/D converters

There are various methods of digitizing different voltage levels of a waveform. Four types we will discuss are: successive approximation, flash conversion, charge coupled devices (CCD's), and scan converters.

Successive approximation compares an input voltage with respect to the output of a digital-to-analog converter (DAC). It selects a position for the most significant bit (MSB) in discrete but fixed-time conversion steps. Therefore, there's a tradeoff involving both resolution and converter speed, which means long conversion times for maximum resolution conversion.

A more commonly used method is that of flash conversion (Fig. 8) involving a number of resistive dividers, an equal number of comparators, and a decoder which produces binary outputs. Flash conversion is used in a number of applications, including video codecs, where signals are applied to one input of the comparators and a reference or bias voltage across equal-value resistors to the other comparator input. With input voltages exceeding the reference, all com-



PANASONIC MODEL VP-5741A has the same features as the 5720A except it has an analog bandwidth of 100 MHz with a sampling rate of 100 Ms/s and a 10K × 3 memory storage.

PANASONIC MODEL VP-5720A is a 2-channel, 50-MHz repetitive bandwidth DSO featuring a 15-MHz single-shot bandwidth and a 40 Ms/s sampling rate. It has a 8K × 3 memory storage and an expandable memory option.

parators deliver a high output, and zero inputs result in a low. In between, combinations of various voltage levels proceed into the encoder and result in a regular binary bit-stream driven by a rapid-system clock.

Flash converters have a fast conversion rate, but they can be expensive and their resolution decreases as the sampling rate is increased. You may want to consider a CCD which accepts inputs at over 100 Ms/s. A CCD is not an actual ADC, but an analog sampler which accesses rapidly and, by bucket-brigade action, converts the samples to a considerably lower rate at some discrete level. Its "bucket" cells are charged accordingly and represent an equivalent number of data points during a single incoming cycle, reserving several cells for CCD control.

The advantages of CCD's are their 100-Ms/s operation and lower cost over flash converters. Also, the resolution does not decrease as the sampling rate is changed. One disadvantage of CCD's is that the scope cannot accept data during the digitizing period.

Scan conversions are also possible with double-ended cathode ray tubes that store intelligence on one side of the CRT target, reading it off with a separate beam on the target's back side. They're very fast but expensive, and no new information may be

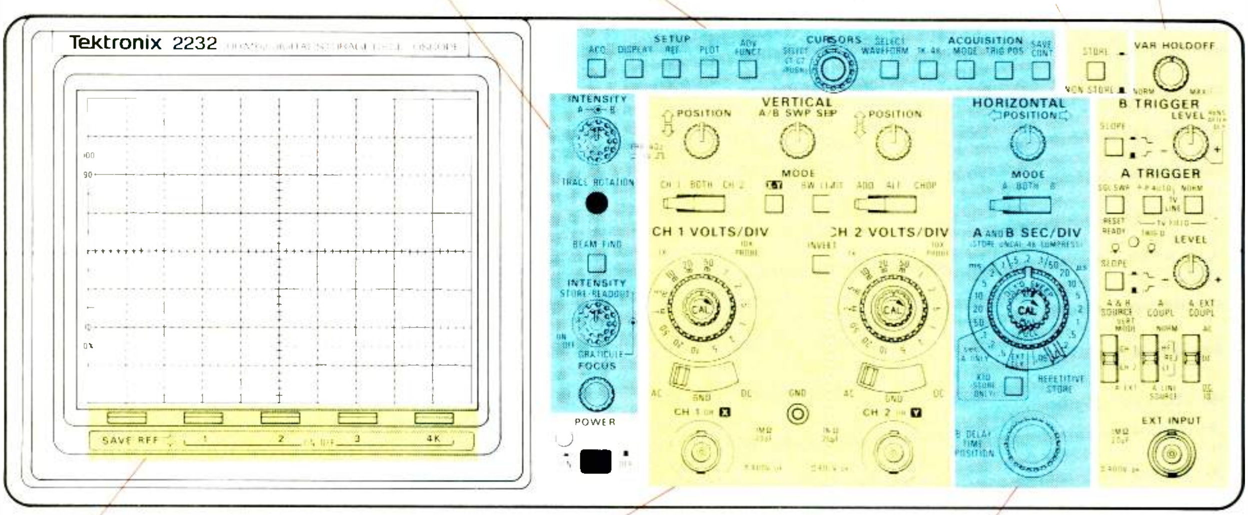


Fig. 9—FRONT PANEL CRT and the various analog and digital controls for Tektronix' 2232 100 MHz and 100 Ms/s analog/digital oscilloscope.

received during reverse target scan.

Storage

Storage, also called memory, has differing record lengths denoting available random access memory (RAM) or read only memory (ROM). RAM's store variables such as incoming data information, while ROM's are fixed and permanent memories of instrument display characteristics, algorithms, and other implanted procedures.

Stored information may be collected on disks, magnetic tape, and possibly bubble memories. But the shorter and more common means of storage are usually metal-oxide semiconductors such as CMOS, NMOS, or emitter-coupled bipolar logic (ECL). The larger the memory, the longer its time to fillup and update refreshment. So record lengths of 4K to 32K could have several interpretations, depending on individual requirements.

Horizontal jitter

Occurring in many analog scopes and some of the older, less expensive DSO's, horizontal jitter can actually ruin precision measurements of both sine waves and pulses. It appears in repetitive situations and is calculated as ± ½ the elapsed time between samples. In most of today's storage scopes, jitter compensation or correction is already built-in and should not be a problem. But unstable voltages entering analog equipment still cause various problems since they are directly related to the scope's internal trigger and its own inherent stability.

Resolution and accuracy

The vertical resolution of an oscilloscope is its ability to distinguish between signals which are close together. Vertical resolution in a DSO is determined by the number of bits used in the ADC. For example, an ADC that uses an 8-bit converter has a vertical resolution of 256 (2^8), or 0.391% (1/256).

If you know the bit count of an ADC, it's easy to find a DSO's vertical resolution. For instance, a full-scale scope graticule setting of 50 mV/div. would become 400 mV, with 8 vertical divisions.

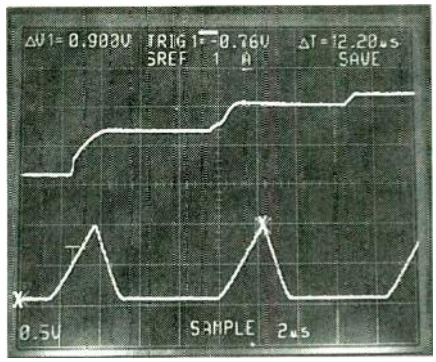


FIG. 10—A SEMI-STAIRCASE reference voltage and an "acquired" channel 1 signal below. All readouts, including trigger reference, applies to the lower signal which was supposed to be a sawtooth.

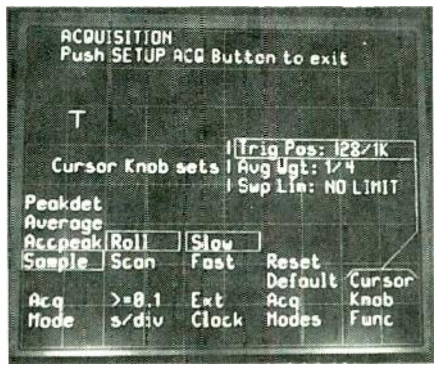


FIG. 11—INITIAL SELECTABLE SETUP for incoming waveforms in one of the storage modes.

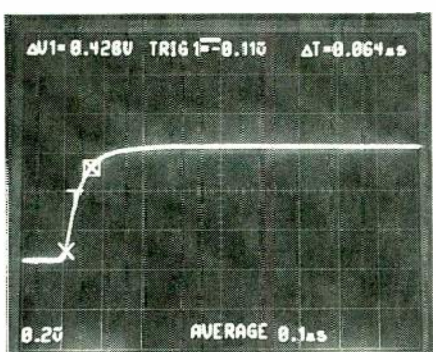


FIG. 12—CRITICAL MEASUREMENTS are both easy and accurate with a good DSO. Here you're looking at a simulated one-shot with a very fast rise time.

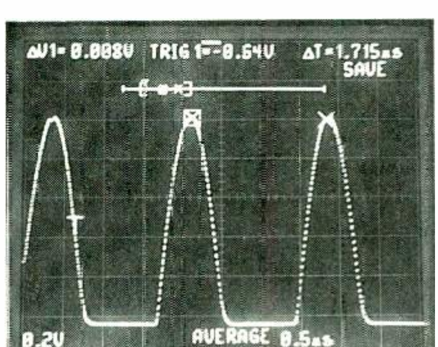


FIG. 13—AT 4K STORAGE, interpolation, or lack thereof, is plainly evident as the relatively flat times of these rounded pulses indicate.

Then, if your A/D offers 8-bit conversion, that would amount to 2^8 discrete levels, or a total binary number of 256. Therefore, your DSO's vertical resolution would become

$$400 \times 10^3/256 = 1.5625 \text{ mV}.$$

Similarly, a 4-bit A/D instrument would only exhibit 25 mV resolution (·4⁄16). So the combination of analog-to-digital conversion bits and vertical scale settings do, indeed, determine a DSO's ability to separate the various details of waveforms. That differs from accuracy, which is an accepted standard value that the scope may or may not fully reproduce. Measurements, however, can't be more accurate than the DSO's resolution, and that's why such resolution becomes extremely important.

Horizontal resolution is a measure of the number of time increments that are stored in digital memory. If the signal is stored in 1024 data words, then the horizontal resolution is 1⁄1024 or 0.098%.

According to Tektronix, analog cathode ray tube resolution is derived from the CRT face area and the size and shape of its electron writing beam. The vertical and horizontal CRT amplifiers generally become further limiting factors in the analog domain. But in a digital scope, vertical resolution amounts to A/D resolution, but its accuracy, like analog scopes, depends on input and output amplifiers and is no more than 2–4% vertically and 1-3% horizontally. However, with images "frozen" on the CRT's face and the use of accurate markers called "cursors," many of the foregoing errors can be largely overcome, especially the horizontal ones.

A DSO uses a crystal oscillator clock instead of a linear sweep to generate its time base. The digital clock is so precise that accuracy of 0.01% is possible with great stability. Consequently, while vertical accuracy is largely limited by analog readout, horizontal accuracy becomes that of the clock, memory length, and/or cursor resolution and precision—a vast difference over ordinary analog which is usually no better than 2% and subject to inevitable drift with aging. Another

TABLE 1—DIGITAL STORAGE OSCILLOSCOPE CHARACTERISTICS

Manufacturer	Model No.	Analog Bandwidth	Maximum Sample Rate	Y-channel Inputs	Cursors	On-Screen Readouts	Vertical Resolution	Standard Acquisition Modes*1	Memory Storage	Time Base (seconds/div.)	Recorder Outputs*2	Price
B&K Precision	2522	20 MHz	10 Ms/s	2	No	none	8 bits	*3	2K/ch	0.2s-0.5µs	Pen lift outputs	$995
Philips/Fluke	95 Handheld	50 MHz	25 Ms/s	2	Yes	Yes	8 bits	*7	Store/recall 8 waveforms	60s-10ns	—	$1,295
	97*6Handheld	50 MHz	25 Ms/s	2	Yes	Yes	8 bits	*7	Store/recall 8 waveforms, 10 setups	60s-10ns	Remote control RS-232C interface	$1,595
	PM3320A	200 MHz	250 Ms/s	2	2 X-Y	Yes	10 bits	*8	4 memories of 4Kx10-bit words	5s-5ns	RS-232 or IEEE 488 interface	$7,750
	PM3323	300 MHz	500 Ms/s	2	2 X-Y	Yes	10 bits	*8	4 memories of 4Kx10-bit words	5s-5ns	RS-232 or IEEE 488 interface	$8,500
	PM3335	60 MHz	20 Ms/s	2	Yes	Yes	8 bits	auto, single multisingle	16K	50s-10µs	RS-232 or IEEE 488 interface	$2,395
	PM3350A	60 MHz	100 Ms/s	2 with auto set	2 X-Y	Yes	8 bits	*3 plus auto zoom	16K (8 traces)	0.5s-0.5µs	X-Y rec. and matrix printer option 40/50	$3,590
	PM3355	60 MHz	250 Ms/s	2 with auto set	2 X-Y	Yes	8 bits	*3 plus auto zoom	16K (8 traces)	0.5s-0.5µs	X-Y rec. and matrix printer option 40/50	$4,490
	PM3365A	100 MHz	100 Ms/s	2 with auto set	2 X-Y	Yes	8 bits	*3	16K (8 traces)	0.5s-0.5µs	Pen lift outputs	$4,990
	PM3375	100 MHz	250 Ms/s	2 with auto set	2 X-Y	Yes	8 bits	*3	16K (8 traces)	0.5s-0.2µs	Pen lift outputs	$5,390
Gould	1604	20 MHz	20 Ms/s	4	2	Yes	8 bits	*3 plus auto zoom	10K	200s-50µs	X-Y	$6,595
	1624	20 MHz	20 Ms/s	4 (with pairs)	2	Yes	8 bits	*3 plus auto zoom	10K	200s-5µs	X-Y	$8,195
Hameg	HM408	40 MHz	40 Ms/s	2	X-Y	Yes	8 bits	*3	2K	1s-50ns	Plotter	$2,398
	HM205-3	20 MHz	20 Ms/s	2	No	No	8 bits	*3	2K	1s-200ns	Plotter	$1,076
Hewlett Packard	54501A	N/A	10 Ms/s	4	2	Yes	8 bits	*3 programmable	501 points	5s-2ns	Plotter	$3,990
	54502A	N/A	400 Ms/s (repetitive)	2	2	Yes	8 bits	*3 programmable	501 points and 2K extendable	5s-1ns	Plotter	$7,450
	54600A	100 MHz	20 Ms/s	2	2	Yes	8 bits	*3	4K	5s-2ns	Plotter and printer option	$2,395
	54601A	100MHz	20 Ms/s	4	2	Yes	8 bits	*3	4K	5s-2ns	Plotter and printer option	$2,895
Hitachi	VC6023	20 MHz	20 Ms/s	2	2	Yes	8 bits	*4	2K	50s-0.2µs	Plotter	$1,995
	VC6024	50 MHz	20 Ms/s	2	2	Yes	8 bits	*4	2K	50s-0.2µs	Plotter	$2,295
	VC6025	50 MHz	20 Ms/s	2	2	Yes	8 bits	*4	2K	50s-50ns	Plotter	$2,595
	VC6045	100 MHz	40 Ms/s	2	2	Yes	8 bits	*4	4K	50s-50ns	Plotter	$3,395
	VC6145	100 MHz	100 Ms/s	4	2	Yes	8 bits	*4	2K	50s-50ns	Plotter	$5,295

Kenwood	CS8010	20 MHz	10 Ms/s	2	2	Yes	8 bits	*5	2K	1s-0.5µs	Plotter	$1,495
Kikusui	DS5020A	20 MHz	1 Ms/s	2	No	No	8 bits	*5	1K/ch	1s-0.2µs	X-Y recorder	$1,495
	DS5040	40 MHz	25 Ms/s	2	No	No	8 bits	*5	1K/ch	1s-0.2µs	X-Y recorder	$1,995
	COM7101A	100 MHz	50 Ms/s	4	Yes plus DVM, Counter	Yes	8 bits	*5	1K/ch	0.05s-10ns	X-Y recorder	$5,895
	COM7201A	200 MHz	50 Ms/s	4	Yes plus DVM, Counter	Yes	8 bits	*5	1K/ch	0.05s-10ns	X-Y recorder	$6,895
Leader	300 handheld	N/A	30 Ms/s	2	No	Yes	7 bits	*5	1.8K words/	200s-0.1µs	Plotter	$1,995
	3100D	100 MHz	40 Ms/s	2	2	Yes	8 bits	*5	2K words/ch	50s-50ns	Plotter	$3,695
LeCroy	9410	150 MHz	100 Ms/s	2	2	Yes	4096 points	*5	10K/ch	10^3s-2ns	X-Y and dot matrix	$6,900
Nicolet	NIC310	N/A	1 Ms/s	2	2	Yes	12 bits with zoom	*5	Floppy disk 88 4K/disk	200s-1µs	X-Y or strip chart	$4,995
Panasonic Factory Automation Co.	VP-5710A	100 MHz	20 Ms/s	4	GND-V, ΔtΔV, t1/Δt	Yes	8 bits	Roll, rep. 8-MHz Single shot	6K×1 or user adjustable memory	0.5s-20ns	GP-IB plotter interface	$3,995
	VP-5720A	50 MHz	40 Ms/s	2	Yes	Yes	8 bits	Programmable	8K×3	50s-5ns	GP-IB plotter interface, X-Y	$5,900
	VP-5741A	100 MHz	100 Ms/s	2	Yes	Yes	8 bits	Programmable	10K×3	50s-5ns	GP-IB plotter interface, X-Y	$8,900
	VP-5750A	100 MHz	200 Ms/s	2	Yes	Yes	8 bits	Roll, rep. Programmable	80K non volatile memory	50s-5ns	GP-IB plotter interface, X-Y	$9,900
Tektronix	222 PS	10 MHz	10 Ms/s	2	No	Yes	8 bits	Roll, scan	512 points	20s-0.05µs	RS-232 interface	$3,295
	TDS520	500 MHz	500 Ms/s	2	Yes	Yes	8 bits	Ref., roll, detect	50K points/ch.	10s-500ps	GP-IB 488.2	$9,490
	2201	20 MHz	10 Ms/s	2	No	No	8 bits 25 levels/div.	Roll/scan	2K	50s-100ns	Epson (optional)	$1,695
	2211	50 MHz	20 Ms/s	2	2	Time and volts	8 bits 25 levels/div.	Roll/scan	4K	50s-50ns	Epson (standard)	$2,795
	2221A	100 MHz	100 Ms/s	2	2	Yes	8 bits	*5 and X-Y plot	1K/4K	0.5s-5ns	X-Y or dot matrix	$3,995
	2232	100 MHz	100 Ms/s	2	2	Yes	8 bits	*5 and X-Y plot	4K extended to 25K	0.5s-5ns	X-Y or dot matrix	$4,995

Notes *1. Standard acquisition modes become special acquisition modes in some cases. Contact the manufacturer for detailed information on variations of acquisition modes.
*2. Recorder outputs are normally either X-Y or dot-matrix plotters, but they can be strip charts and floppy disks as well. The individual specification sheets will list the many available options.
*3. Roll, refresh, single shot.
*4. Roll, average, smoothing, one shot.
*5. Roll, pen, one shot.
*6. Special features of Fluke's handheld model 97 include sine wave or square wave signal generator, component tester output for voltage or current ramp and various multimeter modes.
*7. Min., max., average record, variable persistance.
*8. Auto, auto zoom, single, multisingle, roll, triggered roll, averaging, enveloping, save/stop on diff.

FLUKE'S HANDHELD SCOPEMETER models 95 and 97 feature 50-MHz dual channel, 25 Ms/s sampling rate with autoset. A combination DSO and DMM, these instruments are ideal for rugged field use. Model 97 also has a sine wave or square wave signal generator output with optically isolated RS-232C remote control operation.

strong argument for maximum DSO horizontal accuracy is repeatability of measurements, and reduction of human errors by the use of cursors.

The front panel

Now that you have a general idea of what DSO's are designed to do, let's quickly introduce you to the front panel of a Tektronix model 2232 100 MHz, 100 Ms/s digital/analog oscilloscope from graticule to the front panel, CRT and dot-matrix (they're less expensive) printer readouts.

Figure 9 shows the bezel and all front panel analog and digital controls. The callouts indicate 1× and 10× vertical amplifier settings from 2 mV to 50 V/div., sweep speeds from 50 ns/div. to 0.5 s/div., delayed sweep, TV field and line, variable holdoff, triggering levels, and X-Y mode in the analog sections and setup, display, plotter, signal acquisition, storage, cursors, plotter output, waveform select, memory acquisitions, and save references, plus setup menus in the digital portion. A side panel contains an auxiliary connector and IEEE 488 or RS-232 port.

Applications

The first example shown in Fig. 10 is an output of a less expensive function generator with slight calibration and waveform purity problems, both of which are often found in inexpensive digital circuits. The bottom waveform is "supposedly" a reasonably linear sawtooth, while the top waveform is semi-staircase. The display has a time base of 2 μs/div., is sampled at 1K, its AC voltage develops to 0.9 V since the vertical amplifier is set at 0.5 V/div., the trigger level for amplifier Y1 reads out at 0.76 V, and the time between X origin and X Δ time T equals 12.2 μs. With absolutely no trace movement the mode is "save," and the SREF 1 A is included since it was previously stored. The line under "A" means the cursors are now positioned as shown on the acquired signal. The SAVE REF 1 remains until another waveform writes over this one and takes its place in memory.

Except for the stored SREF 1 A, that same signal could have been shown similarly by an ordinary analog scope but probably without as much stability and probably without the on-screen readouts. The only fundamental parameter not immediately read out in modestly priced DSO's is the voltage difference between pulse peaks, and that is simply the inverse of time which is easily calculated, but not as accurate as 3-place electronic computation.

Incoming information

Now that programmable and primary hardware have been combined, let's begin to move on to some more intricate uses. With the help of a Tektronix/Polaroid C5-C oscilloscope camera, a menu for the Acquisition mode is adjusted so the 2232 will respond

DSO SOURCES

B&K Precision
6470 W. Cortland St.
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(312) 889-1448
CIRCLE 351 ON FREE INFORMATION CARD

John Fluke Manufacturing Co.
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Everett, WA 98206
(206) 356-5500
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Gould Inc. Recording Systems Div.
3631 Perkins Ave.
Cleveland, OH 44114
(216) 361-3315
CIRCLE 353 ON FREE INFORMATION CARD

Hameg Inc.
88-90 Harbor Rd.
Port Washington, NY 11050
(516) 883-3837
CIRCLE 354 ON FREE INFORMATION CARD

Hewlett-Packard Co.
19310 Pruneridge Ave.
Cupertino, CA 95014
(800) 752-0900
CIRCLE 355 ON FREE INFORMATION CARD

Hitachi Denshi America Ltd.,
Test & Measurement Div.
150 Crossways Park Dr.
Woodbury, NY 11797
(516) 921-7200
CIRCLE 356 ON FREE INFORMATION CARD

Kenwood USA Corp.
2201 E. Dominguez St.
Long Beach, CA 90810
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Torrance, CA 90503
(213) 371-4662
(800) 545-8784
CIRCLE 358 ON FREE INFORMATION CARD

Krenz Electronic, Inc.
1020 Calle Cordillera
Suite 107
San Clemente, CA 92672
(714) 361-2433
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Hauppauge, NY 11788
(516) 231-6900
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Chestnut Ridge, NY 10977
(914) 425-2000
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Nicolet Instrument Corp.
Test Instrument Division
PO Box 4451
Madison, WI 53711
(608) 273-5008
CIRCLE 362 ON FREE INFORMATION CARD

Panasonic Factory Automation Co.
Electronic Measurement Systems
9401 West Grand Ave.
Franklin Park, IL 60131
(708) 452-2501
CIRCLE 363 ON FREE INFORMATION CARD

Tektronix Inc.
Test and Measurement Group
PO Box 1520
Pittsfield, MA 01202
(800) 426-2200
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to these or other selected settings in preparation for either convenient or specific measurements (Fig. 11). Our attention will be directed to the various setup possibilities that are available on the setup menu. A rectangle denotes each selected position.

In Fig. 11, the Sample mode is selected which produces 100 samples for each graticule division; the greater than 0.1 s/div. selects either Roll or Scan storage for settings above this figure. Roll mode is somewhat like an electronic chart recorder, permitting slow signals to move across the CRT's face continuously from right to left; and the Trigger, indicated at 128/1K storage by the "T" symbol towards the upper left can be adjusted and positioned incrementally between 4 and 1020 on the 1K record, or from 16 to 4080 on the 4K record.

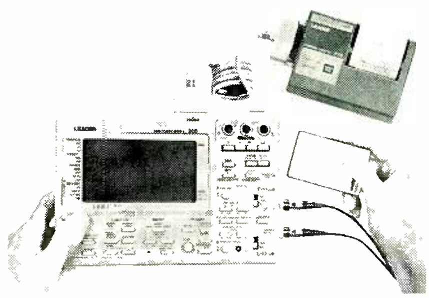
In the Acquisition mode's sister display menu, Δ Time and Δ Frequency may also be selected as well as Peak Detect, waveform smoothing, and a Vectors mode, filling spaces between adjacent data points, producing a smooth, connected image. In Auto, Vectors operate at all times except from 0.5 to 0.05 μs (Repetitive Store).

Examples

Now that parameters are established according to the acquisition setup in Fig. 11, it's easy to look at such critical values as voltage measurements, trigger levels, and rise times shown in Fig. 12. At 0.1 μs/div. and 0.2 V/div., the Δ voltage readout is 0.428 V, the trigger position is at 0.11 V, and the time between 10% and 90% markers measures 0.064 μs which automatically becomes the rise time.

When you turn the scope and signal information off for several hours, the same stored display reappears when power is applied. You haven't missed anything, and all the parameters remain. A Polaroid photo of the display records the image for posterity. If you want to translate those microseconds into nanoseconds, just move the decimal three places to the right and the rise time becomes 64×10^{-9}. It's just that simple.

The waveforms of Fig. 13 are shown at a 4K sample rate which



LEADER'S MODEL 300 features 30 Ms/s digital storage with a DMM, printout, and logic analyzer combination.

builds up the display over a considerable period. The interpolation isn't quite extensive enough to form a continuous pattern among the rise and fall portions. That occurs when sweep speeds exceed 1 μs/div. The bar graph above the "rectangled" cursor signals a switch to a 4K-record length, although only 1K of information is displayed at a time. The T for trigger point remains, but only at the 0.64 V level, and the time between cursors amounts to 1.715 μs. The amplitude (Δ V1) difference between the two cursors is only 0.008 V, which is fairly close to being even. The "Average" notation on the display's bottom means random signal noise is reduced by multiple signal inputs over a number of records.

Where you looking for a glitch among those voltages, you would select the peak or AC-peak detect mode, making the 2232 sample at its maximum digitizing rate as you search for a 10 ns or greater waveform abnormality. Note how nicely those displays photograph with a C5-C camera.

Digital featues are gradually making their way into analog scopes (see our Analog Oscilloscope article in this issue). Tektronix' 2252 is a multi-application analog scope with 4-trace readout and an ADC. The 2252 is strictly analog from input to virtual output, but one large 12-bit A/D converter for hard copy reproduction bars the way. Tek's 2252 is a 4-channel, 100-MHz answer to those who want to see glitches, spurs, preshoots, overshoots, and all associated interruptions greater than 10 ns. It can be used with an Epson FX series dot-matrix printer, and doesn't require one-shot recorded storage. Plotter printouts of this unique one-of-a-kind instrument can show transients, preshoots, overshoots, and random glitches.

Evaluations

Most DSO's we'll mention fall within a 20–200 MHz group and are dual analog/digital units very popular now in the marketplace. Table 1 shows a rundown of many popular scopes now available, with some important specifications. Although several manufacturers, such as Hewlett Packard and Nicolet, do not produce combination units, they occupy strong positions in the industry and are included as well, plus two special digitizers, one of which doubles as a spectrum analyzer and the other a 4-channel analog scope with an A/D digital printer readout.

- Hitachi–A real surprise with eight models already available and more on the way. Prices are attractive, superb, inclusive specifications, and interesting bandwidths. Models VC-6075, VC-5175, VC-6275 are not listed, but are still available.
- Leader–Two new announcements: a 30 Ms/s AC/DC-operated DSO that also features an 8-bit logic analyzer, a data logger for DMM functions, and an auto-ranging digital multimeter, all in one 2.6 pounds instrument (Model 300); and a Mod. 3100 conventional analog/DSO having 100 MHz analog and 40 Ms/s with averaging "settable" from 2 to 256 bits, plus voltage, time, phase, and dB difference ratios.
- Hewlett Packard–Doesn't combine analog and DSO's, but produces DSO's only. Four of their less expensive DSO's are listed with their dual time base displays, custom integrated circuits, 8-bit A/D converters (except the 54502 which has a 6-bit converter), and modular probes. The company's newest is the HP 54510A at $10,950, having a sample rate of 1 Gs/s, repetitive bandwidth of 250 MHz and 8-bit vertical resolution—all portable.
- Tektronix–Not to be outdone by HP, Tektronix has introduced three all-digital scopes, one with a 10-MHz sampling rate and a deflection factor of 50 mV to 500 V/div. called the 222PS Power Scout. The 222PS is intended for rugged field work such as indus-

trial power systems, marine repair, and plant maintenance. Tektronix models TDS 520 and TDS 540 have two and four channels, respectively, and feature surface-mount components so that amplifier and trigger-logic circuits can be mounted on a single PC board.

In both models, digitizers operate continuously at full speed and peak-detect glitches as small as 4 ns, regardless of the time-base setting. The single-channel sampling rate for models TDS 520 and 540 is 500 Ms/s and 1 Gs/s, respectively. Record storage lengths are 50K points per channel, augmented by zoom previews and signal expansions plus 90 on-screen icons, or images, for user aids—the beginning of a brand new TDS series by Tek.

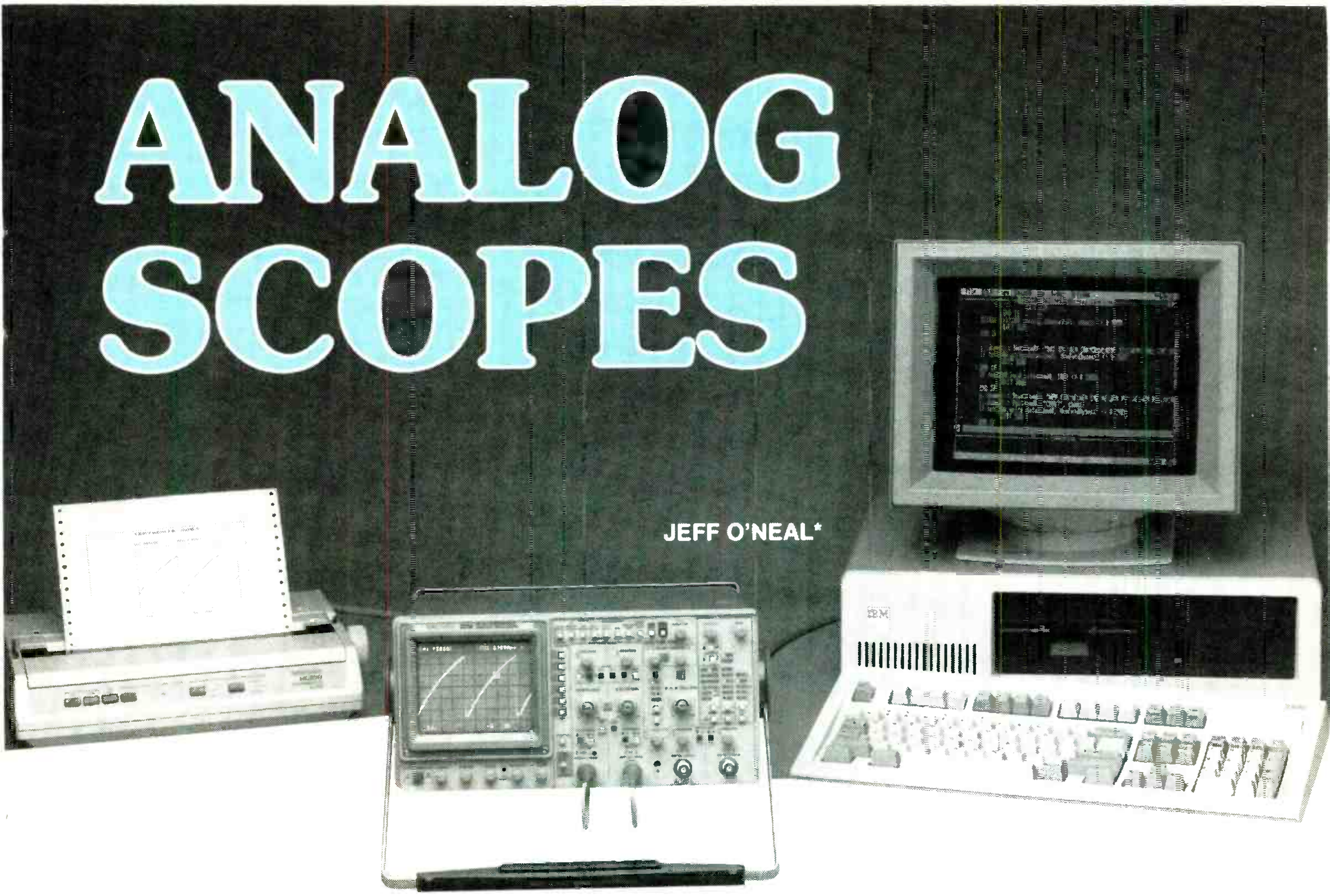
Relatively low cost for 100 MHz, 100 Ms/s, plotter and printer outputs, extensive training, simple controls, ample memory, good application notes, solid performance and long life.

- Nicolet–The NIC-310 is a new model with simplified controls, vertical and horizontal trace expansion to 60×, automatic signal acquisition, massive storage and built-on disk drive controls, also portable.
- LeCroy–Another fine manufacturer of high quality instruments whose Mod. 9410, large-screen scope, optional 512K credit card memory, vertical sensitivities as low as 100 μV/div., pen or digital plotter outputs, offers displays in color, and a 1,000-point fast Fourier transform (FFT) to be completed in less than a second (another option) to operate as a spectrum analyzer!
- Kenwood and B & K Precision—Manufacturers of similar, low frequency, inexpensive scopes with virtually identical specifications.
- Philips–Supplies several lower-cost analog and DSO combinations with interesting features, 100 and 250 Ms/s, 16K memories, and attractive pricing, together with excellent application notes—well worth investing in.
- Hameg–Also offers a pair of low-cost 20 and 40 MHz/Ms/s scopes (models HM205-3 and HM408) with 2K memories, X-Y cursors, and 8 bits of vertical resolution.
- Kikusui–Their COM 7101A and 7201A have four inputs and 200 MHz analog response and 50 Ms/s for digital storage. They include a DVM and a frequency counter.
- Krenz—Model 3350 is a 2-channel, 50-MHz, 100-Ms/s DSO with 8-bit resolution and a 4K memory. Krenz also offers a PSO 5570 MS-DOS compatible main frame with 8 channels, 20 MHz sample rate, up to 12-bit resolution, a 50-megabyte hard drive and a 1.44-megabyte floppy drive. Analog input modules with various preamp, A/D converter, and memory specifications are used with the main frame. Other base units offered are the PSO 7010 and PSO 7040 featuring 8 and 16 channels, respectively, with a 14" color video display for high-resolution color graphics.
- Panasonic—Starting at $3995 and ending at $9900, Panasonic currently produces four DSO's with reasonably large memories; three of the four have two channels with 7-inch CRT's. Model VP-5710A has a sampling rate of 20 Ms/s with 4 channels, model VP-5720 is a 2-channel, 40 Ms/s DSO with arithmetic and waveform functions, 100 Ms/s model VP-5741A has time shift and a calculator, and 200 Ms/s model VP-5750A has an 80K-word, nonvolatile memory in addition to autoranging, programmable, and interpolation functions. All have effective nonstorage bandwidths of DC to 100 MHz, except model VP-5720A which has a bandwidth of 50 MHz.

