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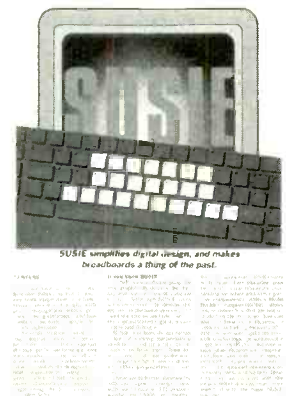

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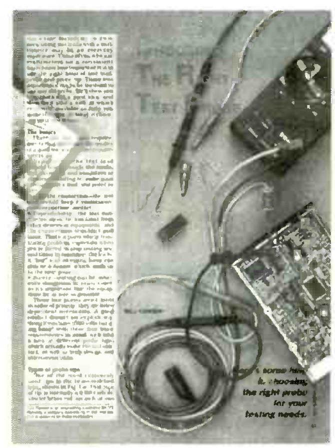

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AND MORE

ON THE COVER

'Tis the season. . .when we all wrack our brains to come up with unique gift ideas. This year, we've made it easy, with a project that's right in the spirit of the holiday season. Our Electronic Christmas Tree is really a PC board whose traces form the branches. Multi-colored LED's look like Christmas-tree lights, and blink in time with any kind of audio. Turn to page 40 to see our festive project that makes a great holiday greeting or window display. And if your wallet's feeling the pinch of holiday shopping, you'll appreciate our Benchtop Frequency Counter. Half the price of commercial models, it offers an impressive array of functions. The versatile, easy-to-use instrument is based on the Intersil ICM7216C. To find out more, turn to page 33.

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A complete listing of our feature articles and departments.

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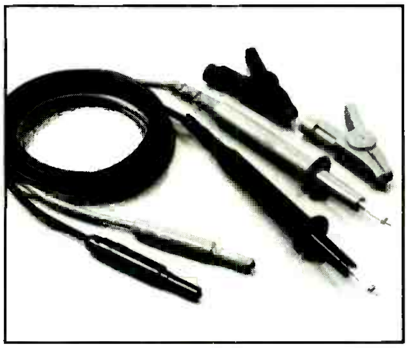

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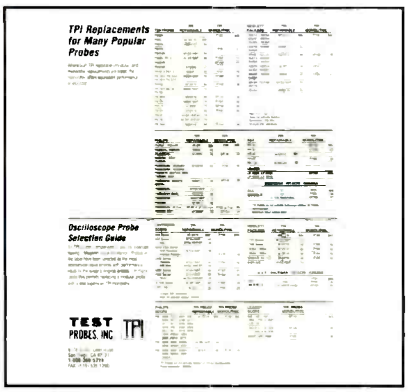

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WHAT'S NEWS

A review of the latest happenings in electronics.

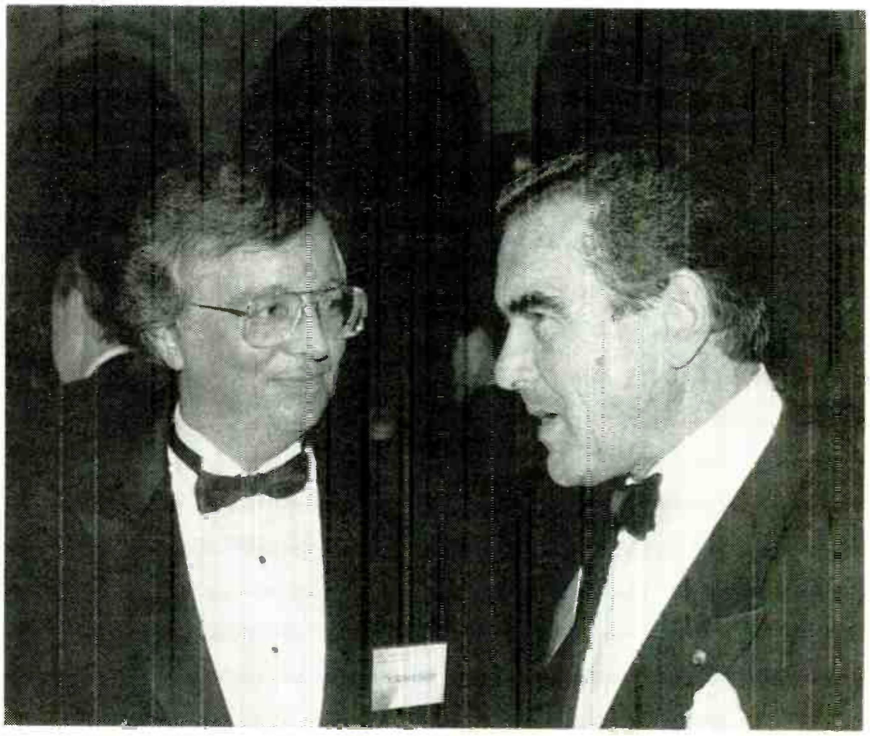
The "new" NESDA

The entire by-laws of the National Electronics Sales & Service Dealers Association (NESDA) were replaced with new ones at membership voting sessions held last August at the annual National Professional Electronics Convention (NPEC) in Las Vegas, NV. Although the rules were completely rewritten, the actual changes in NESDA operations are few, and mainly involve shifting control from the state to the national level. The new laws allow NESDA to control its own destiny as a national association instead of being controlled by state organizations. Under the new rules, NESDA will control the billing of all members, but will encourage "Associate" ventures with regional, state, and local organizations. Local billing will still be permitted under certain conditions. Other changes that were made included replacing the NESDA House of Representatives and Regional Vice Presidents with a Board of Directors.

Elections for several positions were held at the convention, which was attended by more than 600 people. Elected as president of NESDA was Cornelius C. ("Connie") Bell, retired owner of C.C. Bell Electronics in St. Louis, MO. Bill Warren, CET/CSM, of Warren's Audio & Video Service of Knoxville, TN was elected vice president. The ten members of the Board of Directors were also chosen.

Intense laser beam

Researchers at Bellcore (Middletown Township, NJ) have discovered a way to focus 160 extremely small laser beams into a single, powerful beam. Separately, each surface-emitting laser is virtually invisible to the naked eye, measuring about one-tenth the diameter of a human hair, and does not generate enough power for useful applications. The energy that can be harnessed from the experimental arrays, on the other hand, could be used on microchips in optical computers and neural networks or possibly for creating holographic images.



DR. ROBERT TINKER (LEFT), CHIEF SCIENCE OFFICER OF TECHNICAL Education Research Centers, a non-profit organization committed to improving science and mathematics education, was presented with the first Siemens Award for the Advancement of Science at the Computerworld Smithsonian awards event held at the National Building Museum in Washington, D.C. The innovative educator is credited with first introducing networked programs using computer technology into the science classroom. He has developed such influential programs as the National Geographic Kids Network, the Star Schools program, LabNet, and the Global Lab, which engages students, teachers, and scientists around the world in tackling ecological problems. According to Hans Decker (right), president of Siemens Corporation, "Dr. Tinker's vision of children as scientists, tackling real world problems, makes him the ideal recipient of this award."

When the microscopic lasers are packed close together, they each receive a uniform amount of electrical current and can "lase" in concert. Bellcore's array consists of surface-emitting lasers, which direct light up off the surface instead of horizontally, allowing many more lasers to be packed onto a single microchip. According to Hoi Jun Yoo, the principal researcher, "Since you can place lasers anywhere on the surface of a chip, you can make the best of available "chip real estate." The small lasers require about 10,000 times less space than semiconductor lasers used in similar limited applications today.

When etched onto a semiconductor in a special array of 160 2-micron-diameter lasers spaced 0.2-microns apart (one micron equals a 40-millionth of an inch), the vertical beams of light generated blend with one another through a phenomenon called "phase locking," whereby different optical fields overlap to create the equivalent of one light source. The result is the creation of one extremely narrow beam, analogous to several small streams feeding into a powerful river.

The Bellcore experiment is the first time scientists have managed to successfully harness surface-emitting lasers to form a single laser light source.

The research team is now working to integrate the prototype arrays with electronic devices that will be able to accurately control and steer the direction of the beam. **R-E**

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VIDEO NEWS

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

DAVID LACHENBRUCH

• **Who's No. 2?** Philips has ended Zenith's long-time reign as one of the two largest suppliers of TV sets for the American market. The Dutch-owned company's four American brands—Magnavox, Sylvania, Philips, and Philco—aggregated 12.2% of American TV sales in the 1990 model year (mid-1989 to mid-1990), topping Zenith's 11.65% to become America's second largest source of TV's, according to the annual market share survey conducted by *Television Digest*. Thomson Consumer Electronics, a French-owned company, continued to be far and away the leader, its RCA and GE brands aggregating 22.5% of the market.

Philips' advance marked the first time in the 23 years since the *TV Digest* survey has been conducted that the first two places weren't occupied by the manufacturers of RCA and Zenith TV sets. Zenith is the only major U.S.-owned TV-set manufacturer, although some 20 companies have U.S. TV assembly or manufacturing plants. Strictly on the basis of brand names (as opposed to manufacturers), Zenith was still No. 2, following RCA, and Magnavox was the third most popular brand, followed by Sony.

• **Super-Interactivity.** The ultimate in interactive laserdiscs has been demonstrated by Warner New Media, a part of Time Warner Inc. The 12-inch disc will play for one hour per side (as opposed to the 30 minutes normally associated with interactive discs). It can accommodate four simultaneous video tracks with four selectable audio tracks, for a total of 16 combinations. In one suggested application, a viewer could select any of four different views of the same event, with constant audio. The system can display subtitles in up to 15 different languages.