What you see in the scopes we've discussed is both low cost and limited effectiveness, and higher cost with broadly inclusive instruments which have many common and a number of diverse features. New models are appearing rapidly and designs almost improving daily. Some time bases even stretch to 50 and 200 seconds on the low end, highly suitable for measuring power applications, slow mechanical movements, ballistics, electrical phenomena, injection molding, drive controls, and so on.

We advise you to take your own sweet time in DSO selection, study all specifications, check short term and long term requirements, consider the source, review training and applications, then worry about the price. **R-E**

ANALOG SCOPES



JEFF O'NEAL*

...they're far from dead!

IF YOU'VE BEEN LEANING TOWARD buying a digitizing oscilloscope, you might want to take another look at analog scopes before spending your hard-earned money.

It's true that digital scopes offer many features—measurement cursors, automatic setup, programmability, and all those built-in microprocessor smarts. You can even transfer waveforms from a digital scope to a PC and do whatever you want with them—analyze them, store them on a disk, or output them to a printer.

However, modern analog scopes offer many impressive features as well. Many newer analog designs use built-in microprocessors for automatic setup, measurement cursors, and programmability. In fact, some analog scopes can even be hooked directly to a printer for waveform hardcopies. Waveform printouts, as well as many other features, are no longer the exclusive domain of digitizing scopes.

In short, today's analog oscilloscopes are much smarter than yesterday's. They offer many of the same features as digital scopes and even surpass them in a variety of basic measurement capabilities.

The real distinctions, however, are in how each type of scope acquires and displays waveforms for measurement. This has always been the fundamental issue in scope choice and continues to be so. It's an issue of understanding your waveform observation and measurement needs, then understanding how each type of scope addresses those needs.

Keep in mind, though, that each oscilloscope technology offers its own unique advantages. That's why many oscilloscope manufacturers offer both digital and analog scopes. Some scopes may even combine both technologies to take full advantage of the unique strengths of each.

Real-time vs. storage

Figure 1 illustrates a basic distinction between analog and digital scope waveform acquisition. Both waveform photos show the same jittered signal. The difference is that one waveform is displayed in real time on an analog scope (1-*a*), while the other is a digitally stored waveform displayed in vector form on a digitizing oscilloscope (1-*b*).

Notice that the analog scope clearly shows the jitter in its entirety. That includes not only the extremes of the jitter excursions, but the time distribution of the jitter as well. The distribution is seen in the intensity variation of the multiple traces in the jitter region. The brighter areas are

*Jeff O'Neal is a Product Marketing Engineer for Tektronix, Inc.

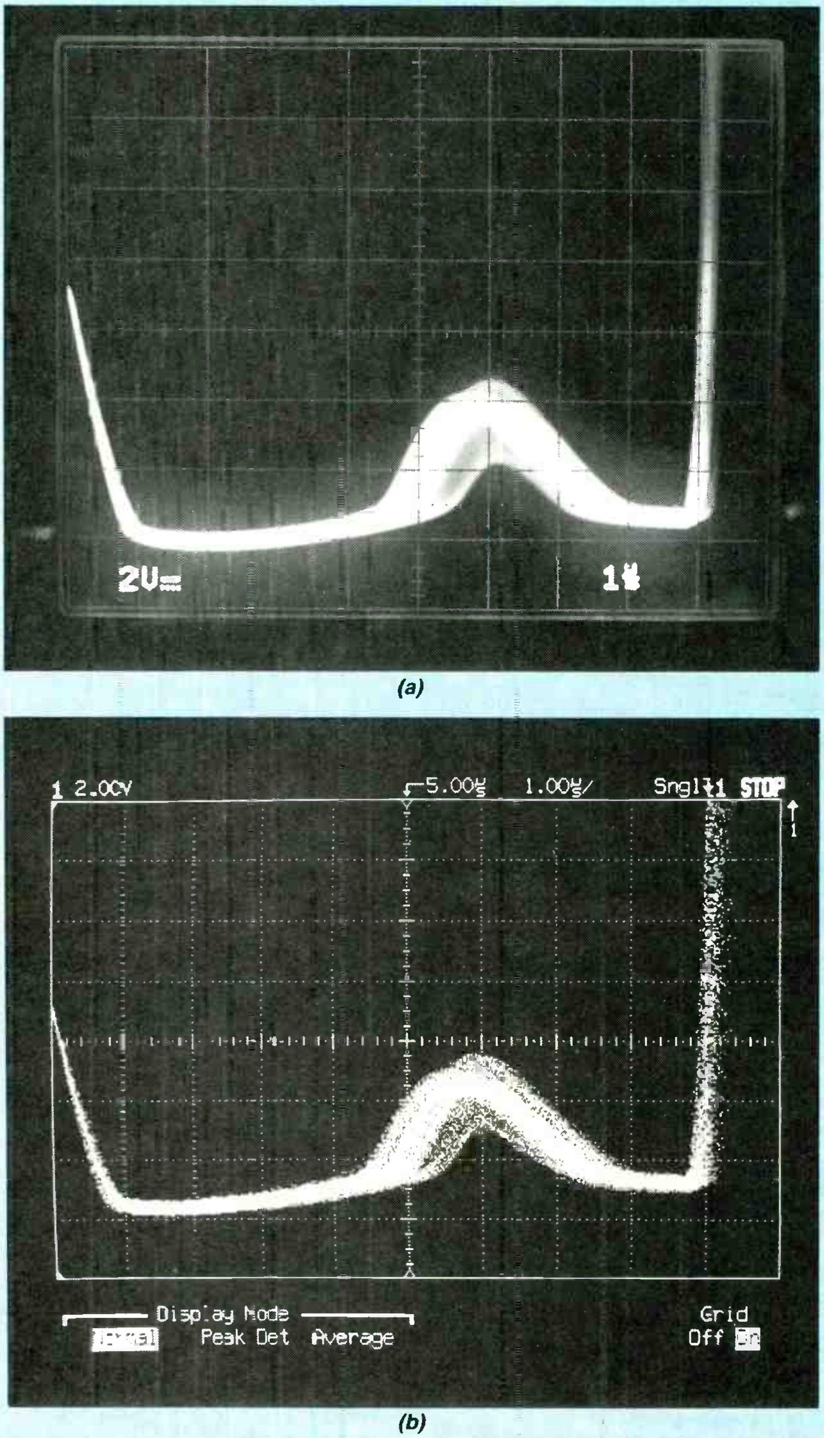


FIG. 1—REAL-TIME DISPLAY OF PULSE JITTER on an analog scope shows far more detail (*a*) than on a digital scope display (*b*).

where the jittered edge spends most of its time; the dimmer areas are where it spends less time.

In comparison, the digital scope shows far less definition of the jittered edge (1-*b*). That's because the digital display is a single trace reconstructed from digitized waveform samples stored in memory. The digital scope's representation of the waveform is restricted to a single-amplitude value for each point in time.

An analog scope display, because it's made up of multiple real-time traces, can show multiple amplitudes at any point in time. That's extremely important for observing and analyzing complex, real-time signal activity such as jitter, various TV waveforms, and modulation, as shown in Fig. 2. Modulated color levels are clearly visible in the intensity variations of an analog scope display (2-*a*), while a digital scope display conveys little information (2-*b*).

The differences between real-time analog and digital scope displays become clearer when comparing the two acquisition processes. The basic architecture of each type of scope is shown in Fig. 3, and the acquisition concepts are shown in Fig. 4.

The capture process

Notice in Fig. 3 that the overall architecture of both types of scopes is the same in many respects. Both scopes must have a high-quality analog front-end with adequate bandwidth and fidelity for the signals being captured. Both must have triggering circuits for triggered capture and display of waveforms. Both must have horizontal and vertical drive circuits in order to trace a signal's waveshape across the CRT display (except for raster-based displays, which work differently). And both can have built-in microprocessors for digital automation of instrument setups and other control functions.

The main difference is in the input signal path from the vertical amplifier to the display. An analog scope has an analog path that passes the signal to the display in real time. In more advanced scopes, this analog path may also include integration of various measurement functions, such as voltmeters and counter/timers. In the case of the Tektronix 2252 oscilloscope, the analog signal is also sampled by an A/D converter to provide output to a printer for hardcopies of repetitive waveforms. But the main signal path is pure analog.

Digitizing scopes, on the other hand, sample and digitize the analog signal as soon after the vertical amplifier as possible. There are numerous schemes for doing this, but the general goal is to sample, digitize, and store points as fast as possible for the price range of the particular digitizing scope.

Figure 4 illustrates the general capture processes involved for both types of scopes. In both types, the capture process occurs over a time period referred to as a capture window. In the case of an analog scope (4-*a*) the window is determined by the scope's sweep speed setting. A 1-μs/division setting, for example, provides a 10-μs window on a scope with 10 horizontal display divisions.

The portion of the waveform captured is determined by the capture-window length and the trigger-system setting. In the analog scope case of Fig. 4-*a*, triggering is set for the beginning of the positive slope on the waveform being measured.

When a positive waveform slope is encountered, the analog scope's sweep circuit is triggered. The waveform is traced on the display. Then at the end of the sweep, the CRT beam is blanked and retraced, and the scope's trigger circuit is rearmed for the next sweep.

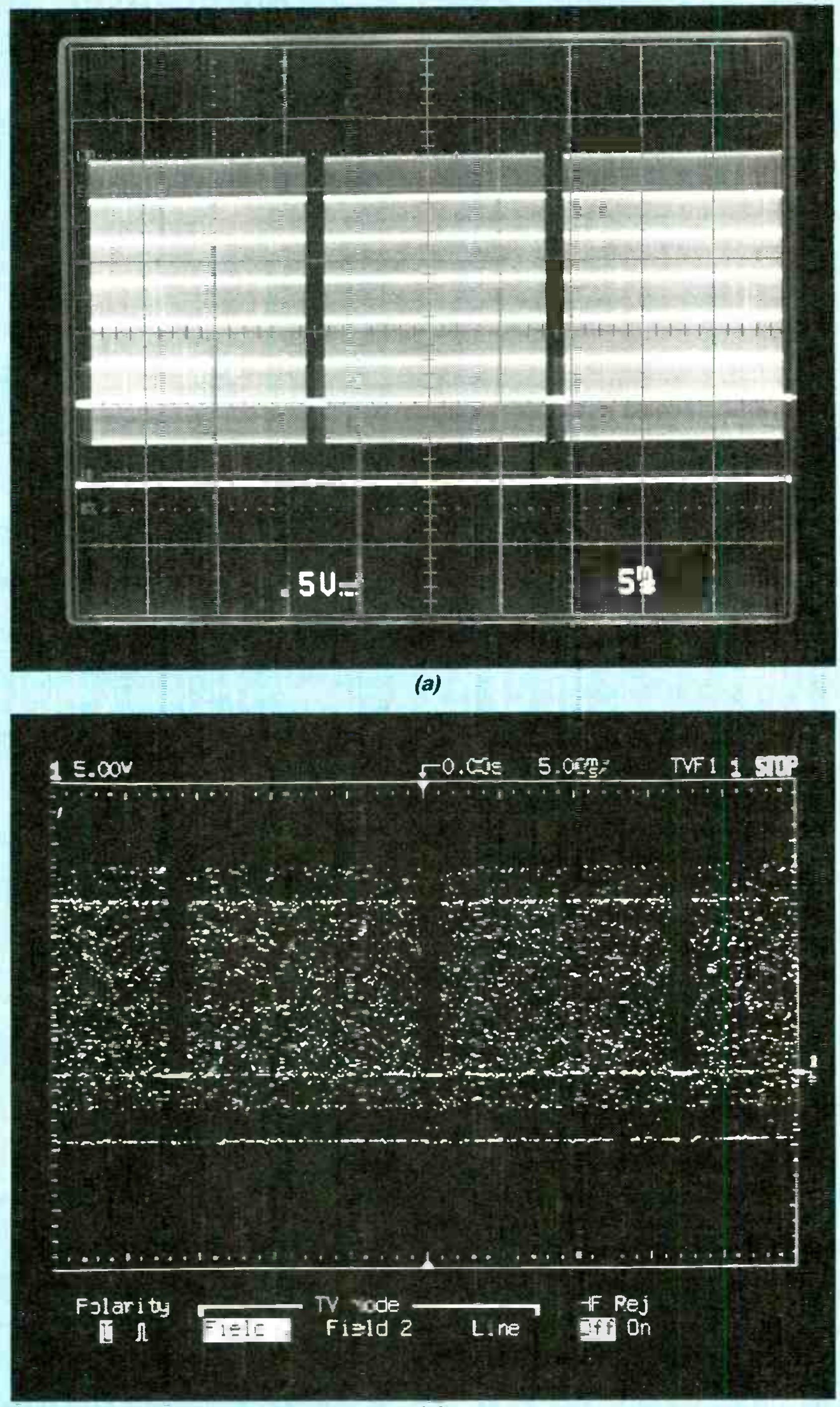
The blank-retrace-rearm sequence, sometimes referred to as rearm dead time, is normally quite short in analog scopes. Thus, an analog scope can trigger through a quick sequence of capture windows. That allows the scope's CRT beam to repeatedly trace the shape of a repetitive waveform, keeping the screen phosphor highly excited for a bright trace. Or, as is the case with the analog capture process in Fig. 4-*a*, it shows the multiple traces of pulse-width jitter.

Digitizing oscilloscopes use the same capture window concept. Strictly speaking, however, a digital scope's capture window corresponds to the waveform memory's length (record length). Digital scopes with record lengths of 512 or 1024 waveform points typically display the entire waveform record over the full horizontal display width. Those with longer records (2048 or more points) usually display only a portion of the record and allow you to scroll the display through the record.

The time it takes for a digital scope to capture a waveform into memory depends upon the scope's record length and sampling rate. For example, with a 512-point record and a 10-μs capture window, the scope must sample, digitize, and store a waveform point every 19.53125 nanoseconds (10 μs/512). In other words, the scope's "real-time" sampling rate must be at least 51.2 megasamples/second (MS/s) to capture all 512 samples in one 10-μs capture window.

There's a wide selection of real-time sample rates available in today's digital scope market. But faster real-time sample rates mean more expensive technology and higher price tags.

For the sake of economics, most digital scopes use equivalent-time sampling on their faster sweep settings (1 μs/division and faster). That allows repetitive waveforms to be captured at apparently high sample rates by building up a complete sample set over multiple capture



(*a*) (*b*)

FIG. 2—THE FIVE MODULATED COLOR LEVELS OF A VIDEO SIGNAL are clearly visible in the intensity variations of an analog scope display (*a*), while a dots-only digital scope display conveys little information about the signal's actual complexity. A digital scope's vector display would connect the dots for a clearer outline of the waveform, but still wouldn't provide the intensity variations that distinctly show the modulated color levels.

windows. This is illustrated in Fig. 4-*b* for comparison to the analog scope's real-time display method.

Notice in Fig. 4-*b* that only a few samples have been taken in two separate capture windows. On fast time-base settings, the scope's sampling rate may allow only a few samples per capture window. Thus, it may take numerous windows to build a full complement of 512 samples to fill the waveform record.

Also, notice that a triggered capture window doesn't occur at every potentially valid trigger point. In other words, some of the pulse repetitions in Fig. 4-*b* are skipped. That's because of the digital scope's longer rearm dead time. Recall in the analog scope that there was a short rearm dead time where the scope's trace was blanked and retraced, then the trigger system rearmed. Digital scopes must complete some digital processing on the input waveform before rearming. The length of their rearm dead time will therefore depend on the amount and speed of that digital processing.

The point is, a repetitive waveform displayed in equivalent-time on a digital scope is really a sampled composite of numerous capture windows. Additionally, the digital display traces a single set of points versus the multiple real-time traces of an analog display scope.

The repetitive pulses have variations in the pulse width. As a result, the trailing edge samples in 4-*b* are actually a composite of numerous, time-shifted edges. When the samples are connected by straight lines (display vectors) for a vector display, the jittered edge looks like a burst of noise rather than the traditional analog scope display of jitter in real time.

If a repetitive waveform is truly periodic (such as a sine wave), the analog and digital scope displays usually are quite similar. The exception is when numerous waveform cycles occur over the capture window. That results in fewer samples per waveform cycle on a digital scope, and the display may contain visual aliasing (see Fig. 5). Analog scopes don't sample, so they don't have this problem.

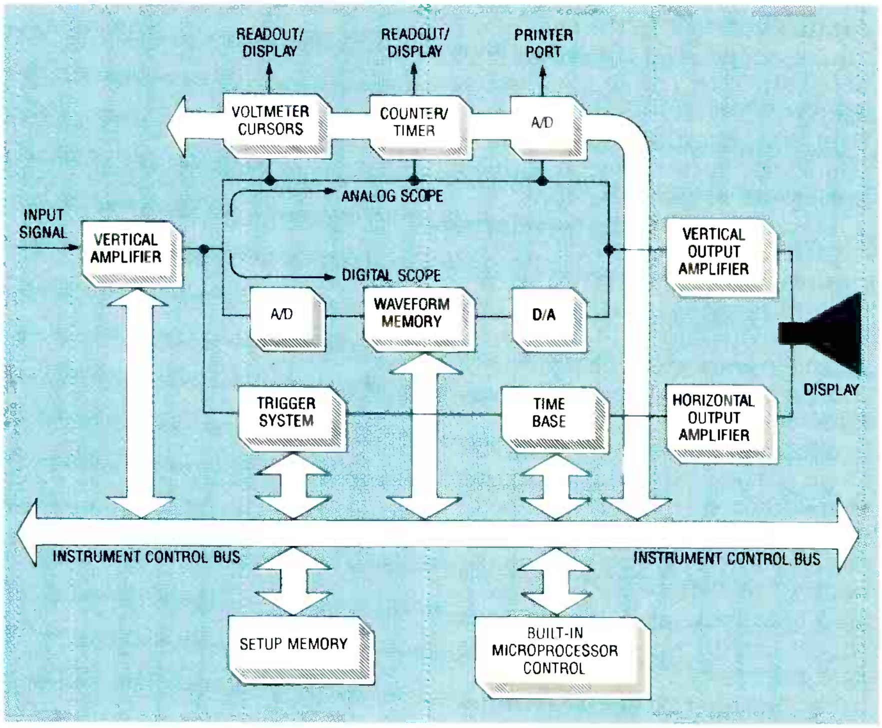


FIG. 3—OVERALL ANALOG AND DIGITAL SCOPE ARCHITECTURES are quite similar today. The major difference is that analog scopes have an analog signal path to the display and digital scopes have a digital storage path.

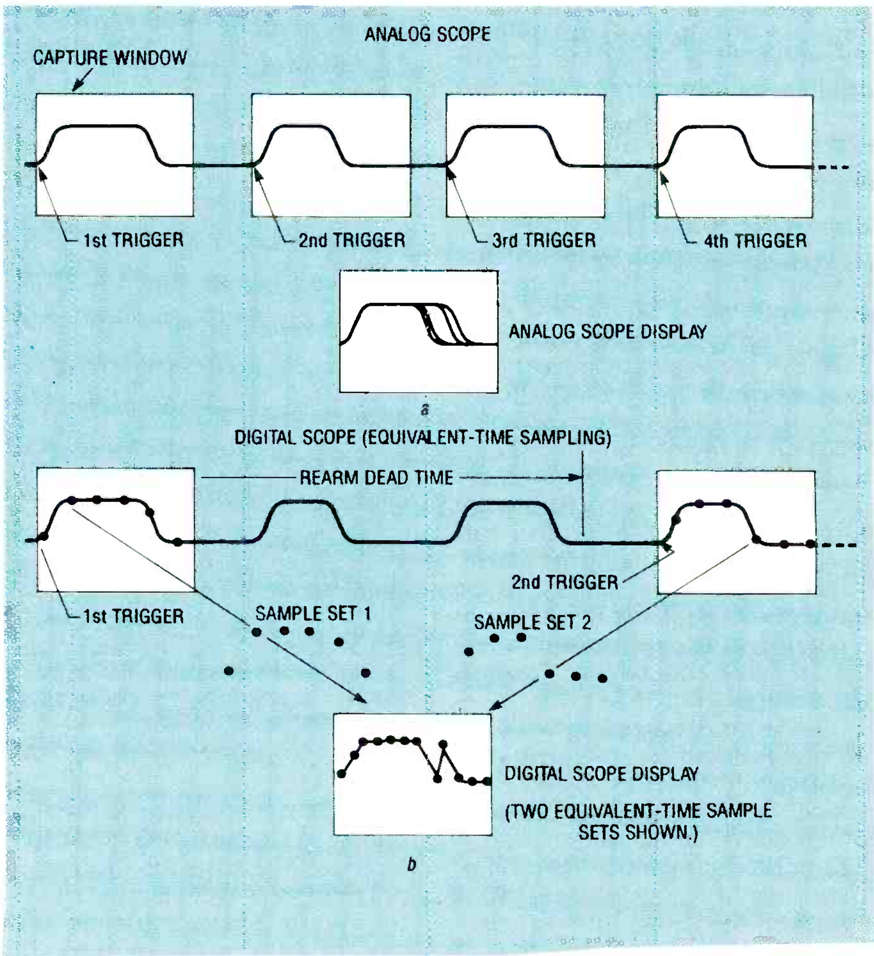


FIG. 4—METHODS OF WAVEFORM CAPTURE remain essentially the same in analog scopes (*a*), while digital scopes may use a variety of sampling schemes to emulate real-time analog signal displays (*b*).

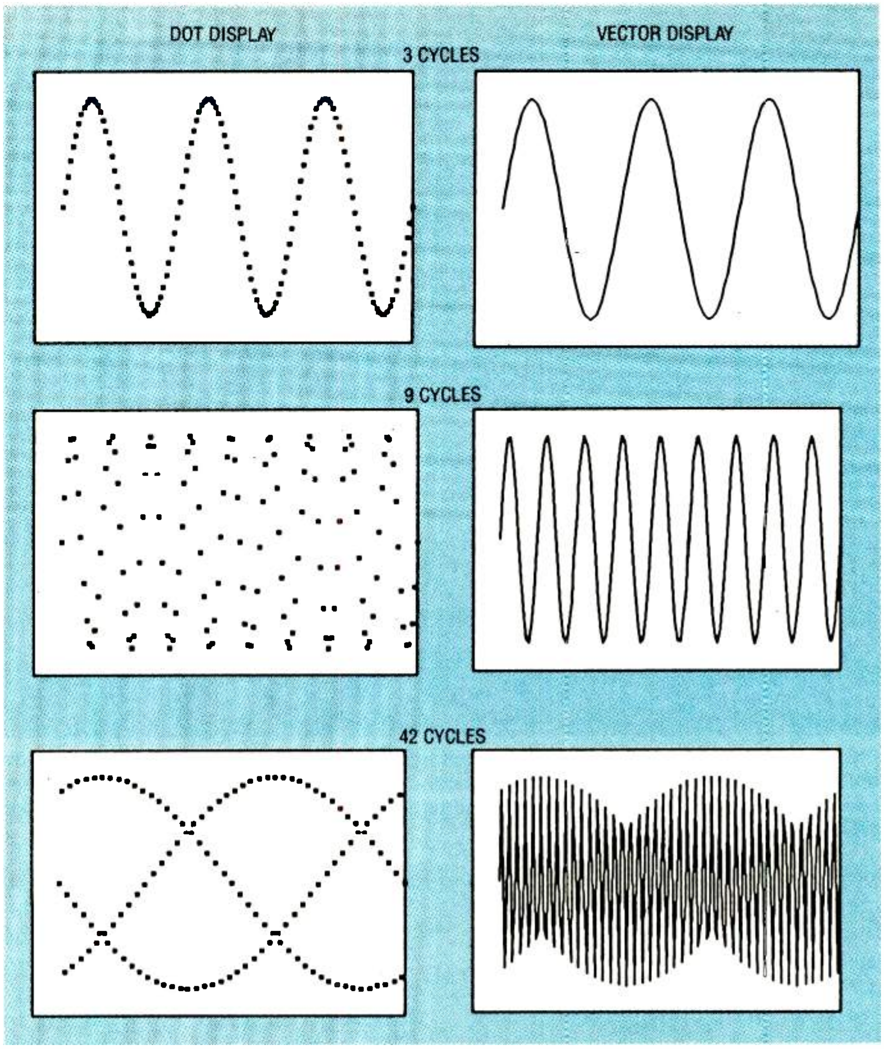


FIG. 5—VISUAL ALIASING occurs when the display of a sampled waveform suggests the presence of different or additional waveforms. Dots-only displays are the most susceptible to visual aliasing and can suggest that the waveform contains a low-frequency sine wave when it actually doesn't.

Rubber screwdrivers

The differences in capture methods can affect how easy a scope is to setup and use as well. Recall that an analog scope re-arms quickly and traces each capture window's waveform in real-time. The display updates in real-time from trigger to trigger. So, if you use an analog scope to observe a waveform and "use a screwdriver" to adjust the waveform's amplitude, you see the change immediately on screen.

With a digital scope, the equivalent-time display must build up over several windows, causing a slower update rate. As a result, when you make a "screwdriver adjustment," you may not see an instantaneous change in the waveform. The delay between adjustment and observed results is like using "a screwdriver with a rubber shaft."

Because of the "rubber screwdriver effect," and for other reasons (especially scope setup ease), some digital scopes offer a real-time analog mode along with the digital storage mode. You can switch between a traditional analog scope display or a digital storage display as needed. More-expensive digital scopes with high bandwidths and fast update rates provide what is essentially a real-time display like an analog scope.

Now, think about what was said about sampling and digitizing waveforms. Sampling means that you get discrete points equally spaced in time on the waveform and nothing in between. If there are 512 points in the record, the time resolution of the captured waveform is one part in 512. These samples are also digitized, usually to one part in 256 resolution (8-bit digitizing). The net result is that, on a digital scope, unaveraged waveform displays have an inherent tendency to look noisy.

So, when you see a noisy waveform on a digital scope, you have to keep in mind that some of the noise is due to sampling and digitizing resolution (quantizing noise), and some of it is actual noise on the waveform. With an analog scope, when you see noise on the waveform, you know that all of the noise (at least up to the scope's bandwidth) is actually part of the waveform.

Cursor differences

Measurement cursors are lines or dots that can be positioned on a scope's display to measure time and voltage differences. There are basically two cursor types: screen-based and waveform-based.

Screen-based cursors are the easiest to implement and can appear on either analog or digital scopes. They can be positioned anywhere on the screen. Their readouts are simply the screen-relative amplitude and time locations of the cursors. If the cursors are placed on the waveform trace, the readouts also represent time and amplitude locations on the waveform display. But, if the display changes, you have to place the cursors back on the waveform in order to reestablish a measurement.

A smarter approach is to somehow tie the cursors to the waveform. The cursors are then referred to as being waveform-based.

In digital scopes, waveform-based cursors are tied to the waveform's stored samples. This is where digital resolution limits can become quite apparent. As you position the cursors, they may appear to jump from point to point on the waveform. This will be most noticeable on pulse edges or other fast transitions where there are fewer samples. In fact, the sample resolution may be so poor that you won't be able to pick off reasonable 10% and 90% levels on the waveform for rise-time measurements.

To deal with that, many digital scopes, especially those with dot-connected vector displays, use interpolation for cursor placement. This allows you to place cursors between samples on the display for interpolated readout values.

An even smarter approach to the resolution problem is to tie the cursors to the waveform trace by direct measurement of input-signal amplitude. An example of this is the SmartCursors appearing on some Tektronix analog scopes.

The SmartCursor system uses a built-in, microprocessor-controlled cursor/voltmeter system. The cursor readouts not only reflect measurements of the actual signal, but the cursors are smart enough to follow signal changes. That allows you to tune circuits for precise signal amplitudes simply by making circuit adjustments until the scope's cursor readout reaches the desired value. It's just like using a voltmeter, except that the analog scope's cursors show you exactly where on the waveform the measurement is being made. In fact, the SmartCursors include automatic placement on the waveform by simply pressing buttons for peak, peak-to-peak, and other commonly needed waveform measurements.

Integrated measurements

Cursors are just the beginning of the measurement capabilities that can be integrated into an analog oscilloscope. Along with automatic placement, cursor measurements can also be gated on and off over selected portions of the waveform. That allows various waveform features or aberrations to be included in or excluded from the measurements as desired.

Another analog scope innovation involves integration of precision counter/timer measurements. Figure 6 illustrates the use of this function in a gated measurement.

In Fig. 6, the counter/timer is measuring the width of a narrow spike that's barely visible in the waveform photo. (The spike would appear clearer if you were looking at the actual CRT display.) The timer measurement area has been restricted to the spike (gated) by placing the intensified zone of the trace on the spike.

The intensified zone shows you exactly what the counter/timer is measuring. A stand-alone counter/timer, by contrast, doesn't provide you with that kind of positive visual indication of exactly what is being counted or timed.

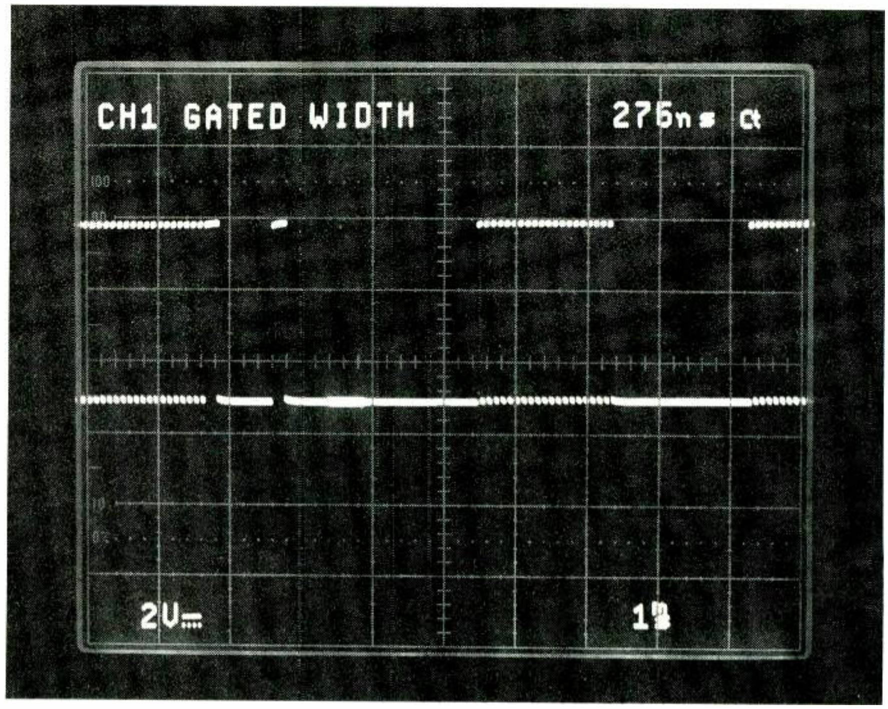


FIG. 6—THE ANALOG PRECISION of a gated width counter measurement allows a narrow spike (276 ns) to be measured with nanosecond resolution, even at a 1 ms/division sweep speed. A digital scope would need a 10-megapoint record length for the same resolution on the same display.

Another plus is that an integrated counter/timer function can provide higher measurement precision than a digital scope. In the case of the scope display shown in Fig. 6, the 200-MHz counter/timer has a crystal-controlled accuracy of 10 ppm (0.001%). That allows nanosecond timer measurements on even the slowest scope sweep speeds. Timing measurements with a digital scope's cursors, by contrast, are constrained to the sample interval resolution.

Programmability

The types of integrated analog scope measurement features discussed here would be next to impossible to implement in a purely analog environment. Controlling and coordinating the data concerning the various scope and measurement functions can be done far more efficiently with a built-in microprocessor and digital methods.

Digital control does not mean, however, that the waveform must be digitized in order to be displayed. The real-time benefits of the analog signal path and display can be maintained while the remainder of the scope is designed to take advantage of digital control. That is apparent in Fig. 3, where the digital control buses extend to all of the major scope functions except the analog signal path itself.

All of the programmability features that are normally found in a digital scope—automatic setup, storing and recalling front-panel settings, programmed control from a bus-connected computer, and being able to output a waveform to a printer—can also be found in an analog scope. So, unless you absolutely need the capability of digital waveform storage, an analog scope could very well be your best choice. The best way to decide, however, is to get a demonstration of both types of scopes on the particular types of waveforms that you deal with regularly. Then you can make an informed decision on the best scope for your needs.

If you still aren't sure whether or not a digital scope is worth the expense, consider what you might do with the money you save if you buy an analog scope. Perhaps there's some other test equipment that your workbench is sorely lacking. R-E

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JOE JAFFE

THE AVERAGE HUMAN HEART CARries out its pumping action over 100,000 times every day. Generating its own electric signals to actuate the heart muscles, the heart contracts and relaxes during each beat. We will show you how you can convert the hearts' motion into audio sounds using ultrasound electronics with our Doppler ultrasonic stethoscope. For less than $150 you can build this educational instrument which will help you learn more about human physiology.

In 1957, an article in *The Journal of the Acoustical Society of America* described how cardiac functions could be inspected by the use of Doppler ultrasound using a frequency of about 2 MHz. The Doppler effect is the change in frequency of sound, light, or radio waves that occurs when a transmitter and receiver are in motion relative to each other. When a transducer sends an ultrasonic beam into the body, a portion of the energy is reflected back by internal body structures. If the structure moves, the frequency of the reflected beam is changed in proportion to the velocity of the movement.

Almost thirty years ago this technology was developed into a valuable and completely harmless tool for non-invasive examination of movements inside the body by the medical profession. Experiments have shown that beaming very low-energy high-frequency sound into the body is not harmful. The technique is used all over the world to listen to the heart beat of unborn babies in a mother's womb. Now you can listen to the characteristic Doppler sounds from your own heart which can be heard with an easily built Doppler ultrasonic stethoscope. It is important to note that this instrument is for experimentation and entertainment.

WARNING!! The information contained in this article is being provided solely to readers for educational purposes. Nothing contained herein suggests that the monitoring system described herein can be or should be used by the assembler or anyone else in place of or as an adjunct to professional medical treatment or advice. Neither the publisher nor the author make any representations as for the completeness or the accuracy of the information contained herein and disclaim any liability for damages or injuries, whether caused by or arising from the lack of completeness, inaccuracies of the information, misinterpretations of the directions, misapplication of the information or otherwise.

Piezoelectric background

Transducers are devices which change one form of energy into another form. Some transducers are reversible, meaning they can change energy forms in either direction. Piezoelectric transducers are reversible. They can change electric energy into mechanical energy and mechanical energy back into electric energy. The quartz-crystal oscillator is a familiar piezoelectric transducer, which is used as a highly stable and accurate frequency source.