In addition to the main digital stereo channels, it can have 16-channel sound. The channels are mixable—for example, each channel could have a different instrument of the orchestra. The videodisc could be used as a sort of super-CD—providing eight hours or more of audio. Although the new super-interactive disc will be compatible with existing laserdiscs and players, it could have special encoded video and audio information available only to those with special players. Warner says that the super discs would use currently available technology and the "LD+" players could cost less than $1,000. Pioneer and Denon helped develop the system, and they could introduce super players in 1991.

• **Lightvalve projection TV.** When Hughes Aircraft embraces a product, it's usually a significant one. That's why the consumer-electronics industry pricked up its radar with the rumor that Hughes has a TV set. Hughes is keeping its mouth shut on this one, but it's known to be working with Samsung, the Korean TV manufacturer, on a new type of lightvalve TV projector. Although both companies say nothing has been signed yet, there are some indications that a home product could emerge early in 1992. No details are available on the system, except that it uses a single lightvalve in place of the traditional cathode-ray tubes and that the lightvalve isn't a liquid-crystal device, or LCD. The system is said to be capable of providing high-definition TV. This will be Hughes' second major foray into consumer electronics. Its Sound Retrieval System (SRS) super stereo audio is used with Sony TV's and is expected to be added to high-end RCA TV's within the next year.

• **Still/motion camcorder.** Quite possibly the biggest flop of the video era is the still-video camera. The reasons for its failure are easy to understand. Who would pay $600 to $1,000 and more for a still camera with low resolution and no practical system for making prints? Although still-video cameras have been successful in newspaper photography because the pictures can be transmitted by telephone, they have failed to impress consumers because they have been more expensive than moving-picture camcorders, and far more costly than film cameras.

Along comes Philips with a super-idea. What's wrong with a combination movie-and-still camcorder? A camcorder made in Philips' Japanese factory for the European semi-professional market can make Super-VHS videos and "high-quality photographic prints," according to the manufacturer. The camcorder uses a ⅔-inch CCD sensor with a resolution of 700,000 pixels, and is claimed to deliver a picture with more than 450 lines of horizontal resolution. Philips will offer a companion printer. It makes good sense to envision future still-picture systems as add-ons to movie camcorders, rather than separate products. Although Philips says that it has no plans to offer the movie/still camcorder in the United States, or as a consumer product, that seems to be a logical next step.

• **A government picture tube.** The Pentagon's Defense Advanced Research Projects Agency (DARPA) has awarded Zenith a contract to develop its Flat Tension Mask (FTM) technology into a cost-efficient high-definition picture tube. Zenith's FTM system, currently used only for high-priced computer monitors, has a completely flat window-glass faceplate, behind which is a shadow mask held under tension, assuring better color rendition because the mask doesn't expand. Reflections are also held to a minimum because the faceplate is absolutely flat and the glass is treated with a special coating. The government contract is designed to fund a major cost reduction in the new tube. Zenith maintains that the phosphors on the tubes can be printed by a silk-screening process, as opposed to the extremely expensive photographic system currently used for color tubes. If Zenith succeeds in fulfilling the Pentagon contract, it should result in a major improvement in picture tubes, lower costs, and, eventually, a new type of high-definition display. **R-E**

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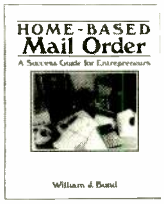

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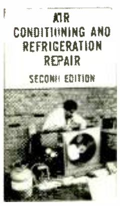

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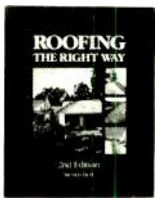

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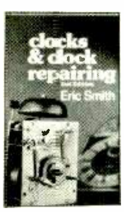

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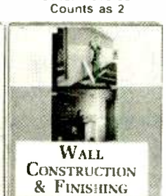

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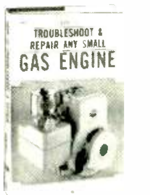

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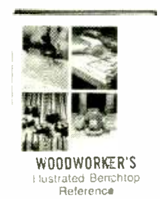

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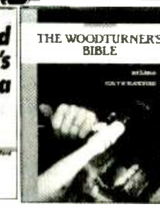

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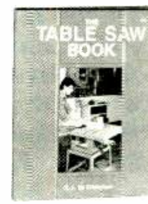

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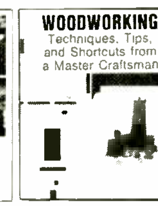

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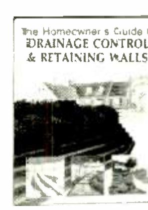

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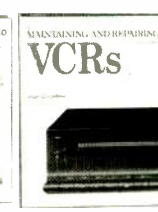

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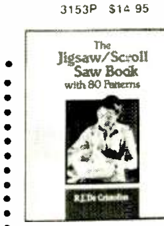

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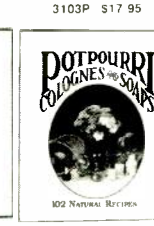

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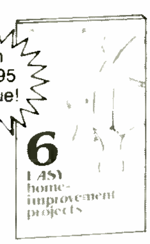

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VOLTAGE CONVERTERS

I have a bunch of tools and some stereo equipment that was designed to run on the standard European supply of 220 volts, 50-Hz AC. Isn't there some way I can easily make, buy, or otherwise acquire a transformer that will let me operate those devices off 120 volts, 60-Hz AC?—A. Sfakianos Placitas, NM

There are lots of places to get transformers that turn 220 volts AC into 110 volts AC, and they should work when their supply connections are reversed as well, but only for the voltage, not the frequency. You indicated in your letter that the frequency difference wasn't important for the equipment you wanted to use so I don't understand why you're having so much trouble.

There are two basic types of commercially available converters used for converting 220 volts AC to 110 volts AC, and they're sold in just about every electronics store; even Radio Shack carries them. With a transformer I use, I can turn the supply leads around and step up the line voltage from 110 volts AC to 220 volts AC (actually 120 to 240). There isn't any problem in doing that as long as you make sure you have the right type of voltage converter.

Converters are made with either transformers or diodes. You can tell the difference between them when you're looking at the package by the weight and the wattage rating. Transformer-based converters are much heavier than the diode-based ones and usually have a maximum rating of about 50 watts or so. The package information should list them as being suitable for electronic equipment, battery chargers, camera flash units, and so on. Since there's a transformer inside the package, the voltage is actually divided in half, (or doubled, when you use it backwards). The output of those converters is a sinusoid.

Diode-based converters are much lighter, and even though the package is the same size, they usually have a maximum rating of 1000 or 1500 watts. You'll find them recommended for things like heaters, lamps, and so on. If you try and use one of those appliances with a transformer operated converter, you'll probably wind up destroying both the converter and whatever you have plugged into it. With the diode-based converters, you can't turn them around and expect to double the input voltage.

Generally, diode-based converters only produce half-wave rectified AC instead of a full sine wave, and they don't cut the voltage in half either. As with any diode voltage drop circuit, the output is .67 times the input voltage. If you put 220 volts AC across the input, you're going to get about 148 volts AC at the output. That may not be much of a problem for most resistive loads, but you should realize that overdriving a heater is going to make it hotter than it was designed to be and that can cause a real problem.

ALARM SYSTEM BACKUP

I've designed an alarm circuit for my house that's powered by line voltage but I want it to switch over to backup batteries if and when the power fails. The control part of the circuit is the only section that has to be constantly powered. I'm not worried about lights and other high current devices since I have a commercial unit for that part of the system. Do you have a simple circuit that can provide the battery backup? I only need 100 milliamps or so.—G. Benjamin Indianapolis, IN

Having a fail-safe power-supply for a home alarm system is a good idea and, if you think of it, is probably the most important part of the alarm system. Fortunately, it's also one of the easiest things to add to the circuit. In your case, it's even easier, since you designed the alarm-control circuit yourself.

There are several ways to add a battery backup to a circuit, but since you're only looking for 100 milliamps, you can keep it simple and the backup circuit can be made so small you'll be able to easily find room for it in your existing enclosure.

The circuit shown in Fig. 1 is a simple design that can do the job. When the line voltage is available and operating, D2 is reverse-biased and current flows into the batteries through R1, the current limiter for the nickel-cadmium (Ni-Cd) batteries, or whatever type of rechargeable battery you want to use. If the main power is disconnected (inadvertently by you or intentionally by a burglar), D2 is forward-biased and battery power is available for the alarm circuit. By adding D1 to the circuit, you can keep the battery from powering other circuitry that's not essential to keeping the alarm system active.

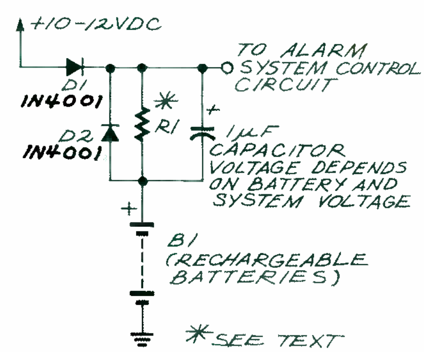

FIG. 1—THIS SIMPLE BATTERY backup circuit can be used to power a control circuit for an alarm system.

The particular diode you should use for D2 depends on the amount of power you want to draw from the battery when the main power is disconnected. If you're sure that you'll never need more than 100 milliamps, you can probably get by with a small 1N914 diode but, if there's a chance you might draw more current, or you just want to play it safe, you're better off with something like a 1N4001.