Early phonograph pickups used piezoelectric Rochelle-salt crystals. Both quartz crystals and Rochelle-salt crystals are naturally occurring materials.

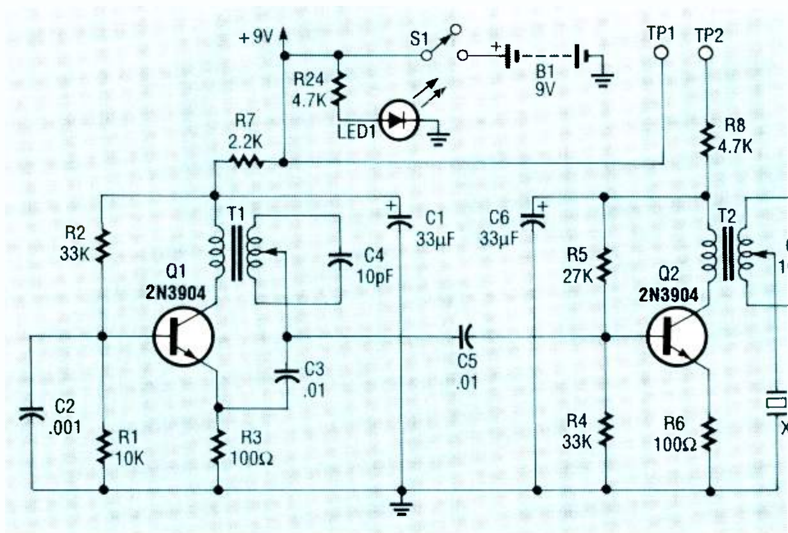


FIG. 1—THE TRANSMITTER CIRCUIT. Q1 is an RF oscillator whose 2.25-MHz frequency is determined by C4 and T1. A secondary tap on T2 provides a low-impedance output to drive XTAL1 in the transducer.

When either of those materials are excited by an applied voltage, they change in dimension or exert pressure if they are constrained from movement. When pressure is applied to these materials, they generate voltage. One of the first applications of piezoelectricity was developed by Professor M.P. Langevin during World War I when he was commissioned by the French to find a way to locate enemy submarines. He solved the problem by developing an underwater piezoelectric microphone.

About 50 years ago the first synthetic piezoelectric materials were developed. Today, commonly used synthetic piezoelectric materials include barium titanate, lithium sulfate, lead niobate, and lead zirconate-titanate. Even quartz crystals can now be man-made.

The stethoscope

The basic component of the stethoscope is the transducer, which contains two lead zirconate-titanate piezoelectric crystals. One of the crystals is energized by the output of a 2.25-MHz oscillator/amplifier so that it expands and contracts at that frequency, setting up pressure or sound waves that are transmitted into the body. When that wave, which is very directional, passes from one medium to another in the body, a portion is reflected back to the second crystal, which generates a voltage. If the reflecting surface is stationary, the voltage generated by the receiving crystal has the same frequency as the transmitted wave. If the reflecting surface is moving away from the transducer, the reflected frequency is lower than the transmitted wave. Similarly, if the reflecting surface is moving toward the transducer, the reflected frequency is higher. By mixing a portion of the transmitted frequency with the received frequency, the received frequency is modulated in both frequency and amplitude. Using an amplitude-modulated (AM) detector, we can obtain an audio signal whose frequency is proportional to the velocity of the moving structure within the body.

Circuit operation

The transmitter circuit is shown in Fig. 1. An RF-oscillator built around Q1 operates at about 2.25 MHz. Positive feedback is provided from a secondary tap in T1 to the emitter of Q1. The frequency is determined by C3 and the inductive tuning of T1. The oscillators' output is coupled through C5 to Q2, an inductively-tuned RF amplifier. A secondary tap on T2 provides a low-impedance output to drive the transmitter crystal XTAL1 in the transducer. The ultrasonic power generated is less than 15 milliwatts per square centimeter of transducer surface.

The receiver and audio circuits are shown in Fig. 2. The receiver uses two identical stages of inductively-tuned RF amplification. The voltage generated in the

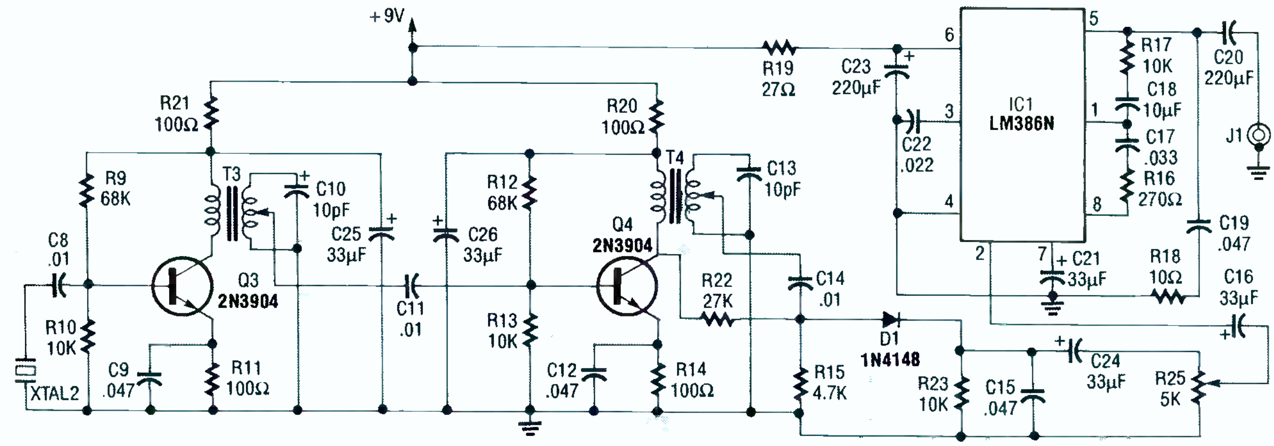


FIG. 2—THE RECEIVER AND AUDIO AMPLIFIER. The receiver uses two identical amplifier stages, with a total gain of 1000. IC1 is a low-power amp which can drive up to two headsets. Bass boost is provided by R17–C18 as many sounds generated by the Doppler effect are in the low audio range, so reducing the gain at higher frequencies improves the signal-to-noise ratio.

receiving crystal XTAL2 is coupled to Q3 through C8, and the output of Q3 is coupled to Q4 through C11. The combined RF gain for the two stages is about 2000. The modulated Doppler signal is detected by D1 to produce audio frequencies in the 50-2000 Hz range.

A low-power audio amplifier, IC1, can drive one or two headsets. It has a gain of 100, which is set by C17–R16 with some base boost determined by C18–R17, as many of the sounds generated by the Doppler effect are in the low audio range. The volume may be adjusted by potentiometer R25 at the input of IC1. The output of the amplifier goes to J1 where the headset is plugged into. If two people wish to listen at the same time, a Y-jack can be used. For classroom demonstrations, an external amplifier with speakers can be plugged in.

The transducer

The construction of the transducer is shown in Fig. 3. The two crystals of lead zirconate-titanate (Vernitron or Channel Industries PZT5A) are ½- × ¼-inch rectangles approximately ⅓₂-inch thick. Silver electrodes are deposited on each crystal surface, and a small silver trace is carried around from one side to the other side so electrical connections to both electrodes can be made on the same side of the crystal. Fine wire, number 36 AWG or smaller, is soldered to each of the electrodes using a silver-bearing solder to avoid lifting the silver electrode from the ceramic crystal surface. Those wires are connected to the terminals of XTAL1 and XTAL2 on the circuit board. Use a minimum of solder to avoid changing the resonance characteristics of the crystal.

When dealing with ultrasound, the quantity of *characteristic acoustic impedance* is used in solving various problems dealing with waveform generation, propagation, and detection. Characteristic acoustic impedance w is defined as

$$w = \rho c$$

where ρ is the density of the medium in kg/m^3 and c is the sound velocity in m/s. The characteristic acoustic impedance is, therefore, expressed as

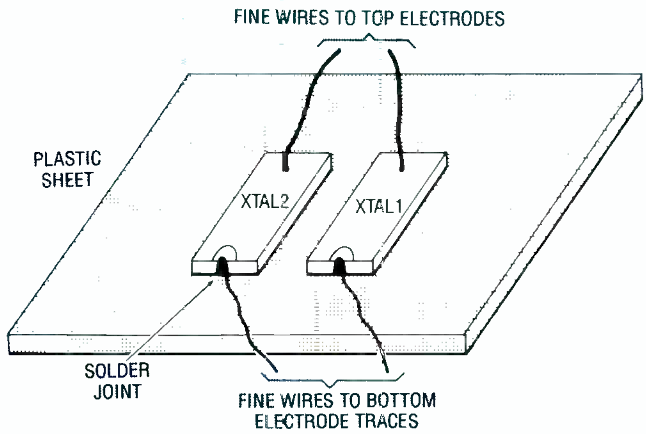


FIG. 3—TRANSDUCER CONSTRUCTION. Silver-bearing solder is used to avoid lifting the silver electrode from the ceramic crystal surface. Energy conversion is most efficient when crystals are "air-backed" resulting in energy being radiated from the front of the crystal.

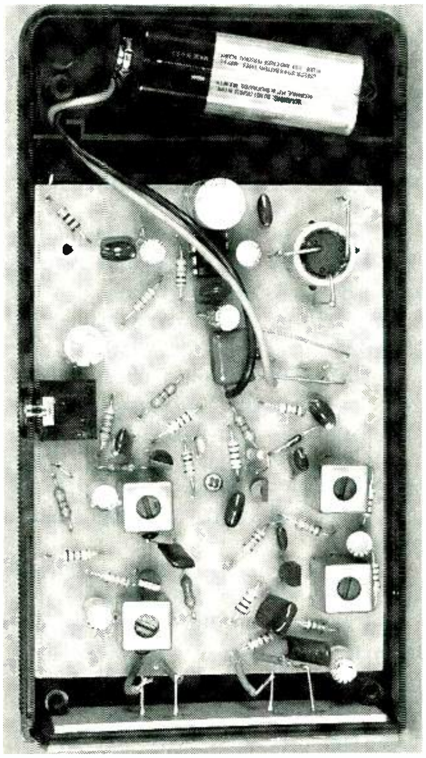


FIG. 4—THE AUTHORS' PROTOTYPE. Note that LED1 and S1 are mounted on the foil side of the PC board. The transducer is mounted on the end plate of the enclosure with its leads close to their solder pads.

CRYSTAL SOURCES

The Piezoelectric crystals (PZT5A) mentioned in this article can be purchased from the following sources:

Channel Industries
839 Ward Dr.
Santa Barbara, CA 93111
(805) 967-0171

Vernitron Piezoelectric Div.
232 Forbes Rd.
Bedford, OH 44146-5478
(216) 232-8600

$$kg/m^3 \times m/s = kg/m^2s.$$

To obtain maximum energy conversion efficiency, the crystals should be acoustically matched with the plastic panel. When two mediums are closely matched, most of the energy will be transmitted through the materials. When an ultrasonic beam meets an interface of dissimilar materials, more of the energy is reflected where there is a large difference in the acoustic impedance between the two materials.

The acoustic impedance of the crystals is about 30 million and that of the body is 1.5 million, with air being less than 50, all in units of kg/m^{2}s. Because the density of air is so much lower than that of the crystal, and the velocity of sound in air is much slower than in the crystal, almost all the energy is reflected at that interface when the back-side of the crystals are in contact with air. That difference in impedance results in most of the energy being radiated from the front of the crystal, and improved sensitivity of the receiving crystal.

Just as you want most of the energy to be reflected at the rear of the crystal, it is desirable that most of the energy be transmitted at the front surface of the crystal and into the body. Because the crystals are too fragile to be placed in direct contact with the body, they are cemented with epoxy to a sheet of plastic about ¹⁄₁₆-inch thick, which should have an acoustic impedance between that of the crystal and the body. This results in

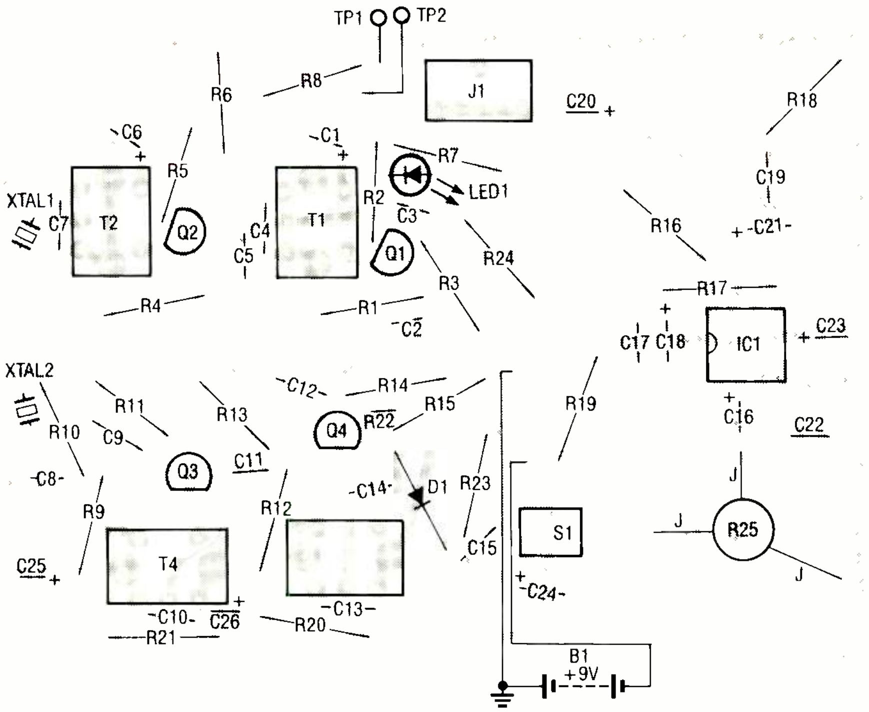


FIG. 5—PARTS PLACEMENT. Mount and solder all components as shown here.

more energy being transmitted into the body instead of being reflected at the skin surface. When gluing the crystals to the plastic, be sure to exclude any air from the interface and use a minimum amount of glue. Sheet acrylic or fiberglass such as that used for PC boards, or a rigid vinyl sheet all have suitable acoustic impedances and provide the required protection for the crystals.

When more sensitivity is required, a dab of ultrasound gel is placed on the transducer face to improve the impedance match and exclude any air that may be trapped between the transducer face and the skin. Water or mineral oil will also work.

Construction

The authors' completed prototype is shown in Fig. 4. All the components, except the transducer, are mounted on a single-sided PC board as shown in the parts placement diagram in Fig. 5. An etched, drilled, and plated through PC board is available from the source mentioned in the parts list, or you can make your own board using the pattern provided. Note that LED1 and S1 are mounted on the foil side of the PC board. The volume control is mounted on the component side with the shaft going through the board. Use two ¾-inch long resistor cutoffs and solder them to TP1 and TP2. After soldering the components on the PC board, the transducer is connected.

The transducer is mounted on the end plate of the enclosure with its leads close to their solder pads. Insert the end plate and transducer into the slot on the top half of the enclosure and solder the transducer leads to their appropriate terminals. Now install the 9-volt battery. The stethoscope is now ready for tuning after you plug in the headphone.

Connect a frequency counter from the emitter of Q1 to ground. Then connect a DMM, set on the 10-mA range, between TP1 and TP2 and turn the instrument on. Your current meter should read less than 10 mA. Tune T1 to 2.3 MHz, then alternately tune T2 and T1 to reduce the current to a minimum. If you don't have a frequency counter, tune T1 for a minimum current between TP1 and TP2 and then alternately tune T1 and T2 for a lower minimum current. As the final current will be between 1 and 2 mA, use a lower 5- or 2-mA range when possible.

After you have correctly tuned T1 and T2, turn off the instrument, remove the DMM and solder the leads of TP1 and TP2 together. Connect the DMM between the cathode of D1 and ground, using the 5- or 10-volt

PARTS LIST

All resistors are ¼-watt, 5%.
R1, R10, R13, R17, R23—10,000 ohms
R2, R4—33,000 ohms
R3, R6, R11, R14, R20, R21—100 ohms
R5, R22—27,000 ohms
R7—2200 ohms
R8, R15, R24—4700 ohms
R9, R12—68,000 ohms
R16—270 ohms
R18—10 ohms
R19—27 ohms
R25—5000 ohms, volume potentiometer

Capacitors
C1, C6, C16, C21, C24–C26—33 µF, 10 volts, electrolytic
C2—0.001 µF, ceramic
C3, C5, C8, C11, C14—0.01 µF, Mylar
C4, C7, C10, C13—10 pF, ceramic, NPO
C9, C12, C15, C19—0.047 µF, Mylar
C17—0.033 µF, Mylar
C18—10 µF, 10 volts, electrolytic
C20, C23—220 µF, 10 volts, electrolytic
C22—0.022 µF, Mylar

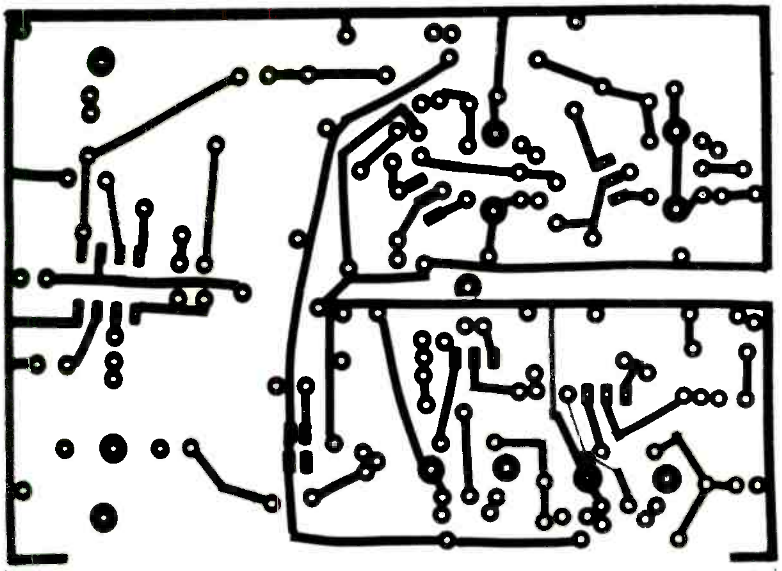
Semiconductors
Q1–Q4—2N3904 NPN transistor
D1—1N4148 diode
LED1—red light emitting diode
IC1—LM386N low-power amplifier

Other components
T1–T4—MOS-E911 transformer (Sumida)
XTAL1, XTAL2—½ × ¼ × 0.035-inch PZT5A (Vernitron or Channel Industries)
S1—SPST slide switch

Miscellaneous: 9-volt alkaline battery, PC board, miniature stereo jack, 16-ohm stereo headphone, and silver bearing solder.

Note: The following items are available from Products & Processes, 9450 Mira Mesa Blvd., Suite #B-321, San Diego, CA 92126 (619) 566-0711:
- **A fully assembled and tested instrument with cassette—$189.50.**
- **A complete kit of all parts (without battery) including an assembled transducer, PC board, headphone, assembly manual, case, and cassette with typical sounds—$135.**
- **An etched, drilled, and plated through PC board—$8.50.**
- **A pair of piezoelectric crystals—$39.50.**
- **Four MOS-E911 transformers (T1–T4)—$12.**

California residents add 8¼% sales tax. Add $5.00 shipping and handling.



4 INCHES

THIS IS THE SOLDER side of the PC board.

range. Alternately tune T3 and T4 for a maximum voltage, which will vary between 1 and 2 volts.

If you don't have a frequency counter or DMM available, you can tune the stethoscope while listening to your heart. With the transducer and headphones connected to the circuit board, put a little mineral oil or ultrasound gel on the face of the transducer and place the transducer firmly on your chest near your heart. Try to place the transducer between a pair of ribs rather than directly over a rib. Turn the volume up until you hear some Doppler sounds, which will probably be low, as well as a hissing noise. Alternately tune T1–T4, starting with T3 and T4, to increase the volume and reduce the hissing. Turn down the volume control during this tuning to prevent overloading and distortion.

If you don't hear any sounds with the above procedure, put a few drops of water on the transducer face and rub it with your finger. If that doesn't produce any sounds, check the circuit board for solder bridges and cold solder joints.

Testing and use

As mentioned earlier, maximum sensitivity is obtained when there is a good impedance match between the transducer face and the skin, with no air is trapped between them. A liquid-gel such as Aquasonic is specifically made for that purpose and is available at medical supply stores.

Apply a small amount of liquid gel to the transducer surface and place the transducer firmly against the bare chest, several inches to the left of the center and about 10 inches below the shoulder. Place the transducer so the ultrasonic beam passes between two ribs for best transmission. You will hear the sounds associated with the movement of the heart. Keeping the transducer firmly against the chest and changing the direction of the ultrasonic beam you will hear different sounds depending on what surfaces are in the path of the beam. When you take a deep breath the sounds may disappear because the lungs fill with air, covering a portion of the heart. As previously noted, air is a poor conductor of high-frequency sound.

There are many aspects of heart action. First, returning blood from the venous system fills the right atrium. A valve connecting this atrium to the right ventricle then opens and contraction of the atrium forces the blood into the ventricle. The valve then closes and another valve connecting the ventricle to the pulmonary artery opens. The right ventricle contracts, forcing blood into the pulmonary system to return carbon dioxide to the lungs to be exhaled and to pick up oxygen from the air we breathe in. The blood then returns to the left atrium where it is pumped into the left ventricle through another valve. Finally the left ventricle contracts, pumping blood into the arterial system to feed the body and the heart itself.

Each of the four chambers of the heart contract and relax at different times of the heart cycle. Their associated valves open and close synchronously. The movement of all those structures and the movement of blood through them provide the Doppler sounds which you hear with the Doppler ultrasonic stethoscope.

When you move the transducer across the skin you'll hear some scratching sounds. To avoid this, turn the volume down while you move the transducer.

Because there is attenuation of the sound wave as it passes through the body, those with a heavy build may have to try alternate body positions to bring the heart closer to the chest wall. Two suggested positions are lying on the left side or leaning forward in a sitting position.

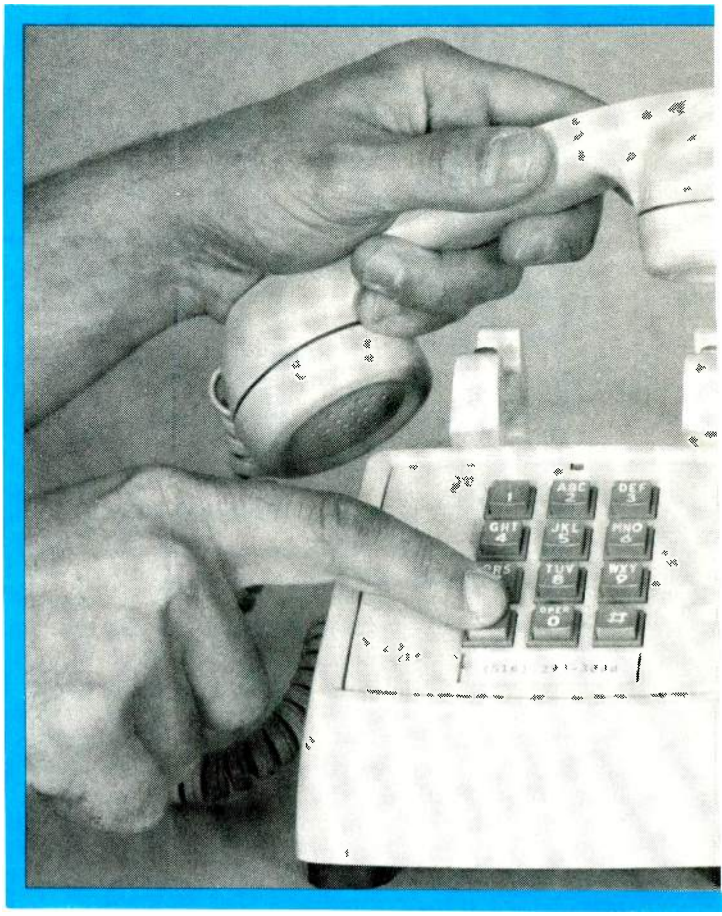
When listening to the heart with Doppler ultrasound a number of different sounds are heard, one after the other, in rapid succession as the heart chambers and valves move and the blood flows through them. One can listen to blood flow separately from other sounds by placing the transducer on the neck where you feel the pulsation of the carotid artery. Because the artery is small compared to the heart, it will take some time to learn how to orient the transducer in the direction of blood flow through the artery. You must use the gel for that experiment. You may be able to hear a slight change in blood flow corresponding to the dicrotic notch in the pulse wave.

Blood flow sounds may also be heard from the brachial artery in the arm on the inside of the elbow. That is the location where the physician places the stethoscope when measuring blood pressure. The transducer is again oriented in the direction of blood flow and gel must be used. When listening to the blood flow in the brachial artery, you may want to try an experiment. Clench your fist to stop the flow of blood in the hand for about 5 or 6 seconds. When the fist is unclenched the blood flows again and you will hear some interesting wind-like sounds. R-E

IF YOU THOUGHT A MUSIC ON-HOLD feature for your telephone was only for high-budget professionals, think again. We'll show you how you can add FM music on-hold to any analog telephone line with a Touch Tone telephone. It's ideal for home offices or for people who want to project a high-tech appearance.

Some of the features of this design include; LED status indicator, audio volume control, built-in antenna, only one operating adjustment, and a mute function to eliminate "hiss" in between stations. You can build this impressive device in under three hours, for only $70.

Construction, test, and alignment is made easy due to the use of specialized IC's, namely a single FM receiver chip, IC4, and a DTMF decoder, IC1. There are no special coils to wind, and no tricky circuit adjustments are required. All you need is a DMM to test and align the circuit. Let's now take a look at how the unit works.



On-hold circuit

A block diagram of the unit is shown in Fig. 1, and the schematic in Fig. 2. The FM on-hold device connects to an analog telephone line via an RJ11 modular jack. It's powered by an external +15-volt DC, 150-mA power pack that plugs into a standard 120-volt AC outlet. The 15-volt DC supply passes through polarity-protection diode D11 to the input of IC5, a 7812 +12.0-volt DC voltage regulator. Capacitors C24 and C25 provide decoupling and anti-oscillation protection for the regulator. The regulated output of IC5 is fed to the input of IC6, a 78L05 voltage regulator, to provide a 5-volt supply for IC4, a TDA7000 FM receiver. Decoupling and anti-oscillation protection for IC6 is provided by C26. Voltage divider R16–R17 provides the +6-volts DC power-supply output, which is filtered by C28.

When a key on any Touch Tone telephone is depressed, the signal is passed through IC3-*d*, an LM324N balanced amplifier. The purpose of this amplifier is two-fold; it acts as a balanced to unbalanced matching network, and its gain is set to 0.1 to act as a line-voltage attenuator. Capacitors C1 and C2 block the phone line's 48 volts DC from entering the amplifier. The ringing-voltage is limited by R1 and R2. The ratio of R3 to R1 sets the gain of IC3-*d* to 0.1. Resistor R4 biases IC3-*d* between its supply voltage and ground allowing, it to operate from the single +6.0 volts DC power-supply line. The output of the balance amplifier passes through coupling capacitor C3 and is then decoded by IC1, a Motorola MC145436 dual-tone multi-frequency (DTMF) decoder IC.

The output of IC1 is a 4-bit word, whose codes are listed in Table 1. It is connected to IC2-*b*, a 4082 dual quad-input AND gate, so that the output of that IC (pin 13) is normally low, and goes high only when the "*" key is pressed. Therefore, when the "*" key is decoded by IC1, pins 1, 2, and 13 are high while pin 14 is low. To switch the output of IC2-*b* high, four logic-high inputs must be present. The high inputs are provided by IC1 pins 1, 2, and 13 and IC2-*a* pin 1.

In order for IC2-*a*'s output to go high, it must also have four logic-high inputs. Two of those are provided by R7, D10, and C27. Those components ensure that the internal power supply is operating. That will prevent the unit from seizing the phone line if power is lost or removed while it is connected to the phone line. The remaining two inputs are provided by a logic high from IC1 pin 12, which is the DV, or DATA VALID, output pin. DV assures proper operation of IC1 by providing internal checks. When those checks are valid, DV will output a logic high. That prevents false triggering due to voice or other tones, such as music, that occur during normal telephone usage.

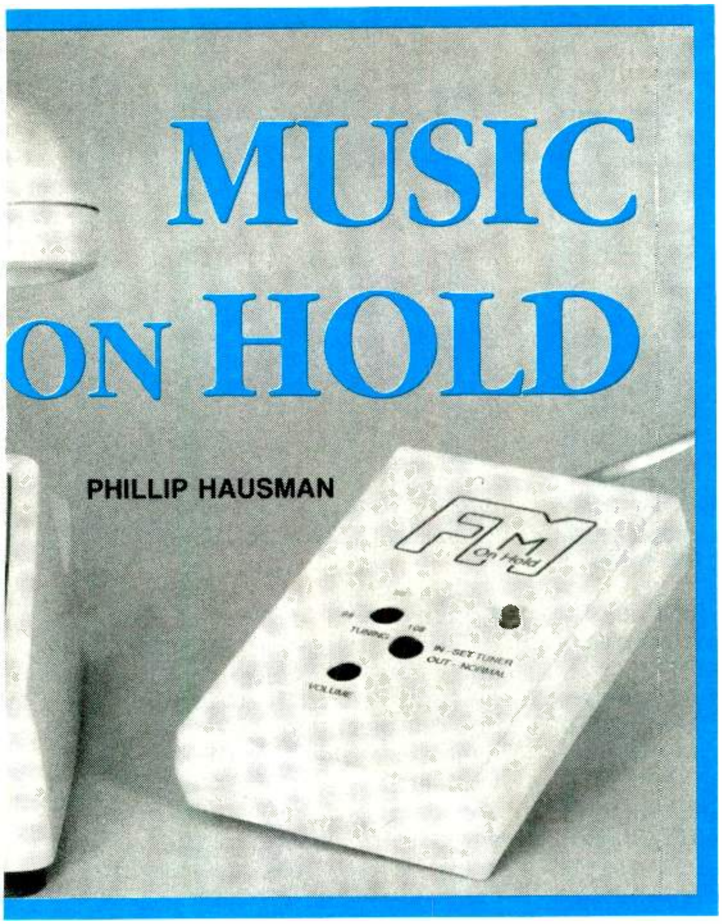
When the "*" key is depressed, IC2-*b* pin 13 goes high, which in turn charges C4 and turns on switching transistor Q1. That activates relay RY1. Diode D1 prevents DC voltage from bleeding back into IC2-*b* pin 13. The timebase oscillator for IC1 is formed from a 3.58-MHz crystal XTAL1 and R5.

The normally open contacts of RY1 close and D7, R9, RY2, R10, C5, LED1, transformer T1 (Sec), and the four diodes from the polarity bridge (D3–D6) are connected across the telephone line and effectively "seize" it. That combination of components is referred to as the seizure network. The unit is now in a "standby" mode and LED1 lights dimly. If jumper J1 is in the IN position and a station is tuned in on the FM tuner, that station will be heard on the telephone line. If J1 is in the OUT position, the station will not be heard until the phone is hung up.

RY1 will stay activated for approximately four seconds. That

MUSIC ON HOLD

PHILLIP HAUSMAN



Impress your callers by adding an FM music on-hold feature to your telephone.

delay is determined by the RC network of R6–C4. Diode D2 prevents relay-coil induction-induced "spikes" from appearing on the +12-volt DC power-supply line.

If the telephone is hung up within the four-second time-out period, additional loop current will flow through the seizure network and activate RY2. That causes normally open contacts of RY2 to close. The project is now in the "on-hold" mode, LED1 will be brightly lit, and the selected radio station will be heard in the telephone line regardless of the position of jumper J1. After the four-second time-out period, RY1 will deactivate. The loop current flowing through RY2 keeps the seizure network across the telephone line and the unit remains "on-hold."

To return to the call, the telephone can be picked up. The loop current flowing through the seizure network is reduced because of the double termination (the telephone and seizure network). RY2 deactivates, and the seizure network is disconnected. Kick-back capacitor C5 ensures the loop current is reduced below the drop-out current for RY2. That reduction in current turns off LED1, disconnects the music, and reconnects the caller.

If the telephone is not hung up within the four-second time-out period, RY1 will deactivate and the project will be taken out of the "stand-by" mode and placed in the "normal" mode. LED1 will not be lit, and the caller will be disconnected if the telephone is hung up.

Latching push-button switch S1 is used to tune in the desired station. When it is in the IN position, the seizure network is placed across the telephone line and the output of the tuner is also connected (regardless of the status of J1). That allows you to hear the output of the FM tuner and adjust the station tuning and volume. (A feature of the receiver is the elimination of interstation "hiss," therefore no audio will be present until a station is tuned in.)

FM receiver circuit

At the heart of the receiver circuit is IC4, a TDA7000 Signetics FM receiver. This IC has a frequency-locked loop system with an intermediate frequency (IF) of 70 kHz. The IF can be chosen by active RC filters. The only function that needs tuning is the oscillator's resonant circuit, which selects the reception frequency.

The antenna is made up from the telephone line and the RJ11 cable. The RF signal travels through that path and is coupled via DC blocking capacitor C6 to the RF input bandpass filter. This broadband low-Q filter consists of C10, C11, and L1. Its primary purpose is to pass RF energy in the 88.0- to 108.0-MHz range while attenuating RF energy from above and below that frequency range. The bandpass filter serves to suppress potential interfering energy from outside the commercial FM broadcast band.

The bandpass filter also acts as a split-capacitor (also known as a tapped capacitor) input impedance-matching network to IC4. It matches a 75-ohm RF input impedance to IC4's 1.5K input impedance. The reverse RF input is decoupled by C12.

After the RF signal passes through the input bandpass filter, it goes to the input of the internal Gilbert cell mixer where it is mixed with the local oscillator (LO) signal. As mentioned earlier, the frequency of the LO is designed to produce an IF of 70 kHz. The tunable LO, connected between pins 5 and 6 of IC4, consists of tank components L2 and D9.

Varactor diode, D9, is DC-voltage tuned by the voltage-divider circuit consisting of R13, R18, and R12. The low end of the tuning range is set by R13 while the high end is set by R12. A high impedance path to the oscillator is provided by R11, keeping it from appearing on the DC tuning control voltage. C21 acts as an RF "short" to ground which prevents the oscillator's RF from entering D9. The IF output of the mixer is routed to a three-stage broadband low-Q IF filter network.

The first section (C20 and C19) determines the cut-off frequency for the second-order low-pass IF filter. The second section (C8 and C7) determines the upper and lower passband. The third section (C9) determines the passband of the third section of the low-pass filter network.