If you use Ni-Cd batteries, you'll need a constant trickle-charging current. You should select R1 to limit the charging current to the battery's C/10 rating, which is 10% of the ca-

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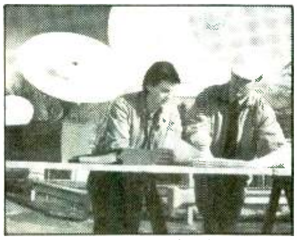
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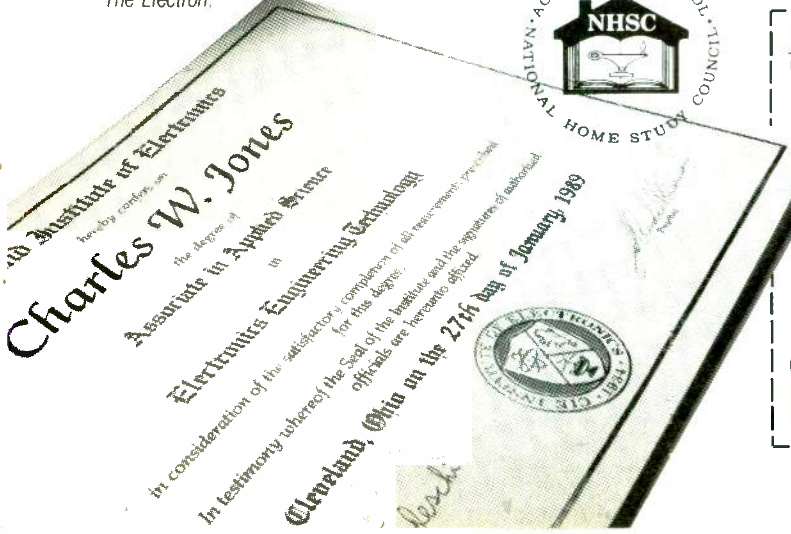

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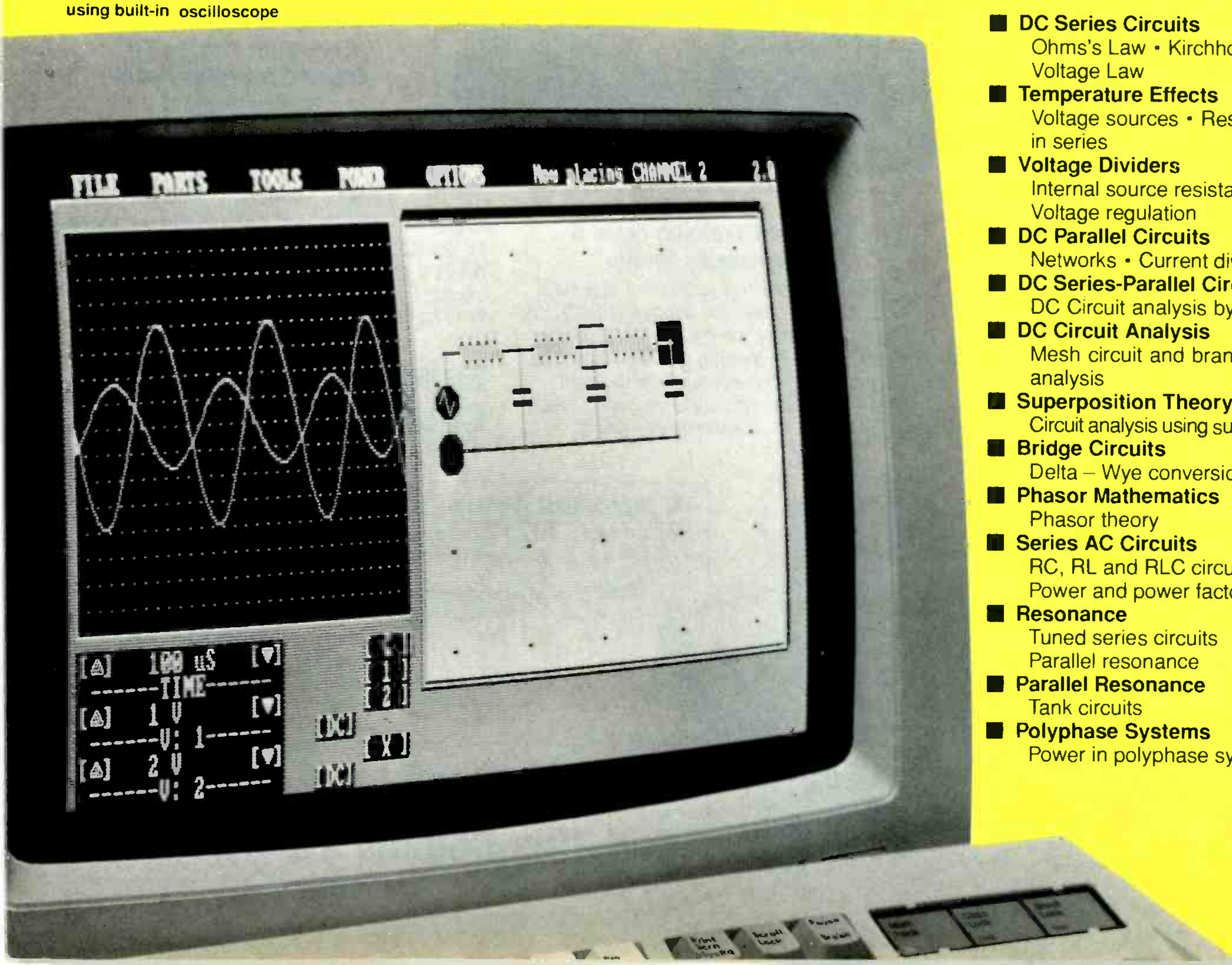

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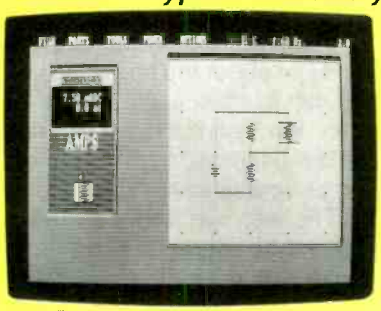
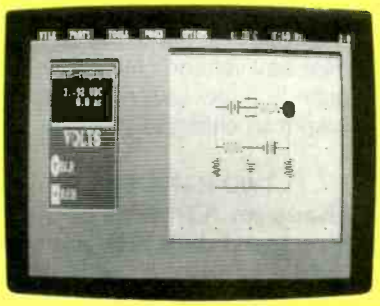
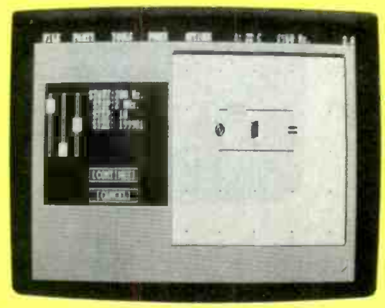


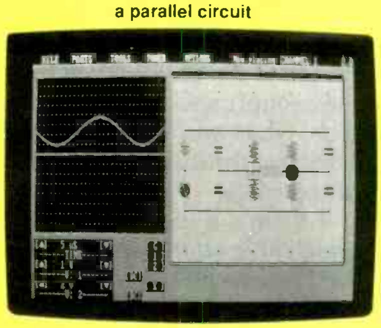
Resistor Series/Parallel Circuit demonstrates current division in a parallel circuit



Thevenin Equivalent Circuit calculating voltage drop and current flow using built-in ammeter/voltmeter



Parallel Resonance LC Tank Circuit using sweep generator to vary voltage across tank, monitoring circuit response



Frequency Compensated Bridge using oscilloscope to measure AC signal offset by DC voltage

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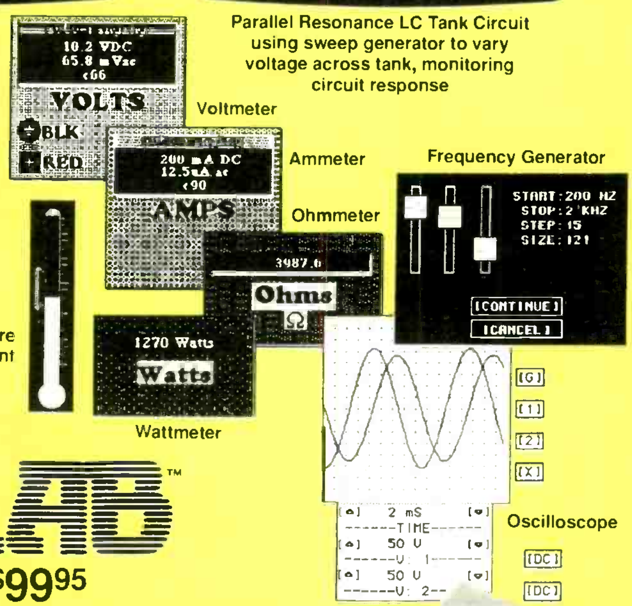

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pacity of the battery. In a C/10 rating. "C" is the charge capacity in amp-hours, and "10" is the number of hours the battery can supply useful power. Therefore, the capacity divided by that operating interval equals the maximum current safely drawn from or supplied to the battery. The trickle current charge, I_c, must be less than or equal to the maximum safe current drawn through the battery.

The value of R1 can easily be calculated using

$$R1 = [(V_c - (0.6 \text{ volts} + V_b)]/I_c$$

where V_c is the circuit voltage, V_b is the battery voltage, and I_c is the charging current.

This is just a straight application of Ohm's Law. The reason it seems more complex is that you have to subtract the 0.6 volt-diode drop and battery voltage from the supply voltage.

The capacitor in the circuit is used to filter any voltage glitches and also to provide a few seconds of power if you want to change batteries.

TWO HARD DISKS

I have an AT-class computer with a hard disk and am trying to add a second hard disk. The controller card can work with two hard disks, but I'm not having any luck connecting the cables. No matter what I do, the computer never recognizes the second hard disk.—W. Meredith Philadelphia, PA

If you're installing the second drive simply to increase capacity, maybe you should consider buying a single new hard drive with at least double the memory of your present one. Not only will that give you extra room inside your cabinet for other add-ons such as tape drives, but you might also benefit from increased overall operating speed—your old drive may not be as fast as the newer ones. You can keep your old drive for emergency backup, or you can sell your old drive to someone who doesn't have one. However, if you're determined to add a second drive, read on.