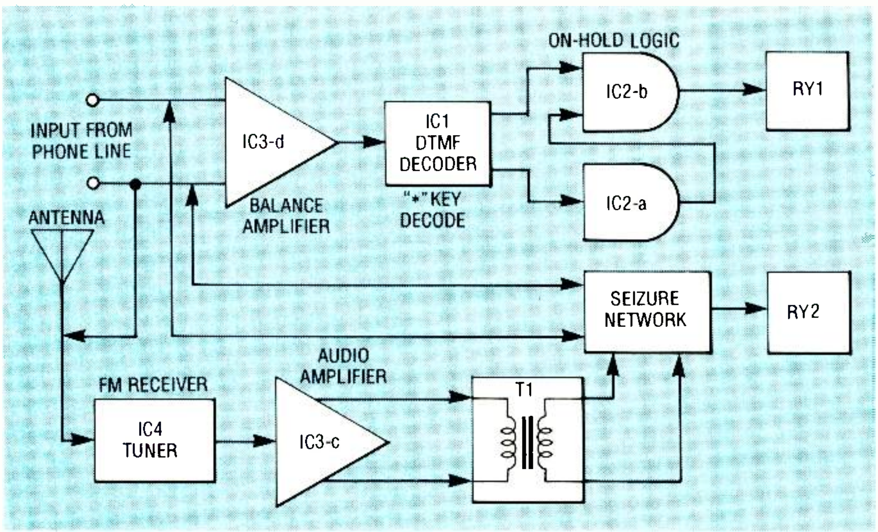


FIG. 1—THIS IS THE BLOCK DIAGRAM of the FM on-hold unit. The circuit consists of three basic sections; a DTMF decoder/on-hold logic, seizure network, and an FM receiver.

TABLE 1—DTMF DECODER OUTPUT CODES

Digit	D8	D4	D2	D1
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
*	**1**	**0**	**1**	**1**
#	1	1	0	0
A	1	1	0	1
B	1	1	1	0
C	1	1	1	1
D	0	0	0	0

After the signal is passed through the IF filter section, it is demodulated. The quadrature detector is tuned by C14. The frequency-locked loop (FLL) filter, which suppresses IF harmonics and prevents them from appearing at the output of the demodulator, is controlled by C18.

The demodulated audio signal from pin 2 passes through a deemphasis network consisting of C22 and R14. A load for the audio output current source is also provided by R14.

The audio signal passes through C23 and R15 to the inverting input of audio amplifier IC3-*c*. Feedback resistor R19 controls the gain of the amplifier from 0 to 10. Transformer T1 matches the amplifier's output impedance to the telephone line impedance.

Construction

The author's prototype is shown in Fig. 3. The entire FM on-hold circuit is mounted on one double-sided PC board. The use of a single-sided board will work as long as the jumper wires are added to the top where necessary. We recommend that a PC board be used because of the VHF range involved in this project. We have provided foil patterns of the

PARTS LIST

All resistors are ¼-watt, 5%.
R1, R2, R11—100,000 ohms
R3, R4, R7, R13, R15—10,000 ohms
R5—1 Megohm
R6—39,000 ohms
R8—2000 ohms
R9—2700 ohms
R10—1200 ohms
R12—130,000 ohms
R14—20,000 ohms
R16, R17—470 ohms
R18, R19—100,000 ohms horizontal PC-mounted potentiometer
Capacitors. All are 50 volts DC, 10% tolerance, mono or ceramic disc unless otherwise indicated.
C1, C2, C6—0.022 µF, 250 WVDC, 20% tolerance
C3, C13, C17, C23–C26—0.1 µF
C4, C27—10 µF, 10 volts, 20% tantalum
C5—47 µF, 63 volts, 20% electrolytic
C7, C20, C21—3300 pF, 50 volts
C8, C14—330 pF
C9—150 pF
C10, C11—39 pF ceramic disc
C12, C22—2200 pF
C15—220 pF
C16, C18, C29—0.01 µF, 20%
C19—180 pF
C28—100 µF, 25 volts, 20% electrolytic
Semiconductors
D1–D7, D10, D11—1N4003, 1 amp 200 PIV rectifier diode
D8—not used
D9—MV209 varactor diode (Motorola)
LED1—Red LED
IC1—MC145436 DTMF decoder (Motorola)
IC2—4082 dual 4-Input AND gate
IC3—LM324N quad op-amp
IC4—TDA7000 FM Receiver (Signetics-Philips)
IC5—7812 +12-VDC, 1-amp regulator
IC6—78L05 +5-VDC, 0.1-amp regulator
Q1—MPSA13 NPN Darlington transistor
Other components
L1—0.138 µH fixed inductor (Coilcraft no. 132-09 or 9T no. 24 ⅛-inch ID)
L2—0.060 µH shielded variable inductor (Coilcraft no. 150-02J08S or TOKO no. MC122)
RY1, RY2—DPDT relay 12 VDC (Aromat no. DS2YE-S-DC12)
T1—audio transformer, 500-ohm primary, 200-ohm secondary (Mouser no.42TM002)
S1—DPDT latching push button switch
XTAL1—3.58-MHz parallel resonant crystal, HC-18/U case
J1—0.1-inch single inline jumper bar and strap
Miscellaneous: Male power jack, female PC board-mounted lug receptacles, 117-VAC power pack (15 VDC at 150 mA), PC board, 6-foot modular line cord, male RJ11 to lugs, project case (Builder's Choice), and 3 14-pin IC sockets
Note: The following items are available from HESC Inc., P.O. Box 12649, Fort Wayne, IN 46864-2649, (219) 482-7190:
• A complete kit of parts including PC board, all components, machined plastic case, and power pack—$69.95 + $3.00 S&H.
• An assembled and tested unit—$119.95 + $3.00 S&H.
Send check or money order, IN residents add 5% sales tax. Allow 6-8 weeks for delivery.

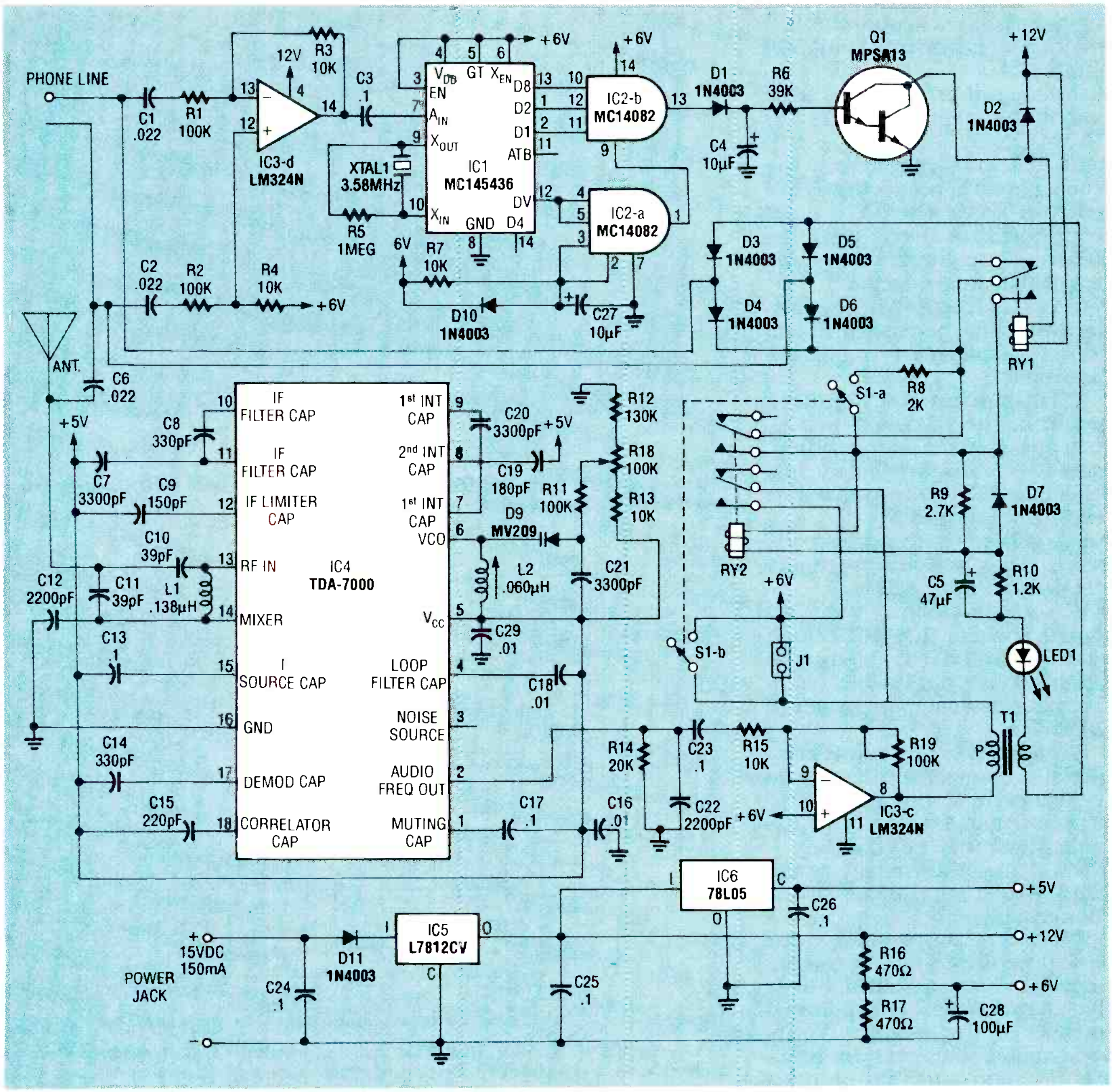


FIG. 2—SCHEMATIC OF THE FM ON-HOLD unit. The output of IC1, a DTMF decoder, is a 4-bit word that controls the on-hold logic. The FM receiver, IC4, uses a frequency-locked loop system with a 70-kHz intermediate frequency, which is tuned by a tank circuit consisting of L2 and D9. Spurious reception is eliminated by a mute circuit in the IC.

component side and solder side of the PC board if you wish to make it yourself. If you choose not to use a PC board, the use of a prototype style board is recommended. You should note that the use of wire wrapping will not work for the receiver portion of this project due to ground return path impedance problems. You can use IC sockets for all IC's except IC4, the TDA7000 FM receiver. The use of an IC socket at VHF frequencies should be avoided.

Figure 4 shows the parts-placement diagram of the unit. Before you begin construction, there are a few things to keep in mind:

- Use proper soldering techniques—The importance of proper soldering cannot be emphasized enough for VHF circuits. We recommend that the flux residue be removed from the completed PC board using a mild non-CFC cleaner that's not harmful to plastics. Always read the manufacturer's label.
- Static sensitive devices—Observe electrostatic discharge precautions when handling individual semiconductors as well as the completed circuit board.
- Component leads—Pre-form component leads before installing them in the board.
- Non-polarized capacitors—When installing these components, orient them so their values can easily be read. This will help if troubleshooting is needed later on.
- Resistors—Mount resistors so they can be read from left to right and top to bottom. This also aids in troubleshooting.
- T1—Bend the tabs flush against the PC board. The audio transformer has a "P" indicating the primary side. The primary mounts towards the outside of

the board. If in doubt, the primary should measure about 500 ohms.

- C6—Mount vertically with the body in the hole closest to D4 and D6.
- L1, L2—It's important the shield have a good electrical connection with the PC board mounting pads. Don't leave the soldering iron on too long as this plastic part might melt.
- IC4 (TDA7000)—When soldering this chip, be careful not to keep a hot soldering iron on the pins too long.
- LED1—For proper mounting height of the LED, cut two ½-inch pieces of insulating tubing. Insert the tubing over both leads. Install the LED with the flat side (short lead) toward T1.
- D9—Mount flush against the board. That will minimize any stray capacitance effects.
- IC sockets—Mount three 14-pin IC sockets (IC1–IC3) flush against the board. Orient the notch towards pin 1, which is indicated on the component side of the board.
- XTAL1—The leads of this crystal can be connected either way to the PC board. Mount it in the vertical position. Do not bend the leads where they exit the body.
- RY1, RY2—These relays are the same type, so they're interchangeable.

The following pre-test steps should be done after all components have been installed. Check that all components are mounted in their proper location. Verify polarized components are properly oriented and that all pads and connections have been properly soldered and de-fluxed. Once those steps have been completed, you can begin bench testing.

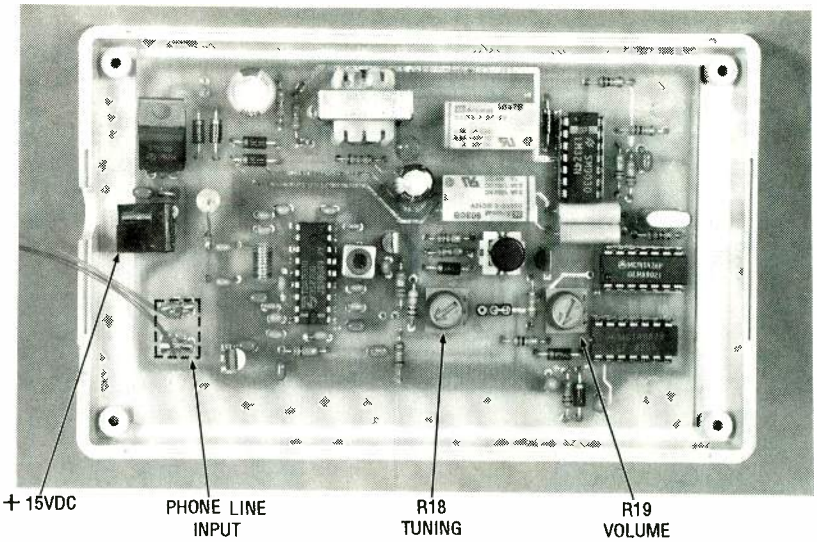


FIG. 3—THE AUTHOR'S PROTOTYPE. Do not use an IC socket for IC4, and be careful when soldering it as excessive heat can damage the chip.

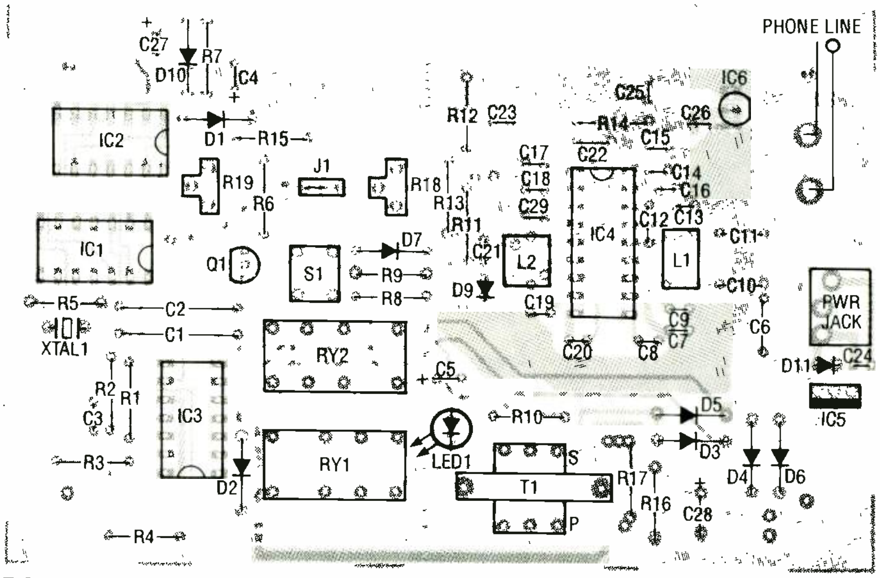


FIG. 4—PARTS-PLACEMENT DIAGRAM. Install all components as shown here. Make sure all components are correctly oriented. The telephone tip and ring conductors can be connected at either phone-line input.

Testing and alignment

The only instrument needed to test the unit is a DMM. Connect the power pack (or a +15- to +28-volt DC power source) to the DC input. Connect AC power to the power pack. Don't connect the unit to the phone line at this time. Next, verify proper operation by making the check out measurements indicated in Table 2. After you have made those measurements, you can proceed with the alignment.

You'll need a plastic alignment tool, a signal source in the FM broadcast band, and a method to hear the audio output. The simplest way of aligning the unit is to connect it to the phone line. The unit was designed to not be sensitive to the tip and ring polarities. Therefore, it doesn't matter which phone lead connects to which terminal on the PC board.

Once the phone line is connected, dial your own number to eliminate the signal tone and off-hook warning tone. Turn the receiver on by depressing push button switch S1. Set the tuning potentiometer to the extreme counter clockwise position (low end of the band). Note that due to the mute function, there is silence until a station is received.

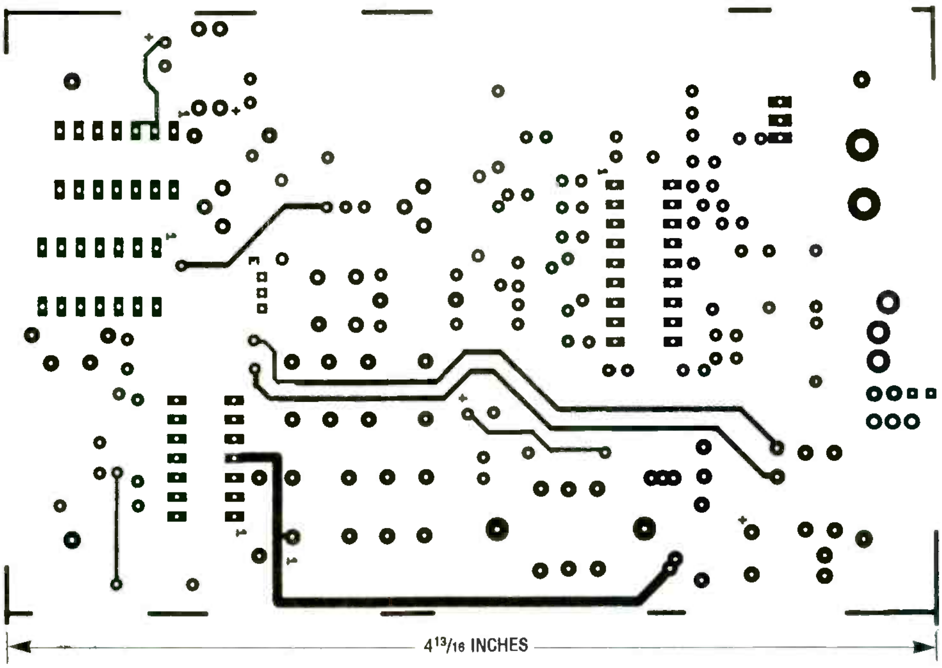
Turn the volume control potentiometer ½ and ¾ clockwise. Adjust the slug in L2 until the station operating at the lowest dial setting in your area is received with the loudest audio output. Use care when adjusting the slug as it is quite delicate and can easily be broken.

Next, set the tuning potentiometer to the extreme clockwise position (top end of the band). Tune back down towards the bottom end of the band (counter clockwise) until the station operating at the highest frequency is received.

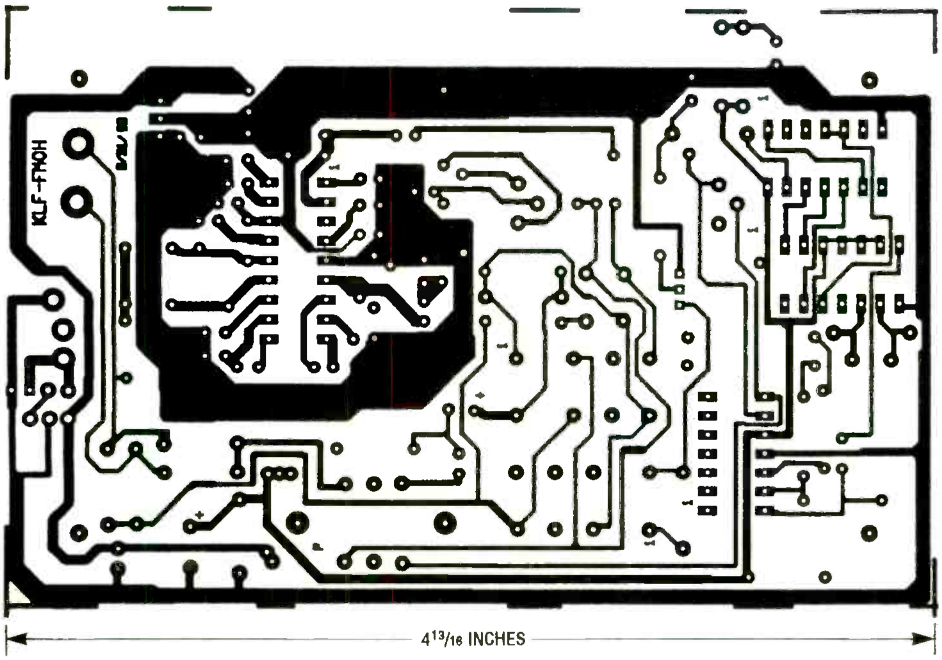
Tune through the entire range

to verify all stations available to your area are being received. The receiver section was designed with a mute function built-in to allow only the strongest stations to be received. That makes tuning easier and suppresses images ("ghost" stations that appear in the wrong part of the tuning dial). Release the pushbutton and hang up the phone.

You can check for proper operation by having a friend call and be placed on hold by depressing the star "*" key (LED1 lights dimly) and then hanging up the phone.



COMPONENT SIDE foil pattern shown actual size.



SOLDER SIDE foil pattern shown actual size.

TABLE 2—CHECKOUT MEASUREMENTS

Parameter	Low Limit	High Limit	Actual Reading
Output of Power Pak	+13.50	+28.00	______VDC
Input Current	31.00	34.00	______mA
IC5 output	+11.40	+12.60	______VDC
IC6 output	+4.75	+5.25	______VDC
+6.0 VDC output	+4.50	+6.50	______VDC
IC3-d pin 12	+4.50	+6.50	______VDC
IC2-a pin 2	+4.50	+6.50	______VDC
IC1 pin 3	+4.50	+6.50	______VDC
IC2-b pin 14	+4.50	+6.50	______VDC
IC3-c pin 10	+4.50	+6.50	______VDC
IC3-d pin 4	+11.40	+12.60	______VDC

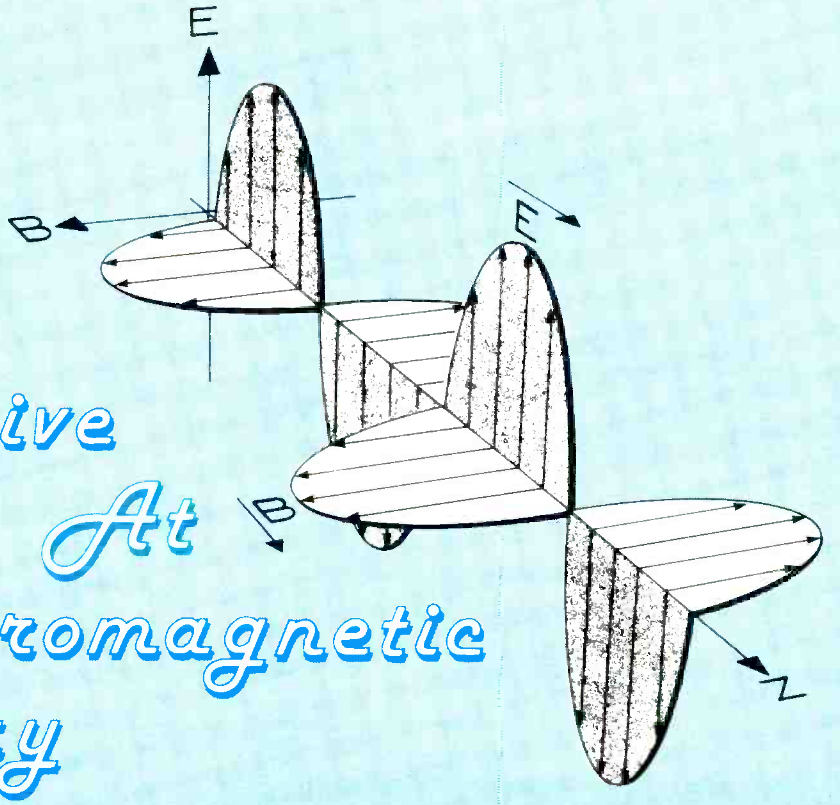
Installation and use

A special feature of this project allows you to select when the music is present in the handset. Some telephone services (call waiting, call forwarding, voice mail) require the use of the "*" key. With J1 in the OUT position (circuit open), music will not be heard in the handset when the "*" key is depressed. It will, however, be heard by the caller when the phone is hung up. With J1 in the IN position (circuit closed), music will be heard every time the "*" key is depressed. Install the jumper according to your available service requirements.

If you would like to connect an external antenna or RF source, such as cable, to the tuner, you can connect it to the junction of C6, C10, and C11. It may be advantageous to disconnect the phone-line antenna by breaking the connection at C6.

It's easy to use the FM on-hold unit. To place a caller on hold press the star "*" key on any Touch Tone telephone. That places the unit in a standby mode and the LED lights dimly. The telephone must be hung up within four seconds for the caller to be placed on hold. When that's done, the LED lights brightly. If it's not hung up within 4 seconds, the unit resets itself and the LED goes out. The caller will be disconnected if the phone is hung up.

After a caller has been placed on hold, all you have to do is pick up the telephone to return to the conversation (any telephone connected to the line, Touch Tone or rotary). When the handset is picked up, the brightly lit LED will extinguish, the music will go off, and you will be connected to the caller. **R-E**



An Intuitive Look At Electromagnetic Theory

Find out more about magnetic phenomena and how inductance is related to the magnetic field.

WILLIAM P. RICE

IN OUR LAST EDITION, WE DISCUSSED the characteristics of a static magnetic field in empty space. In this article we'll look further into the **B** field and its effects on matter. Of particular importance, we will show that the magnetic field in matter can be found by using the linear superposition of free and bound current densities.

Potential

If you recall, the expression $\nabla \times \mathbf{B} = \mu_0 \mathbf{J}$ says that the apparent rotation of the **B** field around a small region about a point is proportional to the current density in that region. Unless the current density or charge per unit area **J** is zero, **B** cannot be the gradient of a scalar potential and therefore is not a conservative field. However, in regions that have no current flow, $\nabla \times \mathbf{B} = 0$. In that case, the field is conservative and a scalar potential can be defined. Suppose a small current loop, the **B**-field instrument $\oint I\mathbf{dl}$, is moved quasi-statically from point A to B in such a region as shown in Fig. 1. The force in the direction of motion $\mathbf{dL}$ gives the work done or change in magnetic potential energy

$$\Delta U_{ab} = -\int_a^b \left[(\oint I \mathrm{dl}) \times \mathbf{B} \right] \cdot \mathrm{dl} \; .$$

The work depends not only on the path taken but on the orientation of $\oint I\mathbf{dl}$ along the path. No work is done if $(\oint I\mathbf{dl}) \times \mathbf{B}$ is always perpendicular to $\mathbf{dL}$. Work is done if, at any place along the path, $\oint I\mathbf{dl}$ is rotated so that $(\oint I\mathbf{dl}) \times \mathbf{B}$ has some component parallel to $\mathbf{dL}$. That is the mechanical energy due to the work done against the torque.

Additional energy is required to maintain the current I in the loop. If the loop has resistance R, then I^2R is the rate of thermal energy loss. That energy must come from someplace, and if the magnetic field enclosed by the loop changes, more energy is required. We'll discuss the reason why additional energy is required in our next article.

Previously, we saw that any field with zero divergence is the curl of some other field. Since $\nabla \cdot \mathbf{B} = 0$, it must be that $\mathbf{B} = \nabla \times \mathbf{A}$. The **A** field is called the magnetic vector potential. It is not an energy field (energy is a scalar quantity), but it can be used in energy calculations. The main advantage in using the **A** field is that calculations required to solve many real-world problems are simplified. Since we won't be doing any calculations here, we will just say that the **A** field is real in the same sense as the **B** field.

We can use the analogy that the **A** field describes action at a distance from the **B** field just as the **B** field describes action at a distance from a current loop. The **E** field is also used to describe action at a distance from an electric charge. An appropriate instrument can be placed in a region of an **A** field, even through the **E** and **B** fields are

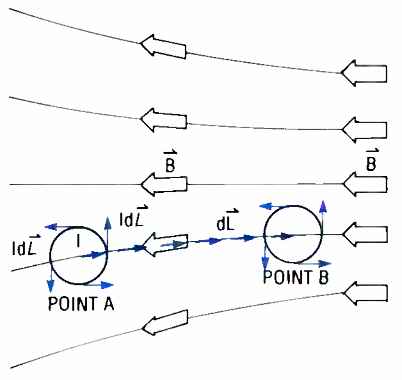


FIG. 1—A MAGNETIC DIPOLE IN A B FIELD is moved from point A to B along the path composed of d_L. The force vector on any small segment of the current loop is $dF_m = Idl \times B$. dF_m is directed out of the page as is the total force $F = \oint Idl \times B$. The force vector is perpendicular to dL, so the work done on $F \cdot d_L$ is zero. If the dipole is rotated so that F was not normal to the paper, then work would be done.

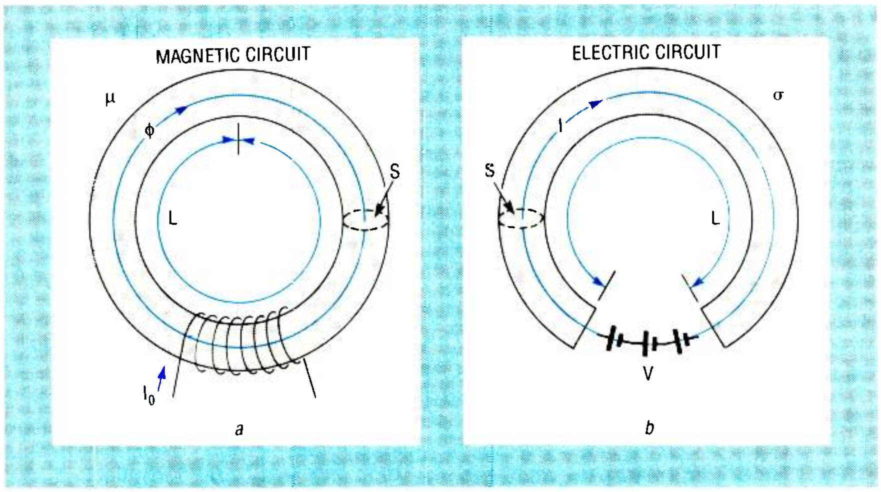


FIG. 2—MAGNETIC FLUX IS ANALOGOUS TO ELECTRIC CURRENT. In (*a*) the magnetic path of length L and cross-sectional area S is in a material of permeability μ. The source of magnetomotive force nI_o is the current I_o encircling the material n times. In (*b*) the electrical path is in a material of conductivity σ. The source of electromotive force nV is a battery of n cells each with a voltage V.

zero there, and an influence can be measured. The Bohm-Aharanov effect is an example.

Magnetic "current"

Recall that $\nabla \cdot \mathbf{B} = 0$ says that the lines of magnetic flux are closed lines. Nothing material flows along these lines but we can make an analogy with the closed path of a constant electric current. The magnitude of **B** in the magnetic circuit of Fig. 2–*a* can be found from $\oint \mathbf{B} \cdot dL = \mu I$, where L is the total length of the magnetic path, μ describes a property of the path material to be discussed later, and I is the total electric current enclosing the path. There are n turns of wire each carrying current I_0 so $I = nI_0$. Since the material is uniform, the magnitude of **B** must be independent when **dL** is being summed. So, denoting the magnitude of **B** as B and summing by integration gives

$$BL = \mu nI_0.$$

The magnetic flux is

$$\phi = \int \mathbf{B} \cdot d\mathbf{s}$$

where **s** is the cross-sectional area of the path. Since the area is uniform

$$\phi = BS = \frac{nI_o}{L/\mu S}.$$

In the circuit shown in Fig. 2–*b*, a current I exists in a material of length L, conductivity σ, and cross-sectional area S. The voltage is supplied by n cells, consisting of V volts each. From Ohm's law

$$I = \frac{nV}{L/\sigma S} = \frac{nV}{R}.$$

The so-called magnetomotive force nI_0 can be compared to the voltage nV. The magnetomotive force is summed in the same way voltages are summed. μ is similar to σ, which suggests that $L/\mu S$ is a magnetic resistance R_M, called reluctance. Those facts, along with the motivating fact that electric current and magnetic flux form closed paths (implying a conservation of something), allow analogous magnetic circuit equations to be developed.

Magnetic field in materials

In any material there are small current loops or magnetic dipoles formed by the atomic-scale rotational and orbital motions of the electrons and charges in the nuclei, as shown in Fig. 3. The vector quantity **Is** (where **s** is the area of each atomic-current loop), is the magnetic dipole moment. Normally the magnetic dipole moments have random orientations, so no average or macroscopic magnetic field is present.

When a material is placed in an external magnetic field $\mathbf{B}_o$, the quantum-wave functions are changed in such a way that there is a higher probability of the magnetic dipole moments being aligned antiparallel to the $\mathbf{B}_o$, as shown in Fig. 4–*a*. The directions may not all exactly align and may not be uniform except in what we call simple magnetic materials. The net effect is that magnetic poles appear at the ends of the material. We say the material has an induced magnetic field, a magnetic polarization, or simply that it is magnetized. This induced magnetic field is called the demagnetization field $\mathbf{B}_d$. The total magnetic field in the material is $\mathbf{B}_i = \mathbf{B}_o + \mathbf{B}_d$. $\mathbf{B}_d$ is antiparallel to $\mathbf{B}_o$ so $\mathbf{B}_i$ has a smaller magnitude than $\mathbf{B}_o$. Such a material exhibiting those characteristics is called diamagnetic.

In some materials there are additional magnetic dipoles resulting from electrons with unpaired spins. Their magnetic dipole moments are normally oriented randomly. When placed in an external magnetic field, the wave functions are changed in such a way that there is a higher probability of the magnetic dipole moments being aligned parallel to the $\mathbf{B}_o$ as shown in Fig.–4*b*. $\mathbf{B}_d$ is aligned parallel to $\mathbf{B}_o$, so $\mathbf{B}_i$ has greater magnitude than $\mathbf{B}_o$. A material exhibiting those characteristics is called paramagnetic.

In many materials, when the external $\mathbf{B}_o$ field is removed, the wave functions return to their original form within a short time and $\mathbf{B}_d$ becomes zero. However, in ferromagnetic materials the wave functions don't return completely and in some regions, called magnetic domains, residual alignment remains. It is as if each domain supplies a $\mathbf{B}_o$ to all other domains, thus maintaining some $\mathbf{B}_i$ in each.

$\mathbf{B}_d$ is not a particularly useful quantity. If there are n magnetic dipoles per unit volume, then a

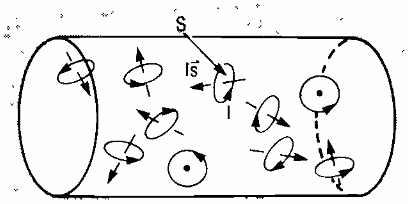


FIG. 3—ATOMIC-SCALE CURRENT LOOPS in a material form magnetic dipoles. The magnitude and direction are given by the magnetic dipole moment Is, where s is the area enclosed by the loop current I. The direction is given by the right-hand rule. Normally, the directions are random and no net magnetic field results.