In order to have two hard disks in your computer, you have to tell the computer the second hard disk is there and then you have to cable it so the computer can find it.

Since you have an AT computer, you have to run the setup utility and set the correct type for the second hard disk. How that is done depends on the BIOS you have since some of them have the setup utility in ROM while others require that you run a program on a disk, such as the IBM AT diagnostics. Be sure and set the type correctly since an incorrect number there can damage the hard drive.

Once you have that done, you have to physically connect the drive to the computer and that involves four things:

1. A power cable has to be connected to the drive.
2. A separate data cable (the thin one) has to be connected from the controller card to the drive.
3. The control cable (the fat one) has to be connected to the drive.
4. The drive select jumpers on the back of the hard drive have to be set to match the type of control cable you're using.

The first two operations are simple and just about the only thing you have to watch out for is the cable's orientation. Pin 1 on the controller card has to be connected to pin 1 on the drive's edge connector.

The last two items on the list go together since the drive select jumper on the back of the disk has to be set according to the type of control cable you're using.

The first hard disk in the system, (your original one), should be attached to the connector at the end of the control cable and the second hard disk, (your new one), should be attached to the connector in the middle of the cable.

If there's a twist in the wires between the connectors for the two hard disks, the drive select jumpers for both hard disks should be set in the second position (sometimes marked as DS2.) If there's no twist in the cable, the drive at the end (your original one) should have the jumper set in the first position and the drive in the middle of the cable, (your new one), should have the jumper in the second position.

The terminating resistor should be removed from the new drive in the middle of the cable and left on the original drive at the end of the cable. If you can't find the terminating resistor or have a hard time trying to remove it, don't worry about it. I've seen several machines in which both drives had the terminating resistors left in and everything worked fine. **R-E**

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LETTERS

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

LOGIC ANALYZER REANALYZED

The review of the Photronics low-cost logic analyzer (*Editor's Workbench*, **Radio-Electronics**, August 1990) does a terrible injustice to the product in stating that its "low speed" and "8-bit operation" are insufficient. That fact is that its speed and data width are usually *more* than adequate for the application areas for which it was designed.

The *LA1* is primarily intended for digital troubleshooting in areas that require more than a dual-trace oscilloscope, a digital voltmeter, and a logic probe while not requiring the power, expense, and complexity of a typical logic analyzer designed for microprocessor applications. When an actual situation places the designer in that predicament, the need for a medial solution becomes obvious. A few examples that prompted the design of the *LA1* are stepper-motor logic circuits, remote-control circuits using the popular 40-kHz IR encoding, and countless applications in the non-microprocessor prototype circuits breadboarded by the professional as well as hobbyists and students. Many of those applications do not require all eight data channels or the full bandwidth of the *LA1*.

Perhaps the label "logic analyzer" automatically conjures up the thought of complex, high-speed, wide-bus microprocessor analysis; nonetheless, that is the most appropriate label for the *LA1*, which completely accomplishes its design goal by introducing a cost-effective means of obtaining that worthy capability at the other end of the spectrum.

DALE NASSAR
PRESIDENT, PHOTRONICS
Amite, LA

Perhaps I should have said "insufficient for the things people normally use logic analyzers for," which does not include IR decoding, stepper-motor circuits, and so on. I liked the device quite well as a teaching aid, but I remain skeptical of its utility outside the educational environment. That is not to denigrate the device; a balanced review must point out both the strengths and the limitations of a product.—Jeff Holtzman, Computer Editor

CABLE SCRAMBLING

I read with interest Robert Grossblatt's *Drawing Board* column, entitled "Scrambling and Macrovision," in the July issue of **Radio-Electronics**. I am only sorry that, as a new subscriber, I have missed some very important information in earlier issues.

However, having worked for the "Phone Factory" for a number of years before retiring, I am well acquainted with COAM (customer owned and maintained) equipment and the pitfalls of the "rules." With divestiture, as Mr. Grossblatt said, we can now connect "most anything" to the line on the COAM side of the RJ block—as long as it doesn't "upset" or interfere with the network. Cable TV, as a franchised company, should operate under the same rules. If they do not want a channel to be available to me, then they shouldn't put it on the network to begin with.

The power company doesn't say that you have to pay higher rates if you have a microwave oven, hair dryer, TV, etc., and I see no reason for any utility to have special concessions. So if they don't want me to have what is on the network, then don't provide it and trap it out—make me the responsible party, not them.

DELBERT McMULLEN
Independence, MO

THE "LONG RANGER"

I am responding to the article "Whatever Happened to AM Radio?" (**Radio-Electronics**, September 1990). After 38 years as a small-market chief engineer and announcer, I feel I have some understanding of AM/FM radio.

A new business climate exists today. Most business firms in this rural area are chain outfits. They advertise little on radio, FM or AM. Ten years ago almost all were Mom-and-Pop concerns and, though some didn't contribute heavily, nearly all advertised. TV and cable were no competition for commercials then or now. But they have captured a large portion of the *audience*. Today, the weekly newspapers, shoppers' guides, and sales flyers get the bulk of advertising dollars.