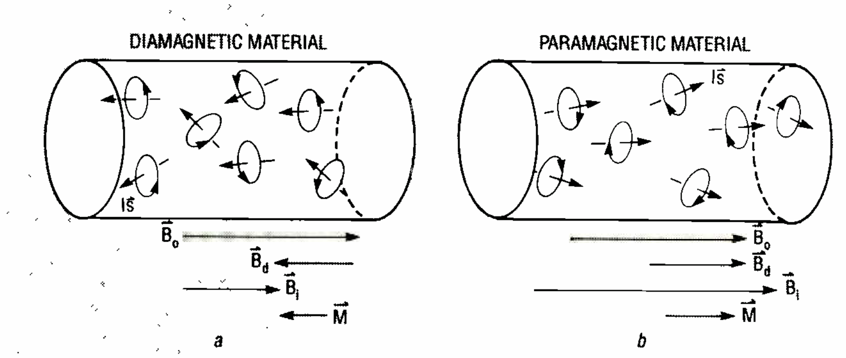


FIG. 4—MATERIALS IN AN EXTERNAL MAGNETIC FIELD B_o exhibit magnetization. In (*a*), magnetic dipole moments tend to align antiparallel to B_o. Demagnetization B_d opposes B_o and the internal magnetic field B_i is smaller in magnitude than B_o. In (*b*), the dipole moments tend to align parallel to B_o due to unpaired electrons. B_i is greater in magnitude than B_o. In both cases the magnetization per unit volume M is related to B_d. The vectors are shown outside of the material for clarity.

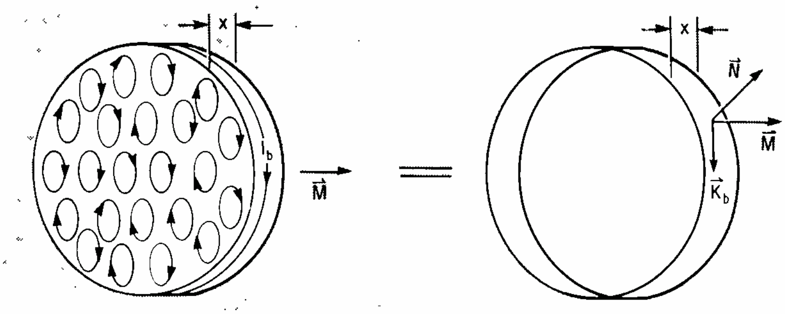


FIG. 5—ELECTRIC CURRENTS associated with individual magnetic dipoles cancel inside the material. At the surface, however, the currents are in the same direction resulting in a net surface current I_b. I_b is bound to the surface since it consists of pieces of the dipole currents bound in the material.

measure of the total magnetic polarization is

$$\mathbf{M} = n(\mathbf{Is})\zeta \text{ (A/m)}$$

called the magnetic dipole moment per unit volume (or just magnetization). ζ is a function of the average alignment of the dipoles with the external field and takes on values from -1 for total antiparallel alignment to $+1$ for total parallel alignment. $\mathbf{B}_d$ and $\mathbf{M}$ are related by a factor that takes into account properties of the material.

We can use the idea of Ampere's law, which says the apparent rotation of a magnetic field around a small region is proportional to the current per unit area in that region, to account for the **M** field. On an average, the atomic-scale magnetic-dipole currents cancel everywhere in a material except at the surface, as shown in Fig. 5. **M** can therefore be attributed to a bound surface current I_b around an area of magnitude S in a material of length x. The magnitude of **M** is simply the magnetic dipole moment per unit volume as illustrated by

$$I_bS/(xS) = I_b/x.$$

It's sometimes convenient to define a lineal-surface current density as

$$\mathbf{K}_b = \mathbf{M} \times \mathbf{N} \text{ (A/m)}$$

where **N** is a unit vector normal to the surface. The curl of **M** is found the same way Ampere's law for static currents was derived, except the current density of concern is the average atomic-scale volume current density bound in the material $\mathbf{J}_b$. That gives us the formula:

$$\nabla \times \mathbf{M} = \mathbf{J}_b \text{ (A/m}^3\text{)}.$$

A convenient way to separate the external and internal contributions is to consider the total current density **J** as a linear superposition of $\mathbf{J}_b$ due to the material and all other currents called the free current density $\mathbf{J}_f$. From Ampere's law, it can then be concluded that

$$\mathbf{J}_f = \mathbf{J} - \mathbf{J}_b = \frac{1}{\mu_o}(\nabla \times \mathbf{B}) - \nabla \times \mathbf{M} =$$

$$\nabla \times \left[\frac{1}{\mu_o}\mathbf{B} - \mathbf{M}\right].$$

The term in brackets is called the magnetic-field intensity or just the magnetic field (not to be confused with the **B** field)

$$\mathbf{H} = \frac{1}{\mu_o}\mathbf{B} - \mathbf{M}.$$

In simple materials, **B** and **M** are along the same line so $\mathbf{B} = \mu_0(1 + \varkappa_m)$ and $\mathbf{H} = \mu\mathbf{H}$. $\varkappa_m$ is called the magnetic susceptibility and μ is the magnetic permeability of the material. A commonly used quantity is the relative permeability which can be written as

$$\mu_r = 1 + \varkappa_m = \mu/\mu_0.$$

μ_r is less than 1 for diamagnetic materials and greater than 1 for paramagnetic materials. In ferromagnetic materials, μ_r is very large but the **H** and **M** relationship is generally more complicated and μ_r is not a simple constant.

Ampere's law now says

$$\nabla \times \vec{H} = \vec{J}_f$$

This says that the apparent rotation of the H field around a small region is due to the density of free current through that region. One of Maxwell's great contribuiton was the modification of Ampere's law.

Inductance

We know that a conductive loop, enclosing empty space or some material, forms an inductor. If the loop is carrying a constant current I, then a proportional magnetic flux exists through the area **s** enclosed by the loop. The constant of proportionality is the inductance, in units of webers per ampere, or henrys

continued on page 87

MICRO MONITOR

Ease microprocessor design chores with our under-$200 logic-analyzer kit.

JIM COOKE

LAST MONTH WE FINISHED OUR DIScussion on the circuitry. Now let's build the unit.

Construction notes

This is a simple project conceptually, but the wiring is complex, hence we recommend use of a PC board. Foil patterns are provided to make your own board: etched, drilled, and silk-screened boards are available from the source mentioned in the parts list.

Using Fig. 5 as a guide, mount all parts, except those mentioned below, on the component side of the board. The LED's should be shimmed so their domes are level with or slightly above S1.

DC power connector J2, a 3.5mm coaxial jack, mounts on the foil side of the board, as do several configuration options (capacitor C4 and option-select jumpers JU1–JU5).

Mount in the position for C4 (on the foil side of the board) a two-pin header socket, and insert a 33-pF ceramic disc. Then mount three-position header pins at JU1–JU4, and a two-pin header at JU5. Insert header jumpers according to the information shown in Table 1. Check for and correct any wiring errors, but don't mount the board in the case yet.

Initial checkout

Before installing the PC board in the enclosure, perform the following tests:

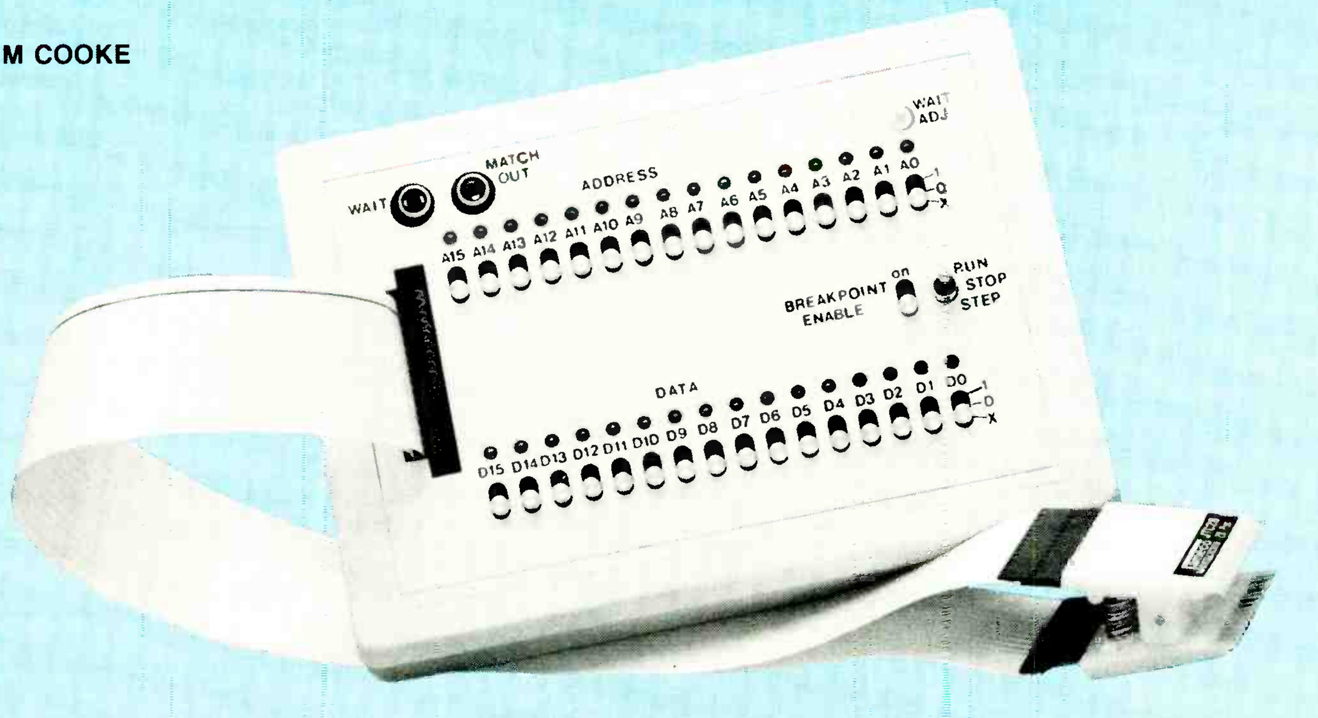
1) Use an ohmmeter to verify that the reading between +5V and ground is greater than 20 ohms.

2) Plug in the wall-mount power transformer and ensure the presence of +5 volts between pin 20 and pin 10 of IC1.

3) With no test clip installed, verify that all LED's are blinking. If not, check whether pin 8 of IC6 is oscillating at about 2 Hz.

4) With one side of a test clip attached to ground, momentarily touch the other side to each address and data input. Verify that the corresponding LED goes out, and that the remaining LED's continue to blink.

5) Verify the correct logic level for the WAIT or READY line.



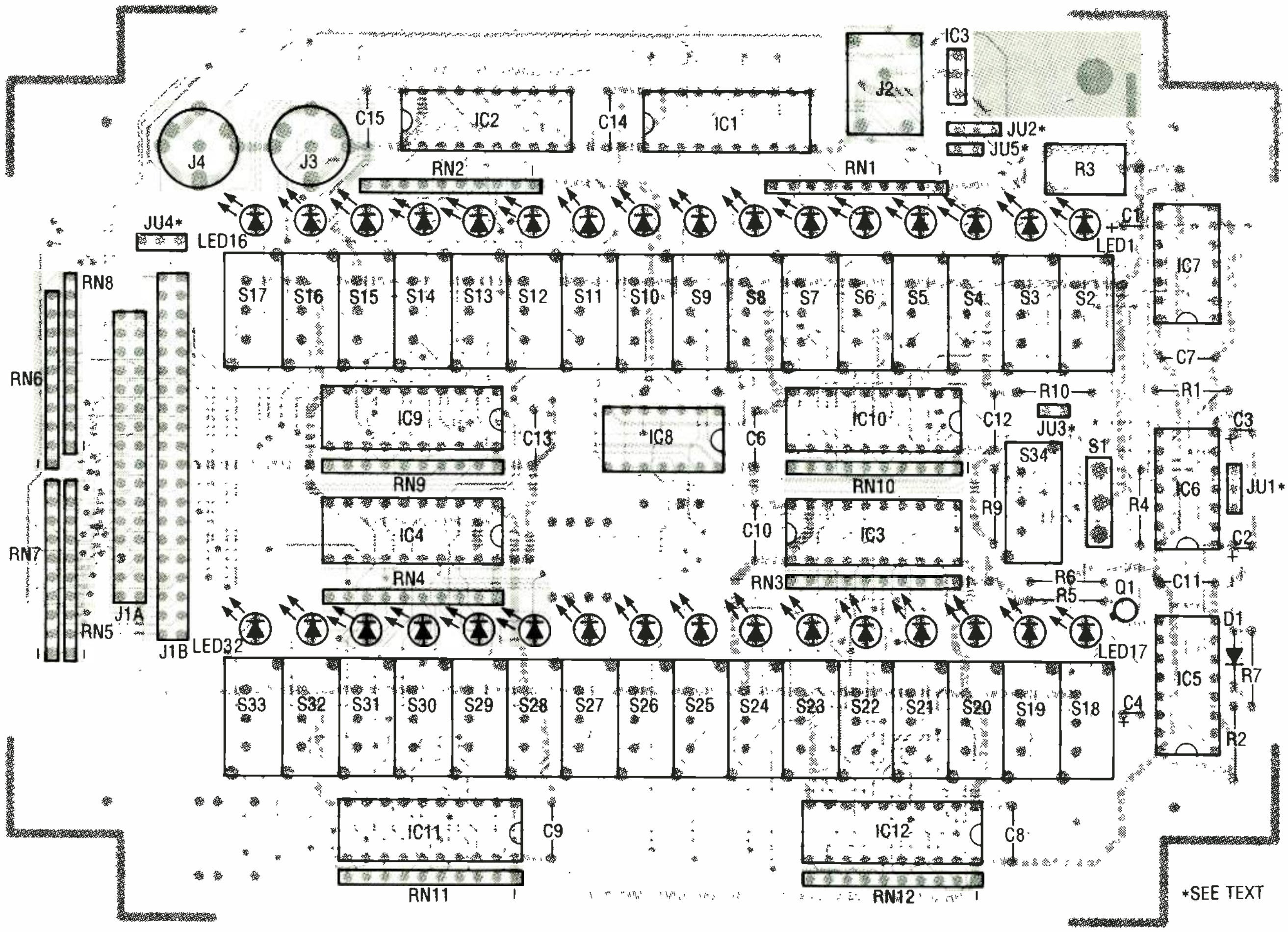


FIG. 5—MOUNT ALL COMPONENTS as shown here. Note that C4, J2, and all five jumper headers mount on the foil side of the board.

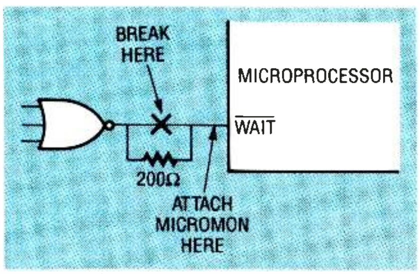


FIG. 6—CONNECT MICRO-MON to the target system directly, or insert a resistor in series with the $\overline{\text{WAIT}}$ line.

6) Verify that when S1 is in the "run" position, an oscilloscope probe attached to the WAIT connector (J4) measures a logic one (5 volts), and when in the "stop" position, a logic zero (less then 0.5 volts).

7) Hold S1 in the "step" position and verify the presence of high-going pulses at J4. The pulse has a narrow width (about 1 μs) and low repetition rate (2 Hz), so it may be hard to see. Use a scope in single-sweep mode or a logic probe with built-in pulse stretcher.

8) Verify that when you release S1, the J4 pulses halt.

9) Move S1 to the "step" position several times, and verify that the J4 signal pulses high when you do that.

If any of those tests fail, remove power and debug the circuit before continuing.

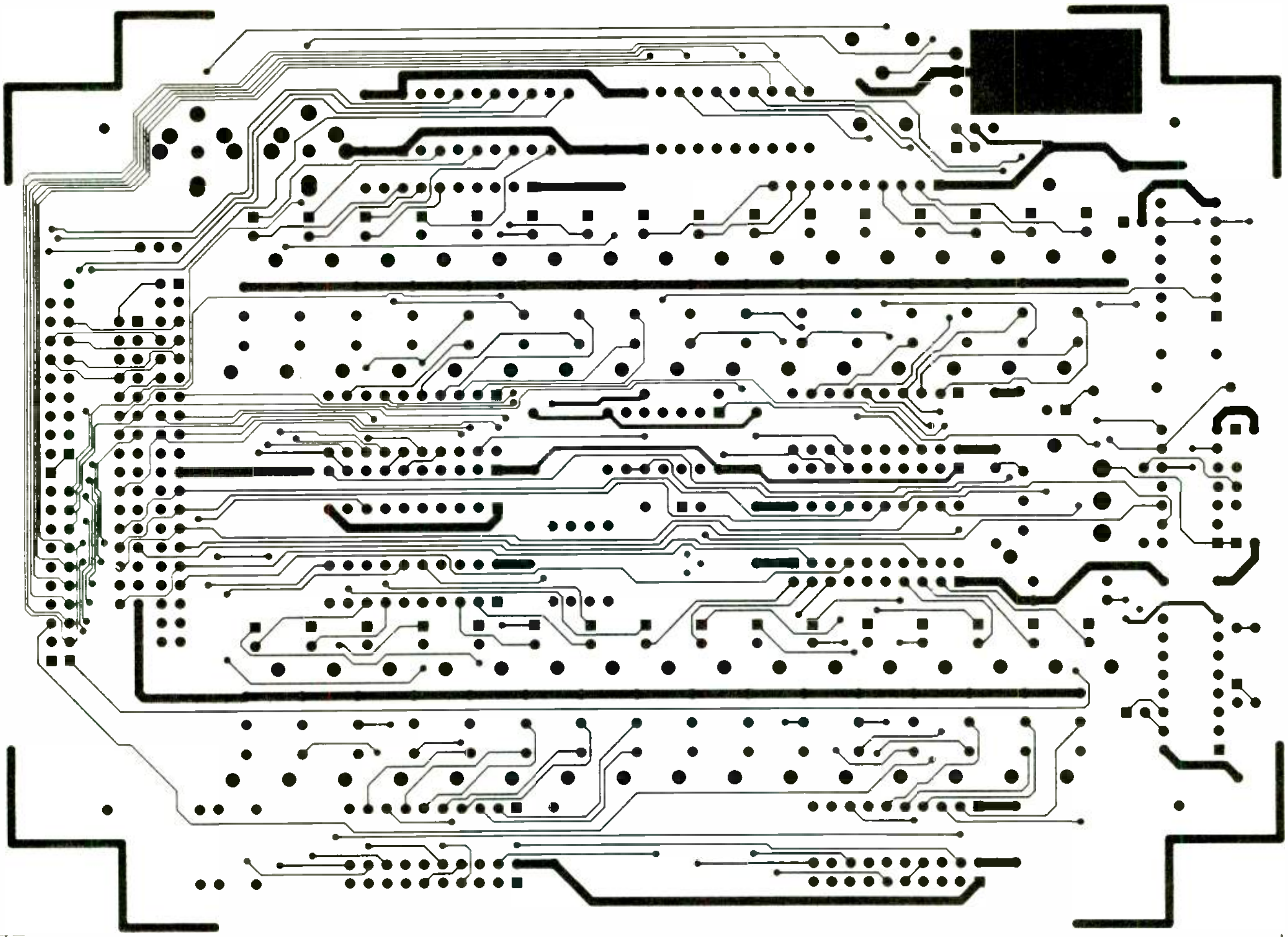
Final checkout

Now you're ready to connect the unit to a target system.

1) Attach a test cable to the MICRO-MON unit and connect the clip over the PROM in the target microprocessor system, at the same time ensuring correct pin-1 orientation.

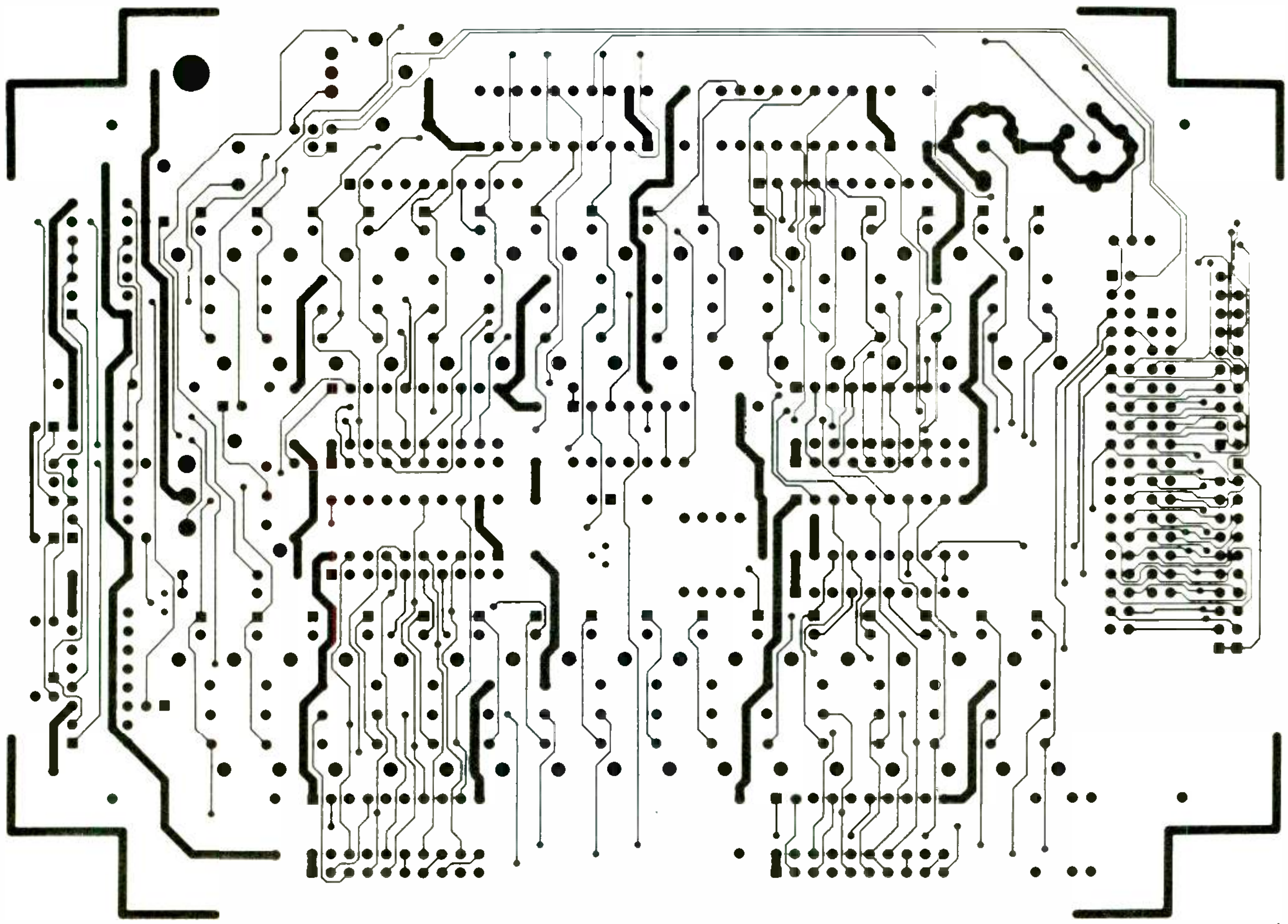
2) If the target microprocessor uses an open-collector or open-drain device in the wait circuit, simply clip the wait cable directly to the wait pin. Another method is to insert a 200-ohm resistor between the target's wait logic

TABLE 1—OPTION SELECT JUMPERS		
Jumper	**Position**	**Description**
1	1-2* 2-3	Wait low Wait high
2	1-2* 2-3	Enable internal power Enable power from test clip
3	On Off*	Enable Match Enable signal to test clip
4	1-2* 2-3	Enable Match Enable to 8-bit test clip Enable Match Enable to 16-bit test clip
5	On* Off	Enable power to test clip pin 30 Disable power to test clip pin 30
* = Default		



6⅞ INCHES

COMPONENT SIDE OF THE MICRO-MON PC BOARD.



6⅞ INCHES

SOLDER SIDE OF THE MICRO-MON PC BOARD.

PARTS LIST

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

R1—150,000 ohms
R2—100,000 ohms
R3—200,000-ohm PC-mount potentiometer
R4—1000 ohms
R5, R10—10,000 ohms
R6—10 ohms
R7—2.2 megohms
R8, R9—47,000 ohms
RN1–RN4—470 ohms × 9 resistor network, pin 1 common
RN5–RN12—47,000 ohms × 9 resistor network, pin 1 common

Capacitors

C1—2.2 µF, 25 volts, tantalum
C2—0.1 µF, 25 volts, tantalum
C3—1 µF, 25 volts, tantalum
C4—33 pF, ceramic disc, with socket (see text)
C6–C15—0.1 µF, ceramic

Semiconductors

IC1–IC4—74HCT240, octal three-state inverting buffer
IC5—74HCT221, dual monostable multivibrator
IC6—74HCT14, hex Schmitt trigger
IC7—74HCT00, quad NAND gate
IC8—74HCT32, quad OR gate
IC9–IC12—74HCT688, eight-bit magnitude comparator
IC13—7805 +5-volt regulator
Q1—2N2222 NPN transistor
D1—1N914 diode
LED1–LED32—red LED (T1-3/4 package)

Other components

J1-a—16 × 2 0.1" header
J1-b—20 × 2 0.1" header
J2—3.5mm coaxial jack
J3–J4—RCA PC-mount phono jack
JU1, JU2, JU4—3-pin 0.1" header
JU3, JU5—2-pin 0.1" header
S1-SPDT toggle, center off, one side momentary (Alcoswitch MTA-106H-PC or equiv.)
SW2–SW33—SPDT slide, middle NC
SW34—SPST slide

Miscellaneous: 6-volt, 300-mA DC adaptor, front panel, enclosure (Hammond P/N A9086265), cables for 28-, 32- and 40-pin ROM's, cable for WAIT line, assembly hardware.

Note: The following items are available from Jim Cooke, P.O. BOX 834, Pelham, NH 03076 (603) 882-4460: Complete kit, $189; PC board only, $29; PC board kit and all components, $99; enclosure with silkscreened front panel, $49; cable assembly with 28-pin chip clip, $49. New Hampshire residents add appropriate sales tax; all orders add 5% for shipping. MC and Visa accepted.

and the microprocessor, as shown in Fig. 6. If neither method is feasible, you must evaluate the target's circuit design to determine the best way to tap into the wait logic. Remember that MICRO-MON uses the WAIT line to control the microprocessor, so stepping and match functions will not work without a wait circuit connection.

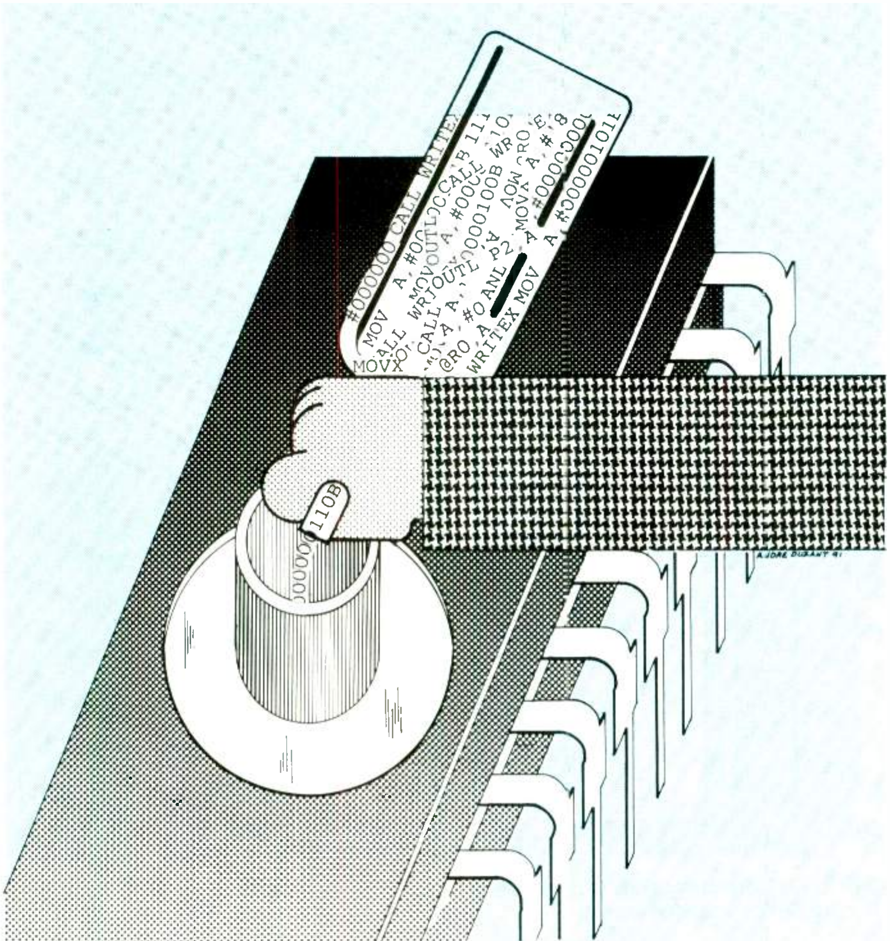
3) Having made the connection to the WAIT line, you must now adjust MICRO-MON's wait timing. The objective is to adjust the WAIT pulse so that the target executes one operation each time the step switch is depressed. Potentiometer R3 adjusts the duration of the WAIT pulse. If the WAIT pulse is too short, the microprocessor may not step at all; if the WAIT pulse is too long, several operations may occur for each step operation. If the target system runs very slowly, you may have to increase the value of C4, which is mounted in a socket to facilitate easy substitution in case you have to experiment with different values.

One way of adjusting the WAIT pulse is to obtain or blast an EPROM containing all "NOP" (No Operation) instructions. The NOP PROM will cause the target microprocessor to cycle through all addresses. After installing the NOP PROM, place S1 in the "stop" position; a random address will appear in the address LED's, and the opcode for the NOP instruction should appear in the data LED's. Pressing S1 once should increment the address by 1, 2, or 4, depending on the instruction word length of your microprocessor.

If the WAIT pulse is too long, the address will increment by more than 1, 2, or 4; if the pulse is too short, the address won't increment at all. The best technique is to start short and increase the WAIT-pulse duration until it just starts to increment by one instruction word.

After adjusting the WAIT pulse, ensure that the auto-step feature works. Hold down the step switch; the LED's should show the address incrementing about twice per second.

Checkout is now complete and MICRO-MON is ready to use on your workbench or in the field. Happy debugging! R-E



874X PROGRAMMER

USING MICROPROCESSORS IN YOUR home projects often turns out to be a complex ordeal. The typical microprocessor project consists of the processor, EPROM, RAM, address decoder circuitry, clock circuitry, input/output ports, and the ever present but essential "glue" components. Things can get a little more complicated if a special-purpose IC like an analog-to-digital converter is thrown in. Then comes the pleasure of putting everything on a circuit board—and most of the time the complexity of the circuit necessitates the use of a double-sided board!

But don't despair. There is an easier and more enjoyable way to exercise your hobby. This article will open the door to a more efficient hobbyist approach to designing microprocessor-based projects. Imagine how much design time could be saved if you had a processor, EPROM, RAM, clock, and input/output ports already integrated into a standard 40-pin package.

Such devices already exist, of course—they're called microcontrollers. Several different varieties of these microcontrollers are now readily and inexpensively available. All you really need to use them is a microcontroller programmer, and we're going to show you how to build one in just one evening for under $50. The programmer is good for the 8748H and 8749H series of microcontrollers made by Intel.

The 8748/49H

The 8748/49H is commonly referred to as a single-component 8-bit microcomputer. The instruction sets for the 8748H and 8749H are identical. The 8749H contains 2K of EPROM and 128 bytes of RAM, while the 8748H contains 1K of EPROM and 64 bytes of RAM. Although that doesn't sound like a lot of memory, you'll find the amount of EPROM and RAM to be more than adequate for most controller applications. And if you do require extra RAM, you can hang it outboard just as you would with any other processor IC.

Both IC's include an interval timer/event counter, two single-level interrupts, an internal oscillator, a true bi-directional bus, two latched quasi-bidirectional I/O ports, two testable input pins, and an 8-bit processor that executes over 96 instructions with most of them consisting of a single byte. If you're short on I/O or memory, the 8748H/49H will accommodate most common peripheral circuitry available for other microprocessors. A minimum circuit configuration consists of the 8748H/49H, a crystal, two 27-pF disk capacitors, a 5-volt DC power source, and a 1-µF reset capacitor.

Software

There are many cross assemblers for the 8748H/49H available in the public domain, and many more advertised by reputable electronics distributors. Just choose one that fits your needs and budget. One cross-assembler software package that can be used with PC-compatible computers is contained in a ZIP file (TASM.ZIP) that's included as part of a larger ZIP file containing all software relevant to this article. The larger ZIP file (874XPGR.ZIP) is available on the RE-BBS (516) 293-2283, 1200/2400, 8N1.

The 8748H/49H lends itself well to applications that require I/O port activity and serial communications (RS-232) with a terminal or supervisory program. This project was designed to take advantage of both. Most of the data storage and screen information are maintained and presented to the user by the terminal program, PROG.EXE, which runs on a PC-compatible computer. The terminal program is DOS based, so you may have to modify the source code (PROG.BAS) to run on a different computer. The software listing

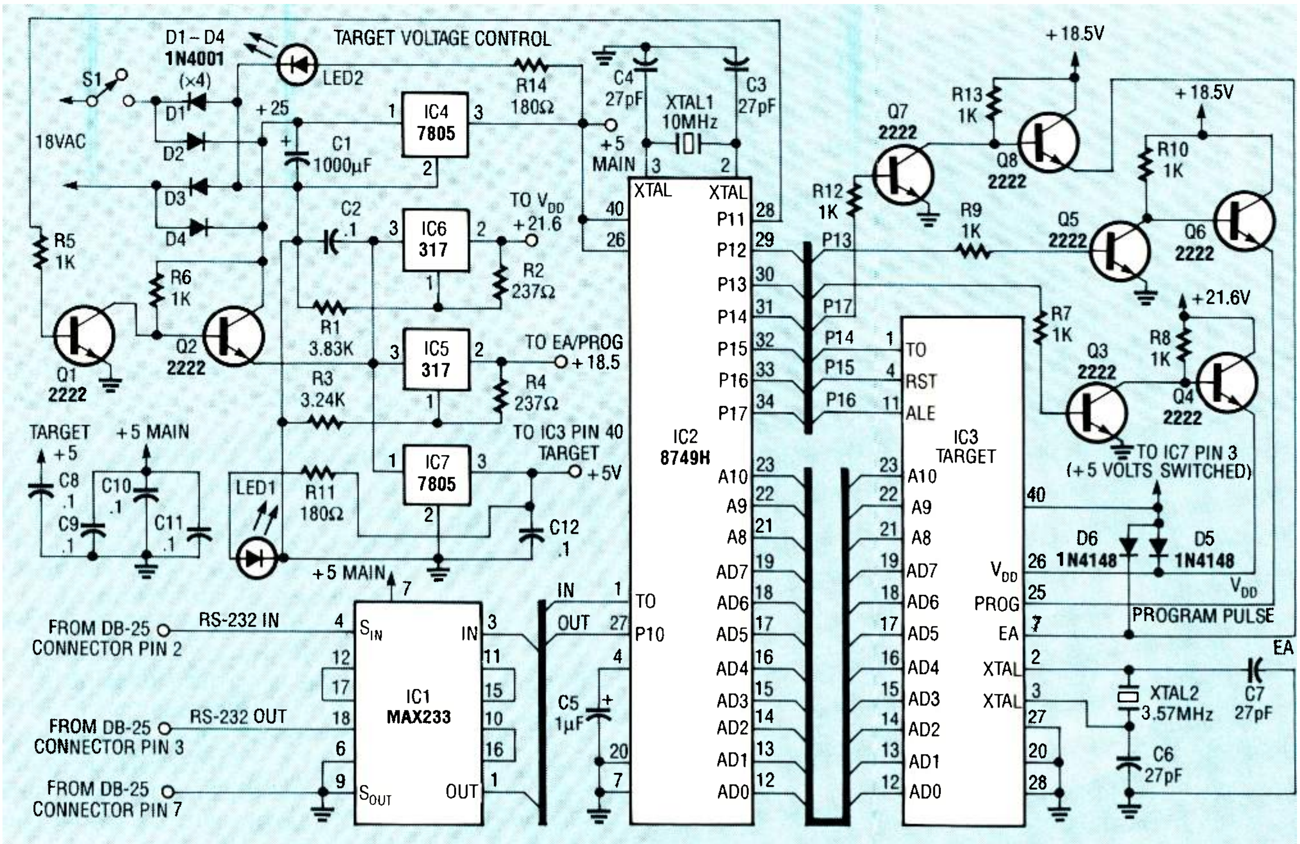


FIG. 1—PROGRAMMER SCHEMATIC. The MAX233 RS-232 driver/receiver (IC1) converts the signals from your serial port to TTL levels for the 8749H and vice versa.

for the terminal program is unfortunately too large to print here, but it is contained in the main ZIP file (874XPGR.ZIP).

Any data or commands are sent serially at 2400 bits per second from the terminal program via serial port to the programmer. The programmer's processor acts on the received data and returns any necessary data to the terminal program. This eliminates the housekeeping functions that would normally be performed by the programmer's processor, and thus simplifies both the hardware and the software of the programmer module.

Circuitry

Looking at the schematic in Fig. 1, IC1 is a MAX233 RS-232 driver/receiver. Its purpose is to convert the signals from your serial port to TTL levels for the 8749H and vice versa. The input serial data stream is fed into the T0 input of the 8749H programmer while the output data stream is fed from I/O Port 1.0. The combination of the driver/receiver IC, the built-in hardware of the 8749H, and firmware in EPROM allows the terminal program to communicate with the 8748H/49H programmer.

Microcomputer IC2 (an 8749H) controls the application of the proper programming voltage levels, pulses, address information, and data to IC3 (the target device), which is installed in a ZIF (zero insertion force) socket when programming. The code for IC2 (874XCODE.HEX) is also contained in the ZIP file 874XPGR.ZIP. (There is also a binary version of the code, 874XCODE.BIN, which is also contained in the ZIP file.) The bidirectional ports contained in IC2 latch output data and read input data that is latched onto an external port by another device. Traditionally that would be handled by both a 74LS373 octal latch used as an output port and a companion 74LS244 used as an input port. Our programmer contains no external latches or address decode circuitry in either the data bus or control ports.

Data and address information are multiplexed on the bus pins AD0–AD7. The bus pins behave in a similar fashion to the bidirectional port pins but tend to be more TTL-like in nature. If you get a data sheet, study the differences in internal hardware construction as it pertains to the bus and quasi-bidirectional I/O ports. In the case of the programmer hardware, the target, IC3, and main processor, IC2, alternately latch output data on their respective busses to be read by the opposing processor's bus. Address pins A8–A10 are actually IC2's I/O port pins P0–P2, and are used as latched output pins. I/O port P1 is used to control the transistor pairs that supply the correct programming voltages to the target device. Since all of the bidirectional I/O pins can drive one TTL load, port P1 is also used to set up TTL logic levels on IC2's port pins P1.4–P1.6 that connect to the target device directly.

Power for IC1 and IC2 is supplied via voltage regulator IC4 and associated circuitry. Crystal XTAL1 along with the two 27-pF capacitors supply the feedback path for the on-chip oscillator. Since precise clock periods are required to generate timing for

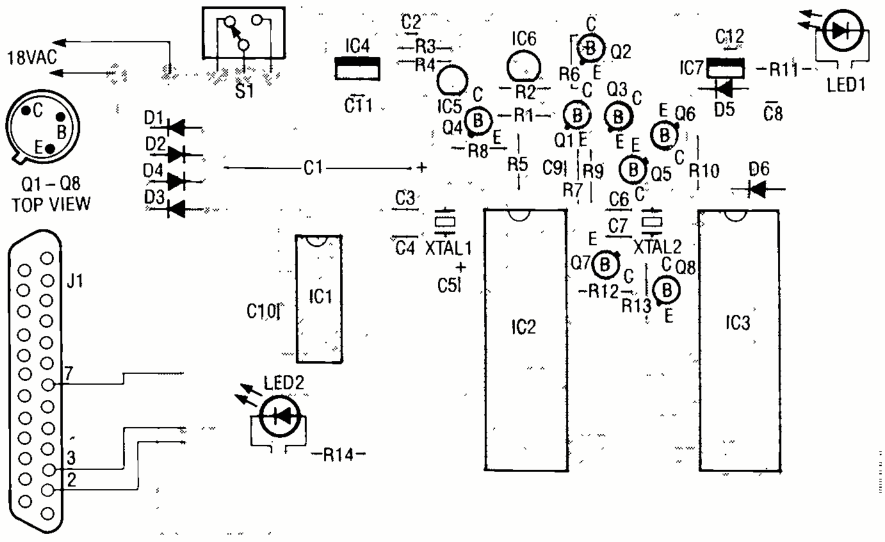


FIG. 2—FIRST INSTALL THE POWER SUPPLY DIODES D1–D4, filter capacitor C1, switch S1, and connect the 18-VAC transformer. With no other parts installed, you should have a full-wave bridge circuit with a +25-volt DC output across C1.

the serial data stream and programming pulses, a crystal-controlled oscillator is essential.

The 1-µF tantalum capacitor, C5, resets the microcomputer. Note the absence of the reset switch, and don't be tempted to add one. If the power is toggled or the processor is reset while a target device is socketed, permanent damage will result to the target due to transient voltages on the transistor pairs generated by a main processor reset. Therefore, NEVER apply or terminate power while a target is socketed. You may add a reset switch across the 1-µF capacitor as shown in the example circuits we'll look at later.

The device to be programmed, IC3, can be either a 8748H or 8749H. You select the type when you run the terminal program. The target device needs +5-, +18-, and +21-volt DC power sources to effect the programming/verify process. The voltages are derived from voltage regulators IC5–IC7; IC5 and IC6 are standard configurations of the low-power "LZ" version of the LM317.

Transistor pairs Q3-Q4, Q5-Q6, and Q7-Q8 provide the high-voltage switching functions necessary for the programming and verification of the target device. Voltage regulator IC7, a 7805T, supplies +5-volts DC to the target during programming and verification. Light-emitting diode LED1 is active when power is applied to the target device. Transistor pair Q1-Q2 is used to switch all operating power to the target device (IC3).

The 8748H/49H needs a clock signal to move data internally. Crystal XTAL2 along with its 27-pF capacitors are used to supply a clock signal for the target device. Any crystal between 3 and 4 MHz will suffice. The target clock period is not critical to the programming process.

The sequence used to program IC3 is similar to programming an ordinary EPROM; the target device is powered up in program mode. Address information is passed to the target by IC2. Then, data information is latched out of IC2 to the target. A pulse is applied to the target's PROG pin and the verification process follows. If verification is good, then the process is repeated for the next byte, and so on.

To sum it up, IC1 converts RS-232 voltage levels to TTL voltage levels and vice versa. Controller IC2 provides communication with the terminal program via a 2400 bits-per-second serial link, provides address and data information to the target, provides precisely timed pulses to the target, and provides voltage-switching information to the transistor pairs that interface with the target. Target IC3 is programmed with the data you specify using the terminal program in conjunction with IC2. All of this is done with a single-component microcomputer on a single sided board!

PARTS LIST

All resistors are ¼-watt.
R1—3830 ohms, 1%
R2, R4—237 ohms, 1%
R3—3240 ohms, 1%
R5–R10, R12, R13—1000 ohms, 5%
R11, R14—180 ohms, 5%

Capacitors
C1—1000 µF, 35V, electrolytic
C2, C8–C12—0.1 µF, 50V, Mylar
C3, C4, C6, C7—27 pF, disk
C5—1 µF, 35V, tantalum

Semiconductors
IC1—MAX233 RS-232 driver/receiver
IC2—8749H microcontroller (programmed)
IC3—8748H or 8749H microcontroller
IC4, IC7—7805T 5-volt regulator
IC5, IC6—LM317LZ low-power adjustable regulator
D1–D4—1N4001 diode
D5, D6—1N4148 diode
LED1, LED2—light-emitting diodes, choose color to suit taste
Q1–Q8—2N2222A NPN transistor

Other components
S1—SPST toggle switch
XTAL1—10-MHz crystal
XTAL2—3.57-MHz crystal
Miscellaneous: 18VAC 1.35A transformer, heatsink for IC4, 40-pin ZIF socket (for target IC3), 40-pin IC socket (for IC2), 20-pin IC socket (for IC1), 25-pin right-angle female DB-25 connector (optional), serial cable, PC board, wire, solder, etc.

Note: The following items are available from F. Eady, PO Box 541222, Merritt Island, FL 32954:
- **A kit of parts including a pre-programmed microcontroller (not including the transformer, ZIF socket, serial cable, or 25-pin connector)—$49.95 + $5.00 S&H.**
- **PC board only—$15.00 + $5.00 S&H.**
- **Software on floppy disk—$5.00 postpaid.**

Check or money orders only.
For technical assistance call (407) 454-9905.

Construction

The first thing you must do is etch and drill a PC board from the pattern we've provided—or purchase a ready-to-use PC board from the source mentioned in the parts list. As shown in Fig. 2, start assembly by installing power supply diodes D1–D4 and filter capacitor C1. Mount the switch S1 and connect the 18-VAC transformer. At this point, with no other components mounted yet, you should have a full-wave bridge circuit that outputs +25-volts DC measured across C1.

Once you are satisfied with the 25-volts DC across C1, install voltage regulator IC4 and bypass capacitor C11. Be sure to install a heatsink on IC4. Apply power and measure the output of IC4; you should have +5 volts DC at the output (pin 3). If so, install the rest of the power supply components: R1–R4, C2, C12, IC5, IC6, and IC7. To check the voltage levels from those regulators you must also install transistor pair Q1-Q2, since this pair supplies power to the regulators. Install LED1 and LED2, along with current-limiting resistors R11 and R14.

Once all of the power components are installed (with no IC's yet installed), apply power and both LED's should light. You should be able to read the voltages on the outputs of the voltage regulators (IC5–IC7). You can now jumper R5 (that goes to the base of Q1) to +5 volts; that should turn off power to the target device and extinguish LED1. That simulates a high TTL level that would normally come from the main processor, IC2, and verifies that the target power-shut off circuitry is working properly.

Finish the assembly by installing the remaining transistor pairs. You can test the transistor pairs and their switching by jumping the base input resistors to +5 volts and noting the change in output voltage at the pair's open-emitter output. The V_{DD} pair should toggle between +21 and +5 volts. The Program Pulse pair should toggle between +18 volts and floating. The EA pair should toggle between +18 and +5 volts. If not, make sure that you have installed blocking diodes D5 and D6 and also recheck the rest of your work.

The prototype used a modified right-angle DB-25 connector for J1, mounted directly to the board using the appropriate nuts and bolts. You do not have to use a connector; you can solder your cable directly to the PC pads if you wish. If you do decide to add the DB-25 connector, cut off all of the pins except 2, 3, and 7. Note that no holes are provided for the

LISTING 1

```
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;                                                                    ;
;         EXAMPLE 1 - INTELLIGENT DISPLAY DRIVER                     ;
;                                                                    ;
;         THIS ROUTINE WRITES "8748" TO THE NSM 1416 4 DIGIT DISPLAY ;
;                                                                    ;
;         LABEL A CODE WRITES THE LETTER "X" TO ALL 4 DIGITS         ;
;                                                                    ;
;         LABEL B CLEARS THE CURSOR WITHIN THE NSM 1416              ;
;                                                                    ;
;         LABEL C WRITES "8748" INTO DIGITS 0-3                      ;
;                                                                    ;
;         LABEL D HALTS THE PROGRAM BY LOOPING ON ITSELF             ;
;                                                                    ;
;         SUBROUTINE WRITEX PERFORMS THE WRITE FUNCTION              ;
;                                                                    ;
;                                                                    ;
; NOTE:   CE- PIN ON THE NSM 1416 IS GROUNDED                        ;
;                                                                    ;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
ADDRESS
|
|   CODE     LABEL
|   |         |
0000 23 07     A        MOV  A,#00000111B    ;WRITE LETTER X TO ALL 4 DIGITS
0002 14 2F              CALL WRITEX          ;WRITE TO DIGIT 3
0004 23 06              MOV  A,#00000110B
0006 14 2F              CALL WRITEX          ;WRITE TO DIGIT 2
0008 23 05              MOV  A,#00000101B
000A 14 2F              CALL WRITEX          ;WRITE TO DIGIT 1
000C 23 04              MOV  A,#00000100B
000E 14 2F              CALL WRITEX          ;WRITE TO DIGIT 0

0010 9A 00     B        ANL  P2,#00000000B   ;CLEAR THE CURSOR
0012 23 00              MOV  A,#0
0014 90                 MOVX @R0,A

0015 23 07     C        MOV  A,#000000111B   ;WRITE LETTER 8 TO DIGIT 3
0017 3A                 OUTL P2,A
0018 23 38              MOV  A,#'8'
001A 90                 MOVX @R0,A

001B 23 06              MOV  A,#000000110B   ;WRITE LETTER 7 TO DIGIT 2
001D 3A                 OUTL P2,A
001E 23 37              MOV  A,#'7'
0020 90                 MOVX @R0,A

0021 23 05              MOV  A,#000000101B   ;WRITE LETTER 4 TO DIGIT 1
0023 3A                 OUTL P2,A
0024 23 34              MOV  A,#'4'
0026 90                 MOVX @R0,A

0027 23 04              MOV  A,#000000100B   ;WRITE LETTER 8 TO DIGIT 0
0029 3A                 OUTL P2,A
002A 23 38              MOV  A,#'8'
002C 90                 MOVX @R0,A

0020 04 2D     D        JMP  $               ;LOOP HERE FOREVER

002F 3A        WRITEX   OUTL P2,A            ;WRITE LETTER X SUBROUTINE
0030 23 58              MOV  A,#'X'
0032 90                 MOVX @R0,A
0033 83                 RET
```

LISTING 2

```
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;                                                                     ;
;       EXAMPLE 2 - EXPENSIVE LED BLINKER                             ;
;                                                                     ;
;       THIS ROUTINE BLINKS AN LED                                    ;
;                                                                     ;
;       LABEL A WRITES 01 HEX TO THE BUS - TURNS ON LED               ;
;                                                                     ;
;       LABEL B WRITES 00 HEX TO THE BUS - TURNS OFF LED              ;
;                                                                     ;
;       LABEL C JUMPS TO THE BEGINNING LABEL A                        ;
;                                                                     ;
;       SUBROUTING KILLTIME DECREMENTS 2 REGISTERS TO CREATE A DELAY  ;
;                                                                     ;
;                                                                     ;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

ADDRESS
  |
  |  CODE     LABEL
  |   |         |
 0000 23 01     A         MOV  A,#00000001B    ;WRITE A BINARY 00000001 TO THE DATA BUS
 0002 02                  OUTL BUS,A           ;TURN ON TRANSISTOR AND LED

 0003 14 0C               CALL KILLTIME        ;KILL SOME TIME

 0005 23 00     B         MOV  A,#00000000B    ;WRITE A BINARY 00000000 TO DATA BUS
 0007 02                  OUTL BUS,A           ;TURN OFF TRANSISTOR AND LED

 0008 14 0C               CALL KILLTIME        ;KILL SOME TIME

 000A 04 00     C         JMP  A               ;GO DO IT ALL AGAIN

 000C B8 FF     KILLTIME  MOV  R0,#0FFH        ;LOAD REGISTER R0 WITH FF HEX

 000E B9 FF     INNERLOOP MOV  R1,#0FFH        ;LOAD REGISTER R1 WITH FF HEX
 0010 E9 10               DJNZ R1,$            ;DECREMENT R1 TO 00

 0012 E8 0E               DJNZ R0,INNERLOOP    ;DECREMENT R0 - IF R0 NOT EQUAL 0 THEN DO INNERLOOP

 0014 83                  RET                  ;DONE KILLING TIME
```

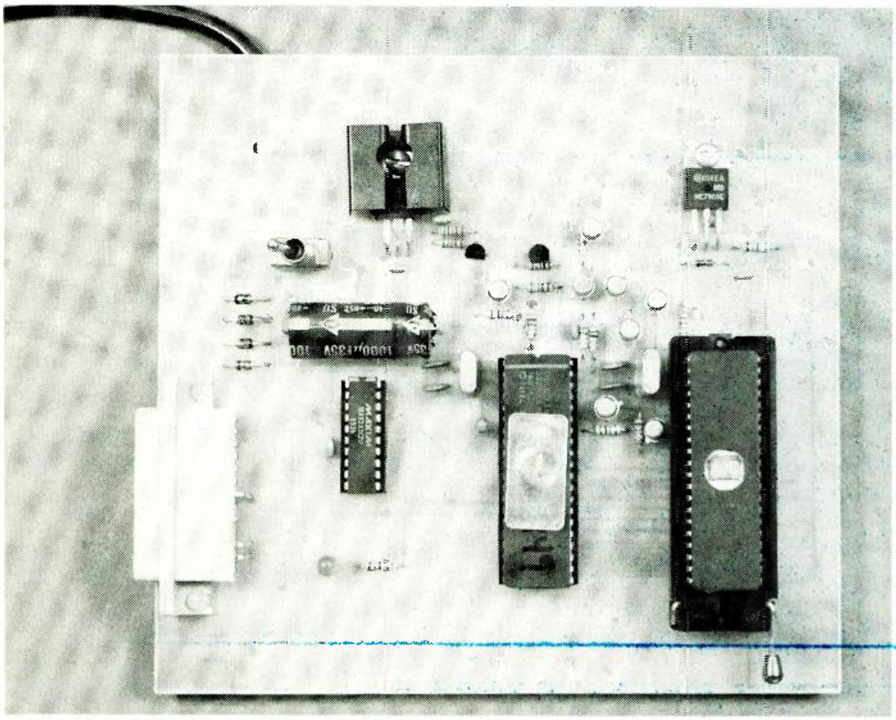


FIG. 3—THE COMPLETED UNIT. Double check all voltages on the pads of IC1 and IC2 before installing them in their sockets. When you apply power, LED2 should illuminate.

DB-25 mounting hardware because of the many different styles of connectors. Install your DB-25 connector and drill mounting holes accordingly.

It's a good idea to double check all voltages on the pads of IC1 and IC2 before installing them. When you are satisfied that all is well, install the IC's. Apply power and LED2, the main power LED, should illuminate. LED1 should not illuminate indicating that IC2 has initialized transistor pair Q1-Q2 properly and no voltage is present at the target ZIF socket (IC3). Figure 3 shows the completed unit.

Using the programmer

Connect the serial port from your computer to the programmer's serial connections and execute the terminal program at this time. If all is well, "READY FOR COMMAND" should appear on your screen. This indicates that the terminal program has established communications with the programmer. If "UNABLE TO COMMUNICATE WITH PROGRAMMER" appears, something is not right with the programmer or your serial port connections.

Power up the programmer and start the terminal program (PROG.EXE)—if you haven't done so already. You should get "READY FOR COMMAND" on the screen before beginning. You may socket the target device in the IC3 ZIF socket any time after you power up and any time LED1 is not on.

Note the list of commands. You may execute a command by typing the letter contained in parentheses preceding the command. The terminal program has been written so that its use will be obvious to the user. For those of you not familiar with programming any sort of programmable device, the basic steps are:

1. Make sure the target device is blank.
2. Load the binary image of the file you want to program into the terminal program.
3. Program the device.

Some sample programs and circuits have been included that use the 8748H in a minimum mode configuration. The intent here is to allow you to enter the machine code into a file using a

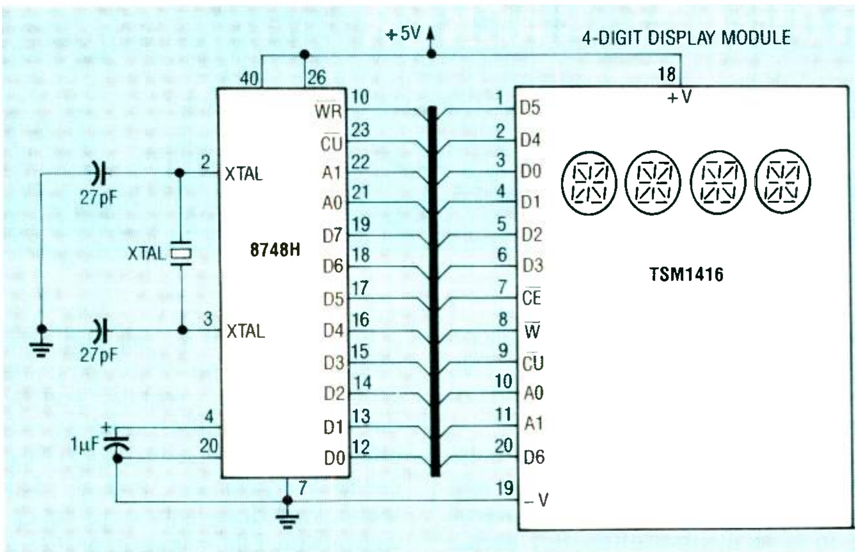
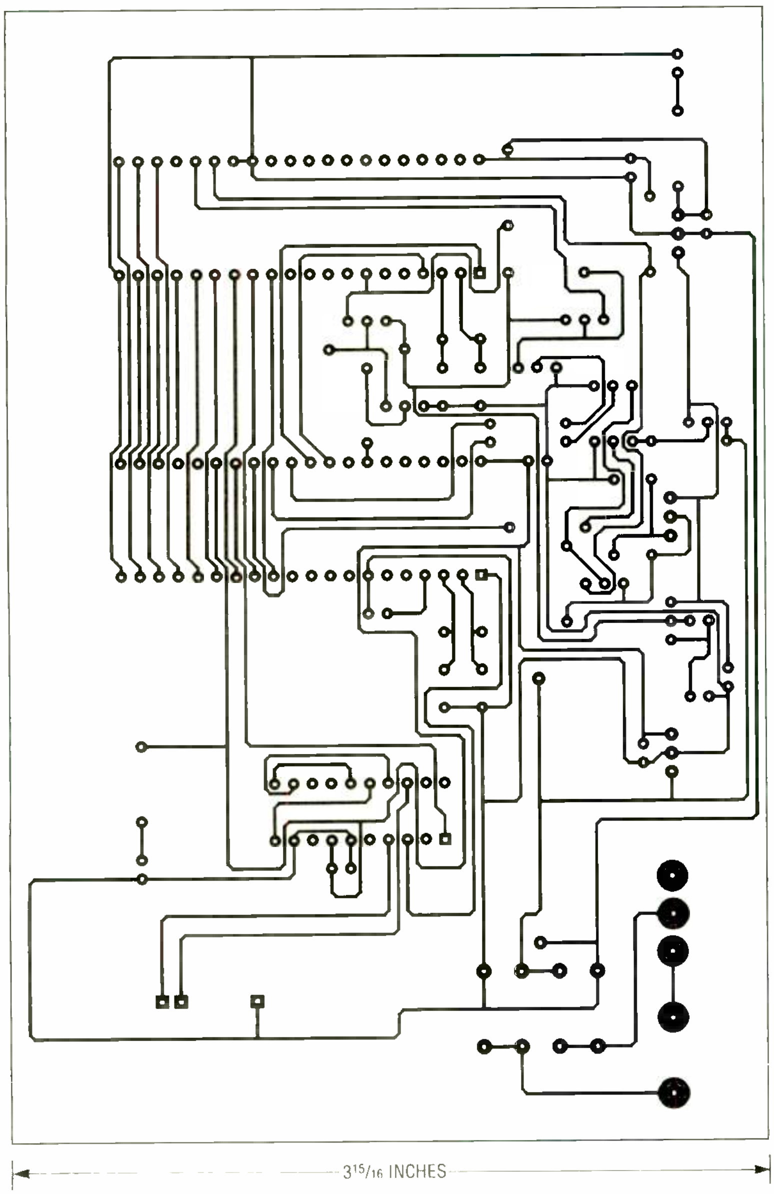


FIG. 4—INTELLIGENT DRIVER for a 4-digit display module. The circuit will first put an "X" in all four digits and then display "8748." The accompanying software is shown in Listing 1. The TSM1416 4-digit display module is manufactured by Three-Five Systems, Inc.

binary editor and then program that file into a target 8748H. This eliminates the initial need for a cross assembler and gives you the opportunity to experiment with minimum cost and effort. The circuits presented illustrate the advantages of using an integrated microcomputer like the 8748H—and they're simple enough to be built on an experimenter's breadboard.

Figure 4 shows an intelligent driver for a 4-digit display module, and Listing 1 shows the accompanying software. The circuit will first put an "X" in all four digits and then display "8748." While it's nothing fancy, it does show you how to make the display work. The TSM1416 4-digit display module is manufactured by Three-Five Systems, Inc.

Our second example circuit, shown in Fig. 5, is our "expensive LED blinker circuit." We say "expensive" because you certainly



FOIL PATTERN for the microcontroller programmer, shown actual size.

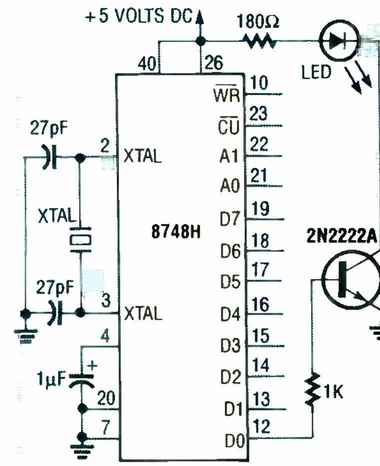


FIG. 5—EXPENSIVE LED BLINKER circuit. While it is somewhat overkill, it is very useful as a teaching tool. The software for this circuit is shown in Listing 2.

don't need a microcontroller to turn an LED on and off—the circuit is somewhat of an overkill. However, the circuit's simplicity becomes extremely beneficial when it's being used as a teaching tool. That way you can concentrate on the microcontroller's operation. The software for the Fig. 5 example is shown in Listing 2.

For the two example circuits we've provided, you can copy the software routines directly from the listings or download them from the RE-BBS as part of the main ZIP file (874XPGR.ZIP). **R-E**

HARDWARE HACKER

Electronic dog tag contest, case & enclosure resources, SMPTE time code standards, photovoltaic panel bargains, and a solar energy breakthrough!

DON LANCASTER

We'll start off with our usual reminder that this is your column and you can get tech help and off-the-wall networking per the "Need Help" box below. Your best calling times are often weekdays 8–5, mountain standard time.

We have some really heavy stuff for this month, so let's have at it...

Solar energy breakthrough?

Well, just maybe. It is far too soon to tell. But I guess we are overdue for a general update on solar energy.

On a bright Arizona day, you can figure around 1000 watts per square meter of incoming solar energy. This is a fairly diffuse and a rather weak energy source. A source that is made much worse by being there only some of the time. And made even more so by today's appallingly poor electrical conversion efficiencies.

Silicon solar cells are *inherently* inefficient when fed sunlight, which makes a diffuse energy source even harder to use. A semiconductor solar cell operates by receiving a precise packet of energy and then using that packet to release one electron to an external electrical circuit.

The energy of incident light is proportional to its frequency. $E = h\nu$ and all of that. At *one* single near-infrared frequency, the light energy packets are exactly the correct size needed by a silicon solar cell to get efficiently converted into electrical energy. All lower frequencies become largely useless waste heat.

What about higher frequencies? Only the magic energy packet size counts, so the higher frequencies will both generate useful power *and* extra waste heat. The higher the frequency, the higher your waste. The "spare change" above your critical energy level will get lost and appears to be unrecoverable. Sort of like a dollar tollbooth that requires you to dump *all* the change in your pocket.

When you consider the *entire* solar spectrum, the best possible overall efficiency you can get from a silicon solar cell is around 25 percent. This appears to be a fundamental and unavoidable physical limit.

Out in the real world, silicon solar panels are much less than ideal, and you are very lucky to get an overall long-term system efficiency above ten percent. And often less.

Which is dangerously close to the seven percent "breakeven" level, below which any solar panel will *never* pay for itself, owing to the materials and labor that go into the system, and the time value of the money used to finance the construction.

At seven percent efficiency, a one-meter square solar panel will generate around half a kilowatt hour per day, or around $5 of electricity per year.

Yes, there are tricks you can pull to raise your efficiency. Such as using a pair of different semiconductors having different work functions. Or using concentrators. Or heating water with the waste heat. Or trying to reshuffle or "downconvert" your solar spectrum to the magic frequency. But these seem mostly laboratory pipe dreams that, in my opinion, are unlikely to see the light of day.

In fact, the existing solar electric power plants are actually being torn down, owing to low efficiencies and really bad economics. Many hackers should be interested in the great bargains in the used (and somewhat degraded) solar panels now being offered wholesale by *Carrizo Solar* and retail by *Surplus Traders*.

NEED HELP?

Phone or write your **Hardware Hacker** questions directly to:
Don Lancaster
Synergetics
Box 809
Thatcher, AZ 85552
(602) 428-4073

Instead, "what if" our sun was a radio source? You would simply get an antenna and a rectifier, and high direct solar-to-electric conversion efficiencies can now be yours. This is called a *crystal set*, and all of the technology does appear to be fairly well proven. Efficiencies near 100 percent would be theoretically possible. With any care at all, the real world long-term efficiencies would not have to be that much worse. Your same square-meter panel could approach $80 per year in electricity, a much more attractive value.

The only little problem is that, until now, nobody was quite sure what an optical antenna or an optical rectifier was. Enter an individual researcher by the name of Alvin Marks who uses crossed pairs of a special *Lumeloid* film that uses the antenna/rectifier method for a direct solar conversion. Figures now including an 80-percent efficiency and a penny per kilowatt hour are being bandied about.

This does look legitimate. No obvious physical laws are being broken and the *Electric Power Research Institute* has seen fit to throw some cash at the idea. And we are certainly getting much better at working with stuff the size of optical wavelengths.

All of this is brand new and was rushed to meet this month's *Hardware Hacker* deadline. All the info I have on it so far is the brief note in *Business Week*, August 12, page 49.

For more on direct solar conversion, stay tuned or check into my PSRT bulletin board on *GEnie*. Other obvious news sources include *Science News*, *Science*, and the technology section of the *Wall Street Journal*.

For ongoing technical info, do try *EPRI* or else the *Dialog Information Service*. The search keywords could include *solar, Marks, Lumeloid, power, EPRI*, and *energy*.

Finally, for the ongoing grass roots shirtsleeves solar energy info, be

(A) LATERAL TIME CODE...

This older and nearly obsolete code needs an auxiliary audio channel and outputs one 1200 baud code string per video frame. The tape MUST be in motion for reading. The code is synchronized to begin on the fifth horizontal scan line of the first field in the frame. The low state equals 0 IRE units and the high state equals 80 IRE units.

The data stream is 80 bits long and follows the format of figure 2. It uses Manchester, or biphase encoding that is self-clocking and can be read in either direction. Various bits in the data are assembled into BCD words identifying the frame, the seconds, the minutes, and the hours. Other bits are used for synchronization, time adjustment, simple parity and special use flags.

Reference: SMPTE 12M-1986

(B) VERTICAL INTERVAL TIME CODE...

This newer and widely used code is embedded each field on single horizontal lines during retrace. The code gets repeated two, and sometimes four times, beginning on line 10 of each field's vertical retrace interval for improved noise immunity. The code begins 10.5 microseconds into the line.

The tape can be stationary or moving in either direction. There are 90 bits to the code, sent at a stationary rate of approximately 1.8 MHz. The format appears in figure 3. It also uses Manchester, or biphase encoding that is self-clocking and can be read in either direction. Various bits in the data are assembled into BCD words for the field, the seconds, the minutes, and the hours. Other bits are used for sync, time adjustment, full CRC error checking, and special flags.

Reference: SMPTE RP-108

FIG. 1—THE SOCIETY FOR MOTION PICTURE ENGINEERS, or SMPTE offers these two standard time codes for video production or editing.

sure to check out that really great *Home Power* magazine and the new *Photovoltaic Network News*.

Video time codes

We are shortly going to see lots of new software and hardware that will make any totally professional video production on a mainstream home computer system roughly as complicated as writing a business memo with a word processor. And that's *real* editing on a precise field-by-field basis. With the full genlock, overlay, station sync, anti-aliasing, and color keying. Plus all of the "gee whiz" bells and whistles.

Real editing demands that you can locate and identify each and every individual field in the entire video. That normally gets done by using a *video time code*.

Figure 1 summarizes the two most popular time-code systems in use today. Both of these are standards published by the *Society for Motion Picture and Television Engineers*. A useful *Time Code Handbook* is now available through *Cipher Digital*. It includes the SMPTE code standards along with the related MIDI electronic music timing code.

My copy was free, but they may panic when they see the humongous stack of reader-service responses that they are certain to get from this column.

The human persistence of vision is somewhere around 40 to 50 Hertz, so tricks have to be played to minimize the flicker of many motion displays. For instance, with any 35-millimeter movie, the light is turned off and a frame is suddenly moved into position by using an intermittent action known as a *Geneva Stop Mechanism*. The light is turned back on by a beam interrupter. The light is turned back off. The light gets turned on again, *projecting the exact same image a second time*. Finally, the light gets turned off and your next frame is moved into position.

We say the sound movie uses a *frame rate* of 24 frames per second. The *field rate* is 48 fields per second. In this case, the two fields per frame are identical.

With standard television, you have a frame rate around 30 frames per second. Each frame gets broken into two fields, one containing the odd scan lines, and another containing the even scan lines. This is known as *interlace* and gets used to reduce the display flicker. The field rate is near 60 fields per second.

Color TV introduces a further complication in that successive frames must be paired as *Frame A* and *Frame B*. This is done to reduce color subcarrier visual artifacts. Thus, only the multiples of *two* frames or *four* fields should ever be cut or edited. A glitch results if B does not always follow A, and vice versa.

The original or *Lateral Time Code* standard was first intended for movie film, and later adapted to videotape. This largely obsolete code is summarized in Fig. 1 and is detailed in Fig. 2. The lateral time code needs a separate audio channel. An entire frame is used to transmit 80 bits of digital data at a normal rate of 1200 bits per second. *The tape must be moving*, either forward or backward before the time code can be read. There is also no provision for error trapping.

A *Manchester* or *biphase* coding is used. This just means that each bit changes at its beginning. A "one" bit also changes at its middle; a "zero" bit does not. A code of this type is inherently self-clocking and can be

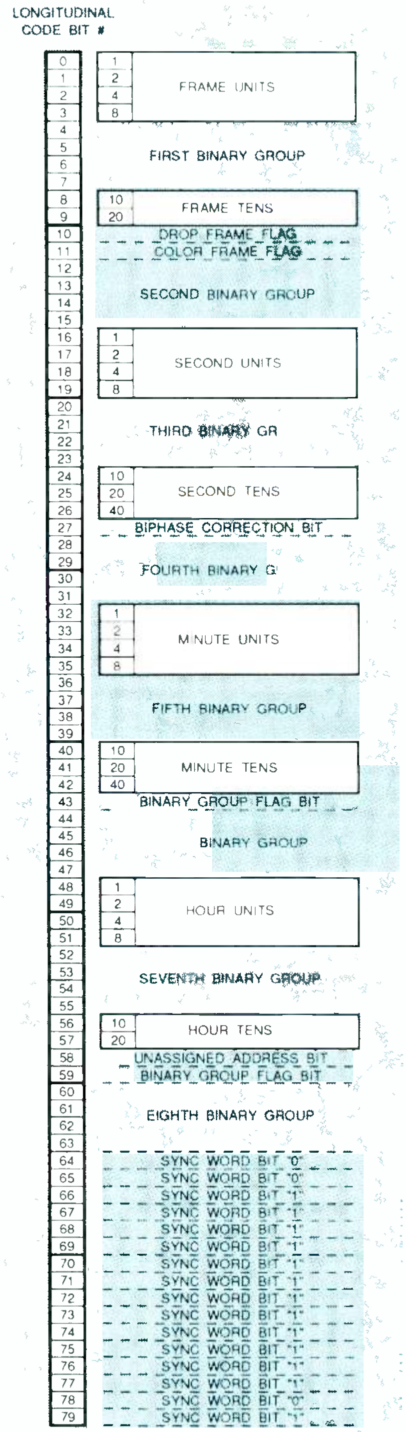


FIG. 2—THE SMPTE lateral time code needs a separate audio channel and requires a full frame to output at its 1200 baud rate. The tape must be in motion to read the code.

read in either direction. The first data bit is supposed to start off on the fifth TV horizontal line

Those individual bits are largely grouped by fours into *Binary Coded Decimal* words. These become the units and tens of the frames, seconds, minutes, and hours. There are also some special bits used for sync,

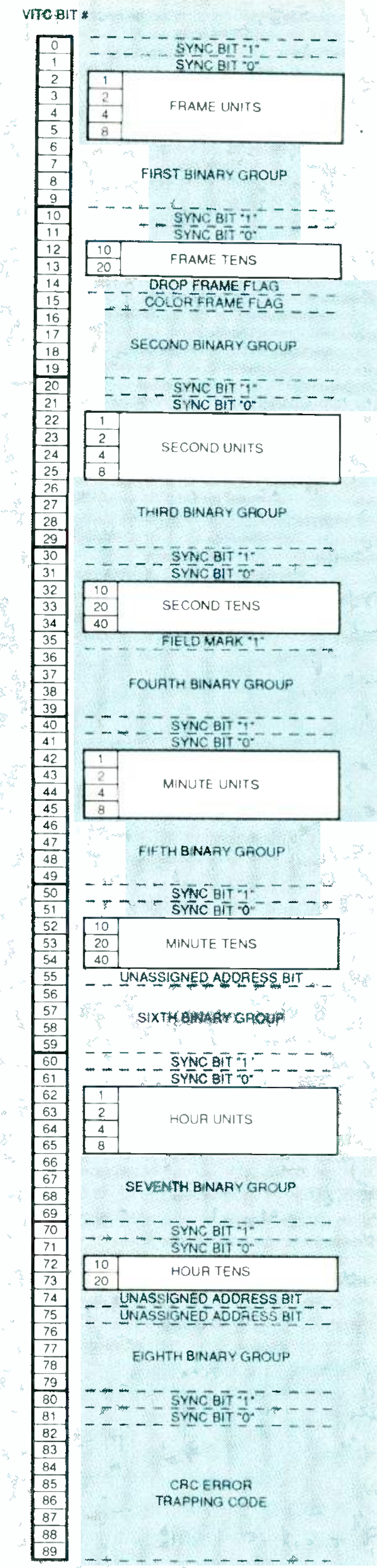


FIG. 3—THE SMPTE vertical interval time code is sent each field on a blank horizontal line at a 180 Kilohertz baud rate. The tape can be stationary or can move in either direction.

user definition, and specific flags. The code is slow enough to be read with machine language code by just about any computer.

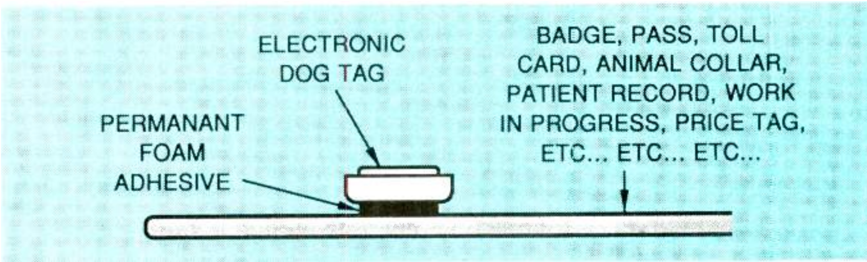


FIG. 4—ELECTRONIC DOG TAGS using the cheap and durable Maxim DS1990 series of touch memory chips can get stuck on virtually anything. They do offer electronic readable serial numbers and several thousand of bits of read-write non-volatile memory. These are the shape of a coin cell and last for ten years.

Their newer, or *Vertical Interval Time Code* is related but is far more sophisticated. It is summarized in Fig. 1 and detailed in Fig. 3. The entire 90-bit time code is transmitted within a single horizontal line. The chosen line should fit somewhere between blanked retrace horizontal lines 10 and 20.

The code must be transmitted twice per field on non-adjacent horizontal lines, and often is transmitted four times for extra noise immunity.

A similar Manchester or bi-phase encoding gets used. This one has a much higher bit rate, typically around 1.8 MHz during a pause. The time code burst begins 10.5 seconds into the selected horizontal line.

The VITC can get read while the tape is stationary or moving in either direction at any reasonable speed. Error trapping and other special bits are also included in the code.

Unfortunately, the bits do fly by a tad too fast to catch using machine language code on most mainstream microcomputers. So a special fast decoder is needed. Faster yet if you want to search and anticipate during a fast forward or rewind mode. But the logic s simple enough for most PLA or EPLD devices. A dual port RAM or an intelligent peripheral driver could make a very useful computer interface.

I do not yet know of a custom time code single chip, but it is reasonable to expect a cheap one shortly. And several simpler but nonstandard field codes are being introduced in new video products, especially by *NEC*. Let me know if there is anything you'd like to see on vide time codes.

CASE AND ENCLOSURE RESOURCES

American Science & Surplus
601 Linden Place
Evanston, IL 60202
(708) 475-8440
CIRCLE 301 ON FREE INFORMATION CARD

Bud Industries, Inc
4605 East 355th Street
Willoughby, OH 44094
(216) 946-3200
CIRCLE 302 ON FREE INFORMATION CARD

Carlon
25701 Science Park Drive
Cleveland, OH 44122
(800) 321-1970
CIRCLE 303 ON FREE INFORMATION CARD

EAI
37 Sherwood Terrace, Ste. 124
Lake Bluff, IL 60044
(708) 295-6664
CIRCLE 304 ON FREE INFORMATION CARD

Hoffman Engineering
900 Ehlen Drive
Anoka, MN 55303
(612) 422-2177
CIRCLE 305 ON FREE INFORMATION CARD

Jensen Tools
7815 South 46th Street
Phoenix, AZ 85044
(602) 968-6231
CIRCLE 306 ON FREE INFORMATION CARD

Lansing Instrument
PO Box 730
Ithaca, NY 14851
(800) 847-3535
CIRCLE 307 ON FREE INFORMATION CARD

Pelican Products
2255 Jefferson Street
Torrance, CA 90501
(213) 328-9910
CIRCLE 308 ON FREE INFORMATION CARD

Rose Enclosure Systems, Inc
7330 Executive Way
Frederick, MD 21701
(301) 696-9800
CIRCLE 309 ON FREE INFORMATION CARD

Zero Corporation
777 Front Street
Burbank, CA 91503
(818) 846-4191
CIRCLE 310 ON FREE INFORMATION CARD

Fancy case resources

What can you do when you need an outdoor-rated and waterproof case for all your electronic projects? For this month's sidebar, I've tried to round up some of the more obvious sources for premium enclosures.

JerryCo, who've recently renamed themselves as *American Science and Surplus* sometimes have great cases at unbeatable prices. Their #10827 and #21085 both cost around $4.

The most obvious source for the "suitcase" style packaging is *Jensen Tools*, who do stock everything from leather through plastic to aluminum to stainless steel. And the ultimate in military quality primo cases come from *Zero Manufacturing*. At the ultimate in military primo prices.

But the fancy electronic case I am the most impressed with is not an electronic case at all. It's the *Guard Box* that is offered by *Pelican Manufacturing*. A reinforced structural resin case measuring roughly 3 × 6 × 8 inches, it comes in four bright colors, and costs around $7 in your smaller production quantities.

The box is airtight and watertight to thirty feet of depth. A handle, a hinged O-ring sealed cover, and positive closure snaps are included.

Electronic dog tags

We've seen a number of times in the past how *Dallas Semiconductor* has come up with really great and super hackable integrated circuits. This time they have totally outdone themselves.

They call their new product line *Touch Memory*, or *Self-Stick Chips*. A typical unit is shown in Fig. 4. What you have here is a low cost and durable stick-on data acquisition and storage system the size and shape of a coin-cell battery.

Inside is a 10-year lithium cell and some unique electronics. Depending on the version, the fancy electronics gives you either a plain old 48-bit serial number or else thousands of bits of read-write memory.

Obvious advantages over a printed bar-code label are that (A) much more info can be stored, (B) you can update it at any time, (C) no expensive laser reader systems are needed, and (D) the stainless case is far more durable than a paper label.

What is really unique is that there is only a *single* contact plus the case ground. Which is all you need for reading and writing. Figure 5 shows you how one lead can be used to both read and write. Your host computer or whatever will first input your serial activation data string. Your touch memory will then respond, returning a serial number and/or your data.

The single contact is exceptionally easy to access. There's none of the alignment or fragility problems that you might have with more traditional connectors.

Several different styles are newly available. The cheapest outputs only a 48-bit serial number. Fancier versions can read or write to 1K or 4K bits of internal non-volatile ROM. On yet others, a security code prevents unauthorized reading or altering.

The reading and rewriting process is destructive, so very bad things can happen with an erratic contact or a partial write. To beat this, your info is first written to an internal scratchpad area. Only the complete and correct write later gets transferred to main memory. An internal checksum is also provided to let you know if your data is still valid.

NAMES AND NUMBERS

American Voice I/O Society 4010 Moorpark Ave, Ste 105M
San Jose, CA 95117
(408) 248-1353
CIRCLE 311 ON FREE INFORMATION CARD

Business News Publishing
PO Box 2600
Troy, MI 48007
(800) 837-1037
CIRCLE 312 ON FREE INFORMATION CARD

Carrizo Solar
PO Box 10239
Albuquerque, NM 87184
(505) 764-0345
CIRCLE 313 ON FREE INFORMATION CARD

Cipher Digital
PO Box 170
Frederick, MD 21701
(800) 331-9066
CIRCLE 314 ON FREE INFORMATION CARD

Dallas Semiconductor
4401 South Beltwood Parkway
Dallas, TX 75244
(214) 450-0400
CIRCLE 315 ON FREE INFORMATION CARD

Electric Power Research Inst
3412 Hillview Avenue
Palo Alto, CA 94304
(415) 855-2000
CIRCLE 316 ON FREE INFORMATION CARD

GEnie
401 North Washington Street
Rockville, MD 20850
(800) 638-9636
CIRCLE 317 ON FREE INFORMATION CARD

Home Power
PO Box 130
Hornbrook, CA 96044
(916) 475-3179
CIRCLE 318 ON FREE INFORMATION CARD

Markel
PO Box 752
Norristown, PA 19404
(215) 272-8960
CIRCLE 319 ON FREE INFORMATION CARD

Personal Engineering
Box 430
Rye, NH 03870
(603) 427-1377
CIRCLE 320 ON FREE INFORMATION CARD

Philips Semiconductor
2001 West Blue Heron Blvd
Riviera Beach, FL 33404
(407) 881-3200
CIRCLE 321 ON FREE INFORMATION CARD

Photovoltaic Network News
Rt. 2 Box 274
Santa Fe, NM 87505
(505) 473-1067
CIRCLE 322 ON FREE INFORMATION CARD

SGS-Thomson
1000 East Bell Road
Phoenix, AZ 85022
(602) 867-6100
CIRCLE 323 ON FREE INFORMATION CARD

Siemens
19000 Homestead Road
Cupertino, CA 95014
(408) 725-3586
CIRCLE 324 ON FREE INFORMATION CARD

Soc Motion Picture/TV Eng
595 West Hartsdale Avenue
White Plains, NY 10607
(914) 761-1100
CIRCLE 325 ON FREE INFORMATION CARD

Surplus Traders
PO Box 276
Alburg, VT 05440
(514) 739-9328
CIRCLE 326 ON FREE INFORMATION CARD

Synergetics
Box 809-RE
Thatcher, AZ 85552
(602) 428-4073
CIRCLE 327 ON FREE INFORMATION CARD

Waferscale Integration
47280 Kato Road
Fremont, CA 94538
(800) 832-6974
CIRCLE 328 ON FREE INFORMATION CARD

In standby mode, the touch memory monitors its receive circuitry and disables its send electronics.

The host computer first enables its tri-state driver and sends out a serial interogation and data code. The host computer then disables its tri-state driver and awaits a reply.

Your touch memory receives the interrogation code and activates its send electronics. The serial number or the requested RAM data is then transmitted. The touch memory then goes into its standby mode to await further commands.

The receiver grabs and interprets the returned data.

To prevent possible contact or destructive write problems, the host computer normally does a read, followed by a write, followed by a verify.

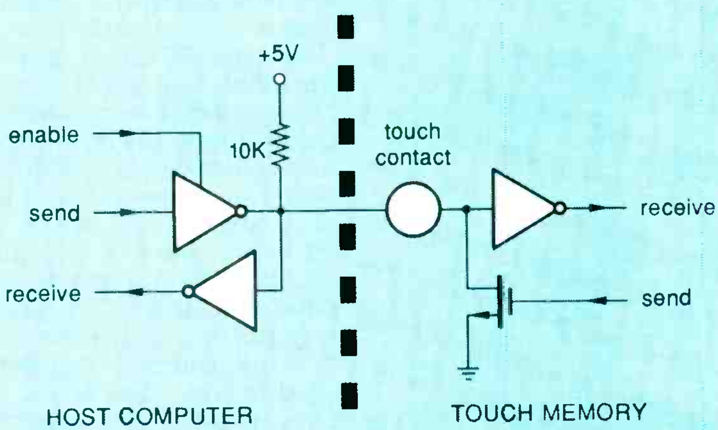


FIG. 5—ONLY A SINGLE CONTACT IS NEEDED to read from or write to your touch memory. Here is how it gets done.

Free samples and more technical details are available directly from *Dallas Semiconductor*. Cost is in the \$1 to \$3 range, depending upon the chip features and complexity.

For our contest this month, just tell me something off-the-wall you would do with an electronic dog tag. There should be all of the usual *Incredible Secret Money Machine* book prizes, with a great all-expense-paid (FOB Thatcher, AZ) *tinaja quest* for two going to the very best of all.

As usual, send your written entries to me here at *Synergetics*, and not to **Radio-Electronics** editorial.

New tech lit

From *SGS* a new *Power Modules Databook* on high-power transistors, Darlingtons, diodes, and MOSFET arrays. From *Siemens*, their *Optoelectronics Data Book* on all the usual LED lamps, arrays, sensors, couplers, and photodiodes. From *Waferscale Integration* a new data book on *High Performance CMOS Memory*.

A really exciting new integrated circuit that I've yet to do anything with is the *Philips* SAA7199 digital encoder. It accepts RGB computer inputs and outputs full NTSC or PAL broadcast-quality video. Included is a full genlocking capability and a powerful computer interface. Wow!

You might find the free *Personal Engineering* trade journal of interest. It mostly covers high end CAD/CAM software and circuit layout programs.

The *American Voice I/O Society*, otherwise known as AVIOS, does exactly what you'd expect them to. They also put on seminars on speech synthesis and recognition.

A freebie folder full of electronic tubing samples is available through *Markel* who stocks everything from shrink tubing up to a very high temperature sleeving. One collection of books on energy management, air conditioning, and humidity control, is available through the *Business News Publishing Company*.

For the fundamentals of digital integrated circuits, do check into my classic *TTL Cookbook* and *CMOS Cookbook*. Autographed copies are available from my own *Synergetics*. My newest *Book-on-demand Resource File* should also be ready by the time you read this. **R-E**

SIMPLE FM TRANSMITTER

This handy FM transmitter makes a great one-evening project, even for first-time builders!

JAMES A. MELTON

THERE IS NO THRILL LIKE THE THRILL you get from operating equipment you have built yourself. If you have never built a project from a magazine before, let this FM transmitter be your first—you'll see how much satisfaction and fun you can have!

The FM transmitter is designed to run from a 9-volt battery and is made from readily available parts. The author's primary use is as a baby monitor, but the uses of a transmitter like this one are almost limitless. It is very sensitive, and easily capable of picking up a conversation in any part of a room. The dimensions and values given here will allow static-free reception within the perimeter of most homes.

No license is required for this transmitter according to FCC regulations regarding wireless microphones. (The emissions must stay within a band of 200 kHz, its output between 88 and 108 MHz, and the field strength of the radiated emissions must not exceed 50 μV/m at a distance of 15 meters from the device.) If powered from a 9-volt battery and used with an antenna no longer than 12 inches, the transmitter's radiated power will be within the FCC limits. The FCC takes a dim view of persons operating outside the legal power limits, so please do not substitute any components in this circuit which would alter the output power.

Circuitry

Take a look at the schematic in Fig. 1. Audio is picked up from the room by an electret microphone and amplified by Q1. Resistors R2–R5 set up the DC operating bias of Q1. Capacitor C3 serves to improve the AC response to the audio voltage, and C2 blocks the DC bias and couples the AC to the next stage, where the RF action takes place. The amplified AC voltage from Q1 is routed to the base of Q2. Transistor Q2 and associated circuitry (C5 and the inductor) form an oscillator that operates in the 80–130 MHz range. The oscillator is voltage-controlled, so it is modulated by the audio voltage that is applied to the base of Q2.

Resistor R6 limits the input to the RF section, and its value can be adjusted as necessary to limit the volume of the input. That will help control the amount of distortion you have on very loud inputs. Resistors R7–R9 set the DC operating bias of Q2, another 2N2222 that's used as the oscillator and modulator of the transmitter. Capacitor C5 is a 6–50 pF trimmer capacitor that's used to tune the oscillator tank circuit, and C4 routes the RF from the oscillator to ground to prevent unstable operation.

Construction

The FM transmitter is built on a piece of perforated construction board with 0.1-inch hole spacing. Component spacing is not critical, but placement is. You should place the components on the board in a layout that is similar to the prototype shown in Fig. 2. Generally, you will also want to make the transmitter as small as possible.

Let's start from the left side of the schematic and work to the right. You'll want to cut out a piece of perfboard that is 12 holes wide and 30 holes long. That will give you plenty of room to work with, but still produce a small unit. First lay out two power lines on the board with bare wire; the positive supply from the battery will be on top, and the negative (ground) will be on the bottom.

A 1K resistor (R1) supplies the bias voltage for the microphone. Remember to install the resistor vertically, next to the positive supply line, and bend the other end of the lead to the board. Go through the board and down toward the ground bus. Now insert the microphone leads into the

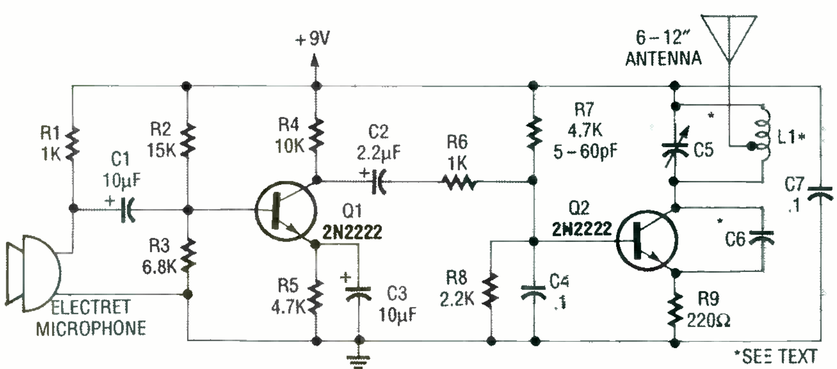


FIG. 1—FM TRANSMITTER SCHEMATIC. When powered from a 9-volt battery and used with an antenna no longer than 12 inches, the radiated power will be within the FCC limits.

PARTS LIST

All resistors are ⅛-watt, 5%.
R1, R6—1000 ohms
R2—15,000 ohms
R3—6800 ohms
R4—10,000 ohms
R5, R7—4700 ohms
R8—2200 ohms
R9—220 ohms
Capacitors
C1, C3—10 µF, 25 volts, electrolytic
C2—2.2 µF, 25 volts, electrolytic
C4, C7—0.1 µF, 25 volts, ceramic
C5—5–60 pF trimmer
C6—hand-made capacitor (see text)
Semiconductors
Q1, Q2—2N2222 NPN transistor
Other components
L1—hand-made coil (see text)
Miscellaneous: perforated construction board, 9-volt battery, battery clip, electret microphone, 24-gauge insulated wire, bare wire, solder, etc.

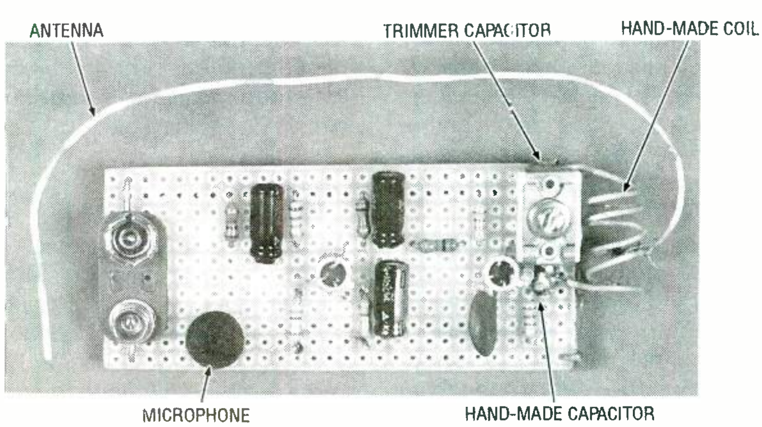


FIG. 2—THE AUTHOR'S COMPLETED PROTOTYPE. Notice how the antenna is soldered to the coil, about 2 turns from the transistor side.

board, making sure that the ground lead of the microphone can be soldered to the ground bus on the board. Route the lead from R1 to the positive lead of the microphone and solder it. The 10-µF capacitor, C1, should be placed in the middle of the board, oriented as shown on the schematic, and soldered to the microphone/R1 junction.

This project requires two hand-made parts—coil L1 and capacitor C6—but you make both of them yourself using only wire and a common pencil for a coil form. The inductor is made by winding two pieces of 24-gauge insulated wire, laid side by side, around a pencil six times. Remove the coil you have formed and unscrew the two coils apart from each other. One of these coils, the better-looking of the two, will be used in the tank circuit (L1) and the other can be

continued on page 99

AUDIO UPDATE

OEM, custom models, and private labels: Inside marketing information for the audio consumer.

LARRY KLEIN

Several months back I had a small adventure that may serve as a cautionary tale. It all started when my almost-20-year-old washing machine had a final, unfixable breakdown. My wife researched the new machines in *Consumer Reports* and decided on a Maytag. We went shopping at Trader Horn, a large discount appliance store, where we selected a Maytag that seemed to have the features we wanted in our price range. Before handing over our plastic, we reaffirmed with the salesman that the store would refund the difference if we found our chosen machine advertised elsewhere at a lower price in the next 30 days.

Several weeks later, I came across a Maytag catalog in another store and idly leafed through it looking for our washer. Its model number and specific combination of features was nowhere to be found, although all of the other machines bore a family resemblance to the one we bought. Puzzled, I called Maytag's 800 number and was told that my washer was a "special-order unit" and not part of the other Maytag line. In a flash, it all became clear—and demonstrated that I can be as naive as the next guy when shopping outside my areas of experience and expertise.

Custom models vs. house brands

Many years ago I became aware of a marketing technique in the audio industry that I found slightly offensive from my holier-than-though perspective of the time. Several of the largest phono-cartridge manufacturers were marketing their high-end cartridges under special model numbers to large audio dealers and chains. The idea simply was to prevent comparison price shopping by audiophiles seeking discounts. Stores selling a Stanton, or a Shure, or an Audio-Technica with special model numbers could easily guarantee that you couldn't buy the same model elsewhere for less. The custom-labeling technique provides the dealer with a proprietary house model that nevertheless has the advantage of bearing a well-known manufacturer's name.

The true house brand works somewhat differently. For example: Many large discount audio dealers have found it profitable in the past to market their own brand of speaker systems that usually do *not* bear the store's name. Speakers are especially suitable for that ploy because they are a "blind" item. That means there's no way for a layman, even if he peeked behind the grille cloth, to judge the quality—and hence the costliness—of the drivers (and crossover) housed in the enclosure. And since audio neophytes frequently can't tell good sound from bad, cheap inferior designs can be sold at large fictitious discounts, which nevertheless provide a far higher profit margin than the standard brands.

A manufacturer of private-label speakers once complained to me that each year when his contract expired, his major dealer would seek a new, lower price on the product. And the manufacturer, if he wanted to continue doing business, had to further cheapen the system. The resulting deterioration in sound didn't bother the dealer as long as the external appearance of the system was pretty much maintained.

Occasionally, you could have a quasi-house-brand situation where a speaker brand might be sold nationally under its own name, but a large dealer or chain might have an exclusive in their own selling area. That brings up the question of limited distribution—which I'll discuss later.

OEM

The term "original equipment manufacturers" originally referred to parts suppliers who provided the resistors, capacitors, and other components used by manufacturers in their products. The term has broadened to include those manufacturers who supply complete products with the brand label—and front panel—of your choice. At one time, when my wife was involved in use-testing VCR's for *Videoplay* magazine, she happened to have for testing VCR's from Quasar, Panasonic, and Magnavox. Despite the fact that their front panels, knobs, and pushbuttons were all different, once the top covers were removed, it was obvious from the identical innards that they all came off the same (probably Matsushita) assembly line. (The fact that each of the three machines performed differently at the slow speed was almost certainly the result of random alignment and QC differences rather than circuit differences.)

A number of former American brand names are now owned by Japanese, Taiwanese, and Koreans, who are producing quite creditable equipment under those names. I know of one U.S. manufacturer who produces his limited production, big-ticket items at home and farms out his receivers and other mass-market items to Far-Eastern factories. Other U.S.-owned brand names are all produced overseas but with the cosmetics, features, and sometimes the circuitry specified here.

Fair trade

A now-obsolete term, a "fair traded" component was one that the dealer was not allowed to sell for less than the manufacturer's list price. Declared an illegal practice about 10 years ago, fair trade was replaced by various limited distribution schemes. In order to maintain control of the products' retail prices, the manufacturer would sell only to dealers who were also concerned with maintaining a no-discount policy on the product. A manufacturer has the right to sell only to those dealers who conform to certain criteria (demo facilities, salesperson competence, quality image, etc.), but a no-discount policy was not something that could be legally demanded.

Over the years, all this has engendered a number of dealer-manufacturer lawsuits, with the dealer usually doing the suing. I testified as an expert witness in one case where a limited-distribution (at the time) Japanese manufacturer was being sued by a large audio retailer. The retailer's claim was that the manufacturer's representative had promised him the line and taken a large order, but it was never delivered because he discovered that the retailer also owned a discount-appliance operation. The dealer was suing for $100,000 in damages because he claimed that he kept a section of his store empty awaiting the arrival of the ordered equipment and lost substantial sales as a result.

How did I get into the act? The manufacturer's lawyers wanted me to testify that the dealer could have filled his shelves with other brands of quality equipment that would have sold just as well. In other words, I said to the lawyers, you want me to say that the equipment under dispute was good, but nothing special. They nodded. I told them that I would be happy to testify to that effect, since that's exactly what I had been telling the company sales manager for years. In any case, I did my expert witness number at the trial—and the judge ruled against us. The manufacturer subsequently won on appeal without my help. **R-E**

ELECTROMAGNETICS

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$$L = \Phi/I = (\int \mathbf{B}\cdot d\mathbf{s})/I \ (H).$$

Since **B** may not be constant across the area, we sum each infinitesimal contribution by integration. Note that we're concerned with the flux through the enclosed area, not the total flux through a Gaussian surface enclosing the loop, which is zero. For simple materials, L is independent of I since the equation $\mathbf{B} = \mu\mathbf{H}$ is proportional to I. However, L is dependent upon the area since the equation $\int \mathbf{B}\cdot d\mathbf{s}$ depends on the total area being summed. The inductance (L) is also dependent on μ.

We can use Ampere's law to see that effect. In empty space, $\mathbf{M} = 0$ and there are no bound currents, so we can say

$$\nabla \times \mathbf{H} = \nabla \times \mathbf{B}/\mu_0 = J_f$$

and

$$\nabla \cdot \mathbf{H} = \nabla \cdot \mathbf{B} = 0.$$

With a simple material filling space, $\mathbf{H} = \mathbf{B}/\text{mu}$, so

$$\nabla \times \mathbf{H} = \nabla \times \mathbf{B}/\mu = J_f$$

and

$$\nabla \cdot \mathbf{H} = \nabla \cdot \mathbf{B}/\mu = 0.$$

Since the divergence and curl of the field completely characterize the fields, **B** is larger by $\mu/\mu_0 = \mu_r$ in a filled inductor.

In our next article, we'll look at the effects of electric and magnetic fields as they change with time. We'll see that these fields are so closely related to each other that they lead to a single electromagnetic field. **R-E**

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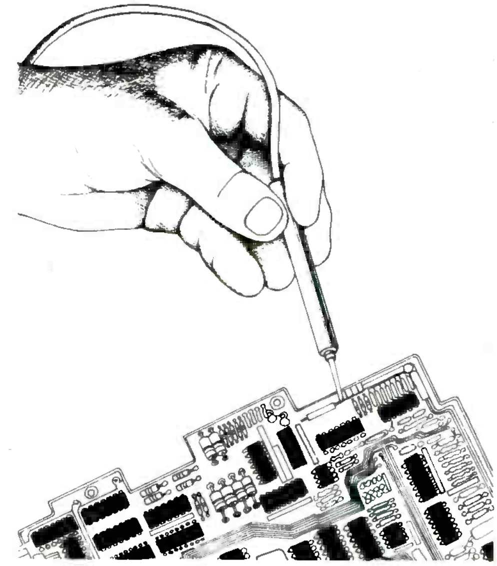

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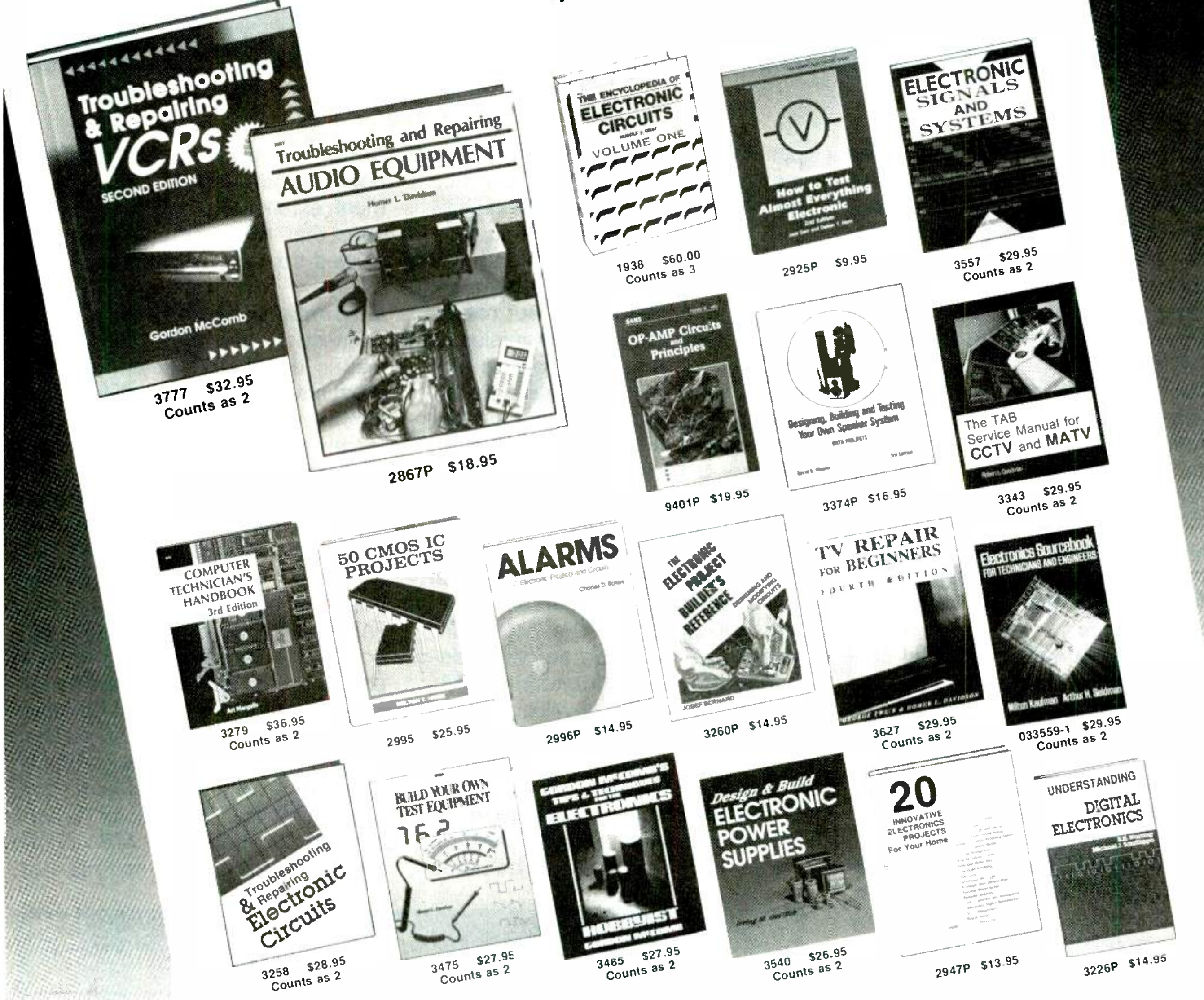

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COMPUTER CONNECTIONS

A new wave in the computer industry.

JEFF HOLTZMAN

IBM and Apple's much-heralded pact was only the first in a new wave of strategic alliances and company buyouts that promises to dramatically shift the balance of power in the computer industry—and in the process affect the nature of every hardware and software product that we use. Since then, Borland bought Ashton-Tate, Novell bought Digital Research, and IBM bought Metaphor Computer Systems. In addition, HP and Sun announced that they have teamed up to deliver an OS-independent programming layer that would allow one application to run on multiple platforms—much like what Metaphor has been working on for some time.

On the hardware front, Intel continues to show more and more marketing creativity, along with correspondingly less technical innovation. Some recent tactics have brought the scrutiny of the FTC down on the chip-making giant.

IBM/Apple/Microsoft update

Microsoft seems to be reeling from recent events. Lately the company has been denigrating OS/2 viciously, and making confusing statements about the directions of DOS 6.0, future versions of Windows, and what used to be called OS/2 3.0, but more recently, both New Technology (NT) and Win32. Microsoft is retrenching on its former commitment to make the new OS run DOS, Windows 3, OS/2 2.0, and POSIX API's simultaneously. Microsoft seems to have dropped support for OS/2 and POSIX, added support for the ACE/MIPS initiative (one report claims that MIPS Computer already has an early version of NT code running at its premises), and is trying to figure out what should be the relationship between DOS 6.0, Windows 4.0, and the NT OS.

Meanwhile, IBM seems to be on track with OS/2 2.0, scheduled for release this fall. As for DOS compatibility, Big Blue already offers more memory and better disk performance on the same hardware running DOS 5.0; the main issue has been Windows 3.0 compatibility. Win3 has been running for a while in real mode; recently, IBM has shown but not released a protected-mode version. If IBM can get this product out on time and achieve the aggressive performance and compatibility goals it has set for itself, Microsoft is right to be nervous. It seems likely that 1991 will be remembered as the year Microsoft lost dominance in both operating systems and graphical environments.

IBM purchased Metaphor, in which it previously held a ten percent share, and will contribute the object-oriented Constellation software developed at Metaphor to the IBM/Apple venture. (Apple will contribute the "Pink" OS, which has been under internal development for several years.) David Liddle, former president of Metaphor and a pioneer at Xerox's Palo Alto Research Center (PARC) in the early 1980's, appears to be slated to run the new joint venture. IBM is now reorganizing its top management extensively, apparently to ensure that the new venture is not slowed down by IBM traditionalists.

Borland/Ashton-Tate

These are two of the older companies in the PC business, both with products going back to CP/M days. However, since then, A-T has only incrementally improved its flagship product (dBASE), and has invested heavily in other products that have never achieved the type of commercial success A-T needed to stay afloat. On the other hand, Borland has continually beefed up its product line and specific items in it, particularly its Pascal and C compilers, and its Paradox database system.

The deal roughly doubles Borland's overall size (to about $450 million), making it the third largest software company, behind Microsoft and Lotus. Together, dBASE and Paradox account for more than 50% of the programmable database market.

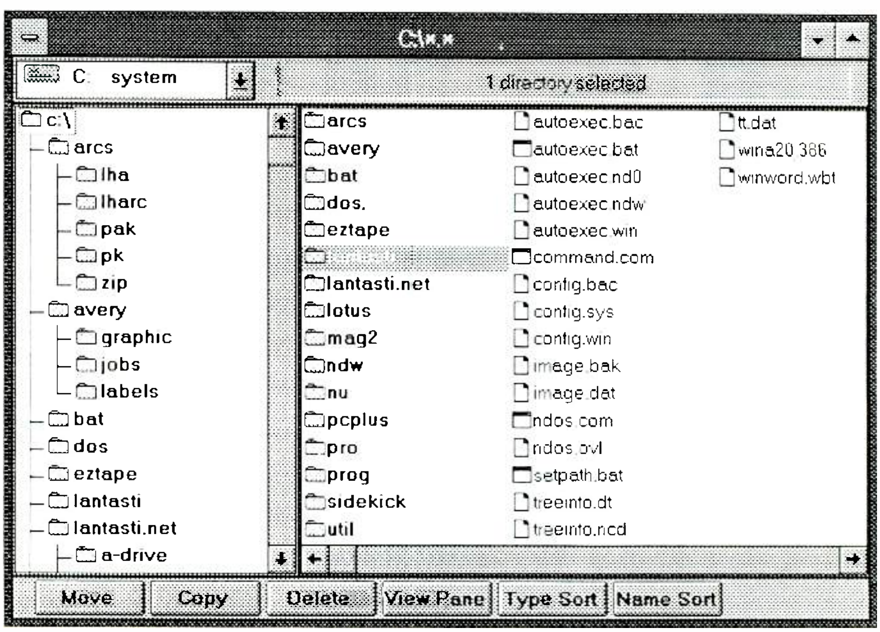

Fig. 1—THE NORTON DESKTOP FOR WINDOWS includes a powerful but intuitive file manager, batch language, many useful utilities, and a Mac-like drag-and-drop interface. Good stuff.

Even before the deal has been finalized, Ashton-Tate began layoffs.

The biggest question about the deal is how the new software giant will reconcile the two competing database lines. Before the merger was announced, Borland had shown early versions of a Windows-based dBASE-compatible system. A-T was also thought to be working on a Windows database product. In any case, it seems likely that Borland will merge the Paradox and dBASE lines together, then gradually phase dBASE out altogether.

Novell/Digital Research

In the late 1970's, Digital Research delivered the first widely supported operating system for 8-bit microcomputers, CP/M. However, due to marketing blunders, the company lost the bid to supply IBM with an operating system for its new PC back in August of 1981. Microsoft won the bidding and bought a 16-bit clone of CP/M from a small company in Seattle. The rest of that story is history.

Meanwhile, Digital Research hung on for dear life, producing a lackluster 16-bit version of CP/M, and subsequently a graphical environment called GEM that helped keep the company afloat during the mid 1980's through popular support of the first versions of the desktop publishing program, Ventura Publisher. DR also produced several graphical tools, some of which were fairly well received. Meanwhile, DR also continued to produce operating system products, including a somewhat awkward multi-tasking environment called Concurrent DOS 386 that competed with DESQview, OmniView, and IGC's VM/386 (all of which have been written up here in the past).

Then, about a year and a half ago, the company introduced DR-DOS 5.0, which in retrospect looks much like MS-DOS 5.0. The program received fairly good press, but achieved little market penetration. Now, with seemingly everyone in the world PO'd at Microsoft, and with the acquisition by Novell, and with a renewed relationship with IBM, DR DOS is starting to look interesting.

After news of the acquisition was released, the trade press immediately started speculating about how serious a threat Novell/DR would pose to Microsoft. What those reports fail to understand is that (1) The 640K-bound real-mode DOS is dying, regardless of who makes it; (2) The plain command-line interface is dying, to be replaced by Windows, OS/2, or perhaps in the long run the system-software component of the new Apple/IBM venture; (3) Novell/DR has a 640K-bound workstation operating system with no GUI; (4) Novell's network operating system is not DOS but UNIX based, so is not impacted in any way by the merger. In sum, strategic importance of this deal is zilch.

News bits

Amiga fans: NewTek has demonstrated version 2.0 of the Video Toaster software that provides enhanced video effects, the ability to transition smoothly between different surface effects (a technique called "morphing"), faster shadow calculations, animated texture maps, and more. Complete systems including an Amiga, 5 MB of memory, and a 50-megabyte hard drive start at about $4000.

Signetics has released the SAA7199, **a multi-standard video encoder chip** that will allow video editing, titling, and special effects on standard PC's. The chip can work with standard 8- and 24-bit video systems, including VGA, and can deliver standard PAL and NTSC video signals. At less than $50 in small quantities, the SAA7199 will help make desktop video as prevalent as the VCR.

Intel has now publicly shown **dual-speed 486SX's**; the company plans to sell chips directly to end users by year end. IBM has developed and is now producing for internal use only a proprietary **20-MHz 386SX with 8K cache.**

Conner peripherals is known for miniaturized disk drives sold in today's sleek notebook and portable PC's. Now the company has teamed up with Intel to begin developing a **solid-state disk drive** based on Intel's flash memory technology. The drives, scheduled for availability by 1996, will have capacities ranging from 40–120 MB, will be cost competitive with drives based on magnetic technology, but will consume less power, occupy less space, and weigh less as well.

Toshiba claims it will be selling **16-megabit DRAM's** in quantity by 1992; IBM has plans to start using its own 16Mb DRAMS's in PS/2's next summer. OEM prices for 1Mb and 4Mb DRAM's reached the crossover point early this summer, which means the beginning of the end for 1Mb parts. A joint venture between TI, Acer, the Chinese government, and several banks has instilled $140 million in a new plant in Taiwan that recently began producing 4Mb chips, with plans for 16Mb devices sometime next year. A new trade accord between the U.S. and Japan may force **DRAM prices up 10–15%,** further slowing an already slow PC market.

Product watch

Symantec has finally released the Norton Desktop for Windows. NDW can function alongside or in place of the Program and File managers in Windows 3.0. I started using NDW with the FileMan and ProgMan, but soon gained enough confidence to use it as the sole interface in both my home and office PC's. What NDW does is ratchet Win3 one level closer to Mac-like ease of use. In the default configuration, the highly customizable program displays a list of icons corresponding to each floppy, hard, substituted, and network drive down the left side of your screen. Double click on an icon, and up pops a tree-structured view of the corresponding drive, as shown in Fig. 1. You can then copy, move, erase, and view (but in a strange oversight not compare) files. These operations work the way they should: select a file, move the cursor to the new location, and release the mouse button. An optional "view" pane allows you to view many common file types in the correct format.

On the right side of the screen are icons corresponding to specific tools. Double-click on an icon, and the corresponding program runs. You can associate icons with documents too; when you double-click, the corresponding application program runs.

Supplied tools include a nifty icon editor; a font viewer for locating odd symbols in any font; an excellent file search utility; two calculators; a backup program (that supports only floppy and hard drives, not tape drives); a scheduling utility that will run any program at a given time on a given date, once or repetitively; a powerful batch language and editor; Windows versions of Norton's famous System

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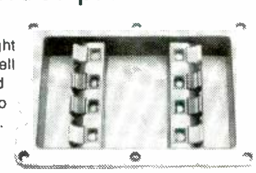

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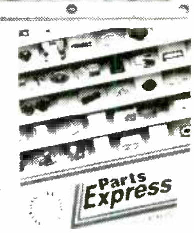

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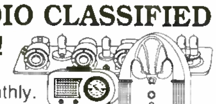

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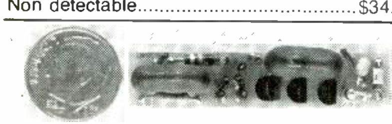

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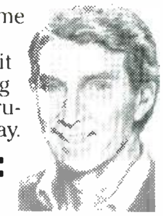

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SIMPLE FM TRANSMITTER

continued from page 85

used in the next one you build.

The other hand-made component, capacitor C6, is part of the oscillator feedback. To make this small value capacitor, take a 4-inch piece of 24-gauge insulated wire, bend it over double and, beginning ½-inch from the open end, twist the wire as if you were forming a rope. When you have about 1 inch of twisted wire, stop and cut the looped end off leaving about ½-inch of twisted wire (this forms the capacitor) and ½-inch of untwisted wire for leads.

Capacitor C7, a 0.1µF capacitor, is one of the most critical components in the circuit. You must place it across the L1-Q2-R9 assembly, as shown in Fig. 1, to reduce the amount of RF feedback you'll get into the rest of the circuit. The antenna (more 24-gauge wire) should be soldered to the coil you made, about 2 turns up from the bottom, or the transistor side, and should be about 8–12 inches long.

Operation

To use the transmitter, set up a radio in the area at least 10 feet from the project. Find a blank spot on the dial and turn the radio up so you can hear the static.

Connect a 9-volt battery to the transmitter and listen to the radio. Slowly adjust the tank capacitor (C5) until you "quiet" the receiver; this is the tuned spot. Note that when you remove your hands from the transmitter, you will detune the circuit somewhat. It is usually best to leave it detuned, and tune the radio in to get the best reception. If you cannot get the tuning range you desire, you can squeeze the coils in the tank circuit closer together to raise the frequency, or pull them apart just a little bit to lower it.

The circuit works best when powered by a battery, but if a wall-derived supply is needed, make certain that the ripple voltage is as low as possible, or you will get hum in the receiver. **R-E**

COMPUTER CONNECTIONS

continued from page 93

Info and Disk Doctor programs; a file "shredder;" a smart file deletion program; and a detailed on-line help system that almost renders the manual unnecessary.

Of course, you can customize which drive and tool icons are displayed. You can also customize the NDW menus and many other aspects of the program. Unlike Windows' own ProgMan, NDW supports nested program groups.

NDW is not perfect, but it's much better than anything else on the market. If you buy only one Windows utility, this should be it. Contact Symantec Corporation, 10201 Torre Avenue, Cupertino, CA 95014-2132. (408) 253-9600.

For 286 owners: Several companies have been advertising 386SX adapters that supposedly provide elegant upgrades. I've requested evaluation units from each manufacturer, and hope to have a report next time.

Book nook

If you're unsure what object-oriented technology is about, order a copy of *Object-Oriented Technology: A Manager's Guide* by David Taylor. The book costs only $10, and is published by Servio corporation, where Taylor serves as Director of Strategic Planning. By reading fewer than 150 pages, you can learn the basics of inheritance, encapsulation, polymorphism, objects, methods, classes, class hierarchies, message-passing, et al. Contact Servio Corporation, 1420 Harbor Bay Parkway, Alameda, CA 94501. (800) 243-9369.

If your work involves PC configuration, you'll want to check out *The Hard Disk Technical Guide* by Douglas T. Anderson. It's filled with detailed technical information on almost 1500 types of hard disks of all types, from dozens of manufacturers. The book also includes configuration information on dozens of hard-disk controllers, SCSI and ESDI installation, and BIOS drive tables. The book is constantly updated, and is currently in Revision E. New purchases cost $49.95+$3 S/H; updates to prior versions are available at lesser cost. PCS Publications, P.O. Box 10492, Clearwater, FL 34615. (800) 741-3282. Fax: (800) 446-3157. **R-E**

LETTERS

continued from page 16

sult in super-miniature vacuum tubes that could compete with transistors in specialized applications.

Sure, tubes require higher voltages, more board or chassis space, a heater power supply, and they're old fashioned. My 1965 reel-to-reel tape deck is old-fashioned too, but its 16-Hz to 35-kHz frequency response will beat most 1991 cassette decks any day. (My father is old-fashioned also, but I don't mock him and I wouldn't throw him in the trash!)

It's time that the vacuum tube was put in its proper place, as the father of transistors and as the device that is responsible for the development of all modern active electronics. As a professional technician and an experimenter, I challenge all these would-be technicians and wise-guy hobbyists who knock tubes to read and think about history, and to respect it. The Audion wasn't a dual-gate MOSFET, you know!

I haven't missed a single issue of **Radio-Electronics** in more than a decade. Keep up the excellent work. You truly are honoring the memory and work of the late Hugo Gernsback.

GREGG VAN DER STUYS
Mission, BC, Canada

AUDIOPHILE ATTITUDES, AGAIN

As previous readers of **Radio-Electronics** (it has been over seven years), we were happy to receive the magazine again after a few of us electrical engineers decided that we wanted to share a subscription at work. **Radio-Electronics** truly is a good magazine.

We opened up the July issue to the *Letters* column and read Paul J. Carlson's letter about "absurd speaker cables," "antiquated tube amplifiers," and "Creation Science." The truth is that tweaking an audio system can easily make substantial audible improvements—but only if you have ears! (Owning decent equipment also helps.) Speaker cables *do* sound different. Some cables sound much better than others, and sometimes cheap 18-gauge zip cord might sound the best. As electrical engineers, the difference in sound bothered us enough to search for an answer.

Without getting into systems design (La Place transforms, differential equations, Mason's Theorem, etc.), here's a brief and simplified explanation. Most reasonable-quality, modern power amplifiers are feedback amplifiers. Loudspeakers are transducers that also act as electrical generators with a very complex transfer function. An amplifier must contend with a loudspeaker's back EMF and particular transfer function. Loudspeaker cables between the loudspeaker and the amplifier also "add" their own transfer function as they have resistance, inductance, and capacitance associated with them. We now have three complex transfer functions to deal with (speakers, cable, and amplifier). Now, look at a schematic of a transistor (feedback) amplifier. Where does the differential input (front end) get its signal to close the feedback loop? Right from the speaker terminals that are getting "hit" with the loudspeaker's back EMF modified by the speaker cables placed in series!

But that's not all that impacts on overall performance. The loudspeaker cables also modify the loudspeaker's transfer function. Neglecting (for simplicity) the capacitance and inductance of the cables and looking only at resistance, three very audible effects can occur. First, the series resistance modifies the "Q" factor, or tuning, of the speaker system. More series R yields a higher woofer "Q" factor, and a "warmer" or sometimes an exaggerated bass response results. Second, varying a cable's resistance also shifts the crossover frequencies and phase response of a loudspeaker system. Third, the cable's series R affects the amount of interaction between drivers in a multi-way loudspeaker system. The back EMF from a woofer is not as easily "shorted-out," because of the cables resistance and hence can affect the other drivers.

Our point is that things aren't always as simple as we'd like them to be. We must keep an open mind. As we learn more, we can quantify more of the parameters associated with what makes something work, or sound, better. Until we "know it all," we can't discount the mysterious "art" part of audio engineering.

FRED J. JANOSKY
DONALD E. KUJAWSKI
Reading, PA

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LS9201	TOSHIBA	670 nm	5 mW	80 mA	2.4v	59.99
LS9211	TOSHIBA	670 nm	5 mW	50 mA	2.3v	69.99
LS9215	TOSHIBA	670 nm	10 mW	45 mA	2.4v	109.99
LS3200	NEC	670 nm	3 mW	85 mA	2.2v	79.99
LS022	SHARP	780 nm	5 mW	65 mA	1.75v	19.99

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41256-100	256K x 1	100 ns	1.99	1.89	1.70
41256-120	256K x 1	120 ns	1.89	1.80	1.62
41256-150	256K x 1	150 ns	1.79	1.70	1.53
511000-70	1 meg x 1	70 ns	5.49	5.22	4.70
511000-80	1 meg x 1	80 ns	5.29	5.03	4.53
511000-10	1 meg x 1	100 ns	5.09	4.84	4.36
514256-70	256K x 4	70 ns	6.49	6.17	5.55
514256-80	256K x 4	80 ns	6.09	5.79	5.21
514256-10	256K x 4	100 ns	5.69	5.41	4.87
541000-80	4 meg x 1	80 ns	26.99	25.64	23.08
544256-80	1 meg x 4	80 ns	31.99	30.39	27.35

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2716	450 ns	3.29	3.13	2.82
2732	450 ns	4.19	3.98	3.58
2732A	250 ns	3.29	3.13	2.82
2764	250 ns	3.49	3.32	2.99
2764A	250 ns	3.09	2.94	2.65
27128	250 ns	4.79	4.55	4.10
27C128	250 ns	4.79	4.55	4.10
27256	250 ns	4.59	4.36	3.92
27C256	250 ns	4.29	4.08	3.67
27512	250 ns	5.49	5.22	4.70
27C512	250 ns	5.49	5.22	4.70
27C1024	200 ns	10.99	10.44	9.40
27C2048	200 ns	21.99	20.89	18.80

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LT7770	543nm (Green)	0.5mW	1.0mW	0.71mm	≤ 1.2 mrad	random	1750v ± 110v	6.5 mA	≤ 8 kV	81k Ω	37 x 350	200	II	799.99	749.99
LT7650	632.8nm (Red)	0.5mW	2.0mW	0.49mm	≤ 1.7 mrad	>100:1	1000v ± 100v	3.5 mA	< 7 kV	68k Ω	25 x 146	70	IIIa	529.99	479.99
LT7656	632.8nm (Red)	0.5mW	2.0mW	0.34mm	≤ 2.4 mrad	random	1050v ± 100v	2.8 mA	≤ 8 kV	82k Ω	22.5 x 118	60	IIIa	134.99	124.99
LT7655	632.8nm (Red)	0.5mW	2.0mW	0.49mm	≤ 1.7 mrad	random	1000v ± 100v	3.5 mA	≤ 7 kV	68k Ω	25 x 150	70	IIIa	144.99	134.99
LT7655S	632.8nm (Red)	1.0mW	2.0mW	0.49mm	≤ 1.7 mrad	random	1000v ± 100v	3.5 mA	≤ 7 kV	68k Ω	25 x 150	70	IIIa	159.99	144.99
LT7632	632.8nm (Red)	1.2mW	3.0mW	0.61mm	≤ 3.0 mrad	random	1300v ± 100v	3.5 mA	≤ 7 kV	81k Ω	20 x 210	70	IIIa	249.99	229.99
LT7621S	632.8nm (Red)	2.0mW	5.0mW	0.75mm	≤ 1.2 mrad	random	1300v ± 100v	5.0 mA	≤ 7 kV	68k Ω	30 x 255	140	IIIa	204.99	191.99
LT7634	632.8nm (Red)	2.0mW	5.0mW	0.75mm	≤ 1.2 mrad	>500:1	1300v ± 100v	5.0 mA	≤ 7 kV	68k Ω	30 x 255	140	IIIa	209.99	194.99
LT7621MM	632.8nm (Red)	5.0mW	15mW	1.0mm	≤ 2.5 mrad	random	1250v ± 100v	6.5 mA	≤ 7 kV	68k Ω	30 x 255	140	IIIb	359.99	334.99
LT7627	632.8nm (Red)	5.0mW	15mW	0.80mm	≤ 1.1 mrad	random	1900v ± 100v	6.5 mA	≤ 8 kV	81k Ω	37 x 350	200	IIIb	369.99	344.99
LT7628	632.8nm (Red)	5.0mW	15mW	0.80mm	≤ 1.1 mrad	>500:1	1900v ± 100v	6.5 mA	≤ 8 kV	81k Ω	37 x 350	200	IIIb	389.99	364.99
LT7627MM	632.8nm (Red)	10mW	30mW	1.2mm	≤ 4.0 mrad	random	1750v ± 100v	6.5 mA	≤ 8 kV	81k Ω	37 x 350	200	IIIb	479.99	444.99

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Can sink 10 ma. With suitable output pull up, can be used directly with bipolar or CMOS logic circuits. Especially suited for electronic commutation in brushless D.C. motors using multiple ring magnets. Very tiny surface mount package 0.175" X 0.09"X 0.06" thick.
CAT # HESW-5 2 for $1.00
100 for $45.00 Large quantities available

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Pushbutton Switch

SM Manufacturing 0.47" square black pushbutton. SPST normally open. 4 p.c. pins for mounting. Ideal for low current switching applications.
CAT# PB-29
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Miniature snap-action switch with lever. Rated 1 amp @ 125 Vac. 0.50" L X 0.26" H X 0.22" W. Lever extends 0.05" beyond end of switch. **CAT# SMS-282**
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Two L.E.D.'s flash in unison when a 9 volt battery is attached. This kit includes a p.c. board, all the parts and instructions to make a simple flasher circuit. A quick and easy project for anyone with basic soldering skills.
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Easy to build kit includes pc board, parts and instructions. Ideal for special lighting effects, costumes, etc. Operates on 3 to 9 volts. PC board is 5" X 2.25". A great one hour project.
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- Hitachi
- Varta

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N1200C	3.45	3.05	1.2V	1.2 Amp	C
N1800C	3.95	3.55	1.2V	1.8 Amp	C
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- UL approved
- Input: 120VAC @ 60Hz
- Conn.: 2.5 mm DC Plug (except WTMT)

Order #	1-9	10+	Voltage	Power	Weight
WT9200DC	3.95	3.75	9VDC	200mA	6.1 oz.
WT9500DC	4.15	3.95	9VDC	500mA	8.8 oz.
WT12500DC	4.95	4.75	12VDC	500mA	10.4 oz.
WT9500AC	4.15	3.95	9VAC	500mA	8.8 oz.
WTMT	5.95	5.75	3,4,5,6,7.5, 9 & 12VDC	500mA	9.4 oz.

DC POWER CONNECTORS

Order #	1-9	10+	Description	Diam.
JR1811	.50	.40	DC Plug (Walkman Type)	1.3 mm
JR1812	.50	.40	DC Plug (Mini)	2.1 mm
JR1813	.50	.40	DC Plug (Stand.)	2.5 mm
JR1817	.60	.50	DC Chassis Jack (Mini)	2.1 mm
JR1818	.60	.50	DC Chassis Jack (Stand.)	2.5 mm
JR1819	.90	.80	DC Chassis Jack	2.1 mm
JR1820	.90	.80	DC Chassis Jack	2.5 mm

LO-PRO ZIF SOCKETS

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- CAM: Cast Metal
- Contacts: Spring Temper Beryllium Copper, Tin Plated
- Housing: Glass Filled Polyester, UL94V-O

Order #	Price	Description	Pins
SZ24	5.95	Zero Insertion Force Socket	24
SZ28	6.25	Zero Insertion Force Socket	28
SZ40	6.95	Zero Insertion Force Socket	40

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- Test most standard DIP packages
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EC20	6.95	6.45	Test Clip	18/20
EC24	7.95	7.45	Test Clip	22/24
EC28	8.95	8.45	Test Clip	28
EC40	11.95	11.45	Test Clip	36/40

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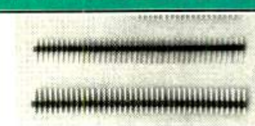

- Contacts: Gold Plated
- Double or Single Row
- 90° Right Angle or Straight

Order #	1-9	10+	Description	Contacts
H401	.89	.79	Header Single, Straight	40
H401R	.99	.89	Header Single, 90°	40
H402	1.49	1.39	Header Double, Straight	80
H402R	1.69	1.59	Header Double, 90°	80

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- 2 Sizes: Small & Large
- Mounting: 0.78" (19.2 mm)
- Radial 7 Pin Tumbler Mechanism
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- Brass Housing & Cylinder, Chrome Plated
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Order #	1-9	10+	Size
EG051S	4.25	4.05	Small
EG051L	4.45	4.25	Large

MINI PB SWITCH

- Contact Rating: 1A @ 125VAC
- Mounting Hole: 9/32" (7 mm)

Order #	1-9	10+	Desc.	Color
E1033R	.49	.39	N/O	Red
E1033B	.49	.39	N/O	Black
E1034R	.59	.49	N/C	Red
E1034B	.59	.49	N/C	Black

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- 22 Awg wire
- Stripped 0.25"
- 14 assorted lengths (25 pieces each length)

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22 AWG JUMPER WIRE

JW100RD

- 100 foot spools
- Single core/solid wire

Order #	1-9	10+	Color
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- Round needle file
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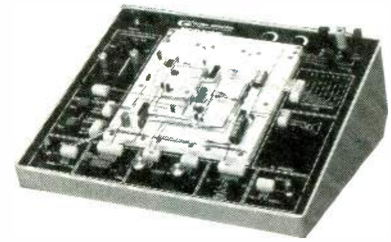

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- Includes power supply, instrumentation and breadboarding

PB503..$299.95

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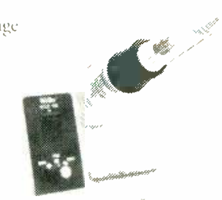

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DS600 Desoldering Station.............$549.95

WCC100

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LP540...................................$16.95

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• Max Frequency 80MHz • Minimum detectable pulse: 10ns • 120KΩ input impedance • Max. supply voltage: ±25V • TTL threshold: (Lo)+0.8V ±0.1V, (Hi) +2.3V ±0.2V • CMOS threshold: (Lo) 30% VCC ±10%, (Hi) 70%VCC±10%

MS104...................................$24.95

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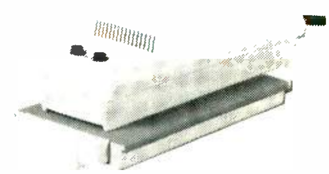
- Programs all current EPROMs in the 2716 to 27512 range plus the X2864 EEPROM
- RS232 port • Software included

EPP...................................$199.95

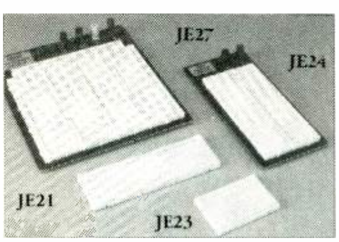
UVP EPROM Eraser



- Erases all EPROM's • Erases 1 chip in 15 minutes and 8 chips in 21 min
- UV intensity: 6800 UW/CM²

DE4...................................$89.95

Jameco Solderless Breadboards



Part No.	Dim. L" x W"	Contact Points	Binding Posts	Price
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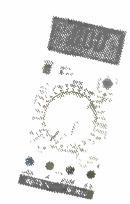
JE23	6.5 x 2.125	830	0	6.95
JE24	6.5 x 3.125	1,360	2	12.95
JE25	6.5 x 4.25	1,660	3	17.95
JE26	6.875 x 5.75	2,390	4	22.95
JE27	7.25 x 7.5	3,220	4	31.95

Metex Digital Multimeters



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• Also measure frequency and capacitance

M4650 only: • Data hold switch • 4.5 digit

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DMM905...........................$39.95

EPROMs - for your programming needs

Part No.	Price	Part No.	Price	Part No.	Price
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TMS2532A	6.95	2764-45	3.49	27256-20	4.95
TMS2564	5.95	2764A-20	3.75	27256-25	4.49
TMS2716	5.95	2764A-25	3.19	27C256-15	5.95
1702A	3.95	27C64-15	3.95	27C256-20	4.95
2708	4.75	27C64-25	3.25	27C256-25	4.25
2716	3.39	27128OTP	3.49	27512OTP	4.95
2716-1	3.75	27128-20	7.95	27512-20	6.75
27C16	4.25	27128-25	7.75	27512-25	5.95
2732	4.95	27128A-15	4.95	27C512-15	6.75
2732A-20	4.49	27128A-20	4.49	27C512-20	6.49
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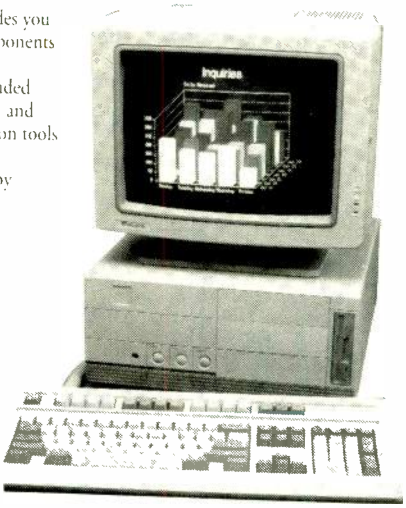

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Relisys 14" VGA Color Monitor

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- Input: DB15-pin (analog)

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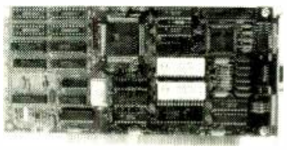

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Part No.	1-9	10+
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7404	.29	19
7405	.29	19
7406	.35	25
7407	.35	25
7408	.35	25
7410	.29	9
7411	.29	9
7414	.35	5
7417	.35	5
7420	.29	9
7427	.35	5
7430	.29	9
7432	.35	5
7438	.45	5
7442	.49	9
7445	.75	5
7446	.99	[illegible]
7447	.89	[illegible]
7472	1.19	[illegible]
7473	.49	[illegible]
7474	.39	[illegible]
7475	.49	[illegible]
7476	.45	[illegible]
7483	.69	[illegible]
7486	.45	
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7493	.45	
74116	1.29	
74121	.49	
74123	.49	
74125	.45	
74151	.39	
74160	.59	
74161	.69	
74192	.79	
74193	.79	
74194	1.19	

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Part No.	Description	Price
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4164-120	120ns, 64K x 1	1.69
4164-150	150ns, 64K x 1	1.49
41256-60	60ns, 256K x 1	2.49
41256-80	80ns, 256K x 1	2.19
41256-100	100ns, 256K x 1	1.95
41256-120	120ns, 256K x 1	1.79
41256-150	150ns, 256K x 1	1.69
511000P-80	80ns, 1MB x 1	7.25
511000P-10	100ns, 1MB x 1	6.75

Miscellaneous Components

Potentiometers

Values available (insert ohms into space marked "XX"):
500Ω, 1K, 5K, 10K, 20K, 50K, 100K, 1MEG

43PXX	3/4 Watt, 15 Turn	$.99
63PXX	1/2 Watt, 1 Turn	.89

Transistors And Diodes

PN2222	$.12	1N751	$.15
PN2907	.12	C106B1	.65
1N4004	.10	2N4401	.15
2N2222A	.25	1N4148	.07
1N4735	.25	2N3055	.69
2N3904	.12	1N270	.25

Switches

JMT123	SPDT, On-On (Toggle)	$1.15
206-8	SPST, 16-pin (DIP)	1.09
MPC121	SPDT, On-Off-On (Toggle)	1.19
MS102	SPST, Momentary (Push-Button)	.39

Connectors

Part No.	Description	Price
DB25P	Male, 25-pin	$.65
DB25S	Female, 25-pin	.75
DB25H	Hood	.39
DB25MH	Metal Hood	1.35

LEDs

XC209R	T1, (Red)	$.14
XC556G	T1 3/4, (Green)	.16
XC556R	T1 3/4, (Red)	.12
XC556Y	T1 3/4, (Yellow)	.16

IC Sockets

Low Profile		Wire Wrap(Gold) Level #2	
8LP	$.10	8WW	$.49
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