There are too many AM stations, especially at night. We can receive a half dozen that are relatively free from interference. But one picture is worth a thousand words, so we watch TV at night. And some areas have too many stations, in the day and evening.

The National Association of Broadcaster's (NAB) grand scheme to institute the National Radio Systems Committee's (NRSC) pre-emphasis to AM is largely a wild idea, in my opinion, and will cause additional interference (albeit some improvement in the cheap sets with poor audio quality). The plan is to change back in the future, removing pre-emphasis. Why not attack the problem head on? Yes, even manufacture our own receivers if the Japanese won't cooperate. We have the know-how, the facilities, and plentiful parts.

AM radio, as we old-timers remember it, is gone. But with some prudent managing it is far from dead. In fact, we just might see an AM resurgence in the future—it is definitely the long ranger!

GENE VINSON
Thomasville, AL

MORE ON AM RADIO

Mr. Dexter's article about the problems facing AM radio contained a serious technical error. Mr. Dexter wrote that AM transmissions are limited to a bandwidth of 10 kHz, and an audio response upper limit of 5 kHz. Actually, the FCC has always allowed AM stations to transmit audio out to 15 kHz (the same as FM radio), with a corresponding RF bandwidth of 30 kHz. AM radio's poor sound quality is because almost all AM receivers have a 10-kHz bandwidth, limiting received audio response to 5 kHz.

When broadcasting began, there was no such thing as "high fidelity."

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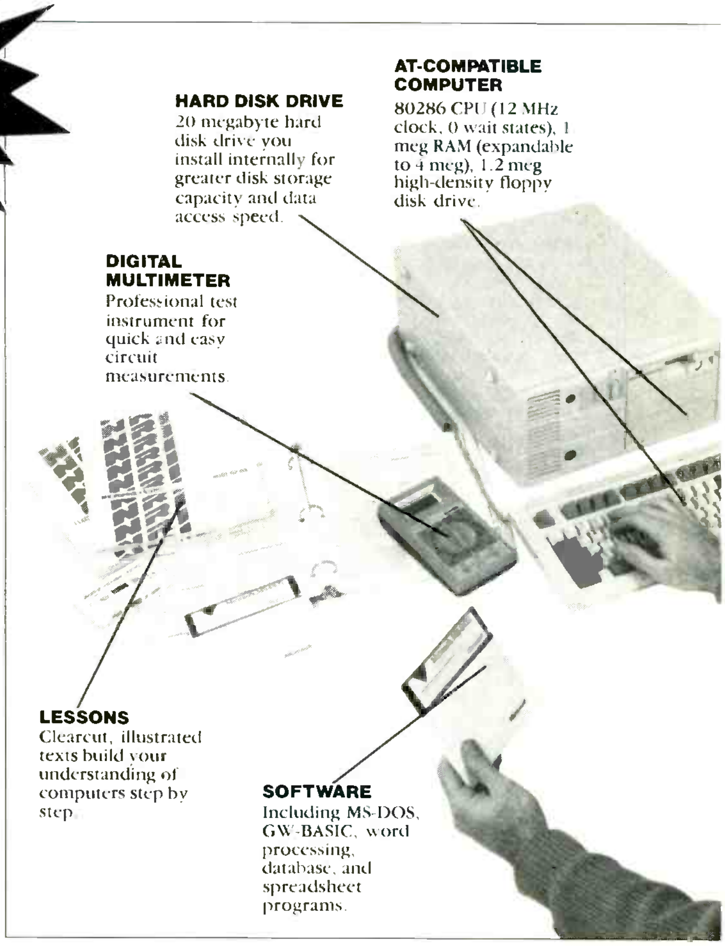

No doubt about it. The best way to learn to service computers is to actually *build* a state-of-the-art computer from the keyboard on up. As you put the machine together, performing key tests and demonstrations at each stage of assembly, you see for yourself how each part of it works, what can go wrong, and how you can fix it.

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Only NRI gives you a top-rated micro with complete training built into the assembly process

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NEW

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in school, on the job, how to troubleshoot and like NRI

Using your D/A converter along with the exclusive text-to-speech software also included, you explore the fascinating technology behind both digitized and synthesized computer speech.

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Many AM stations used standard telephone lines, which have upper limits of 5 kHz, to send audio from the studio to the transmitter. AM radios were built with narrow bandwidth IF filters to minimize interference. Even when high fidelity was introduced in the 1950's and 1960's, AM stations still used standard phone lines to link the studio with the transmitter. In the 1980's, almost all stations converted to high-fidelity 15-kHz telephone lines, but AM radios were still built with narrow bandwidths, due to the added expense entailed in a "wideband" option.

The standards proposed by the NRSC are intended as a compromise between interference and audio fidelity. Under the plan, AM stations will limit audio response to 10 kHz, thus limiting RF bandwidth to 20 kHz. The improvement in sound quality involves AM radios, which will be built with a "wideband" function that will receive the entire 10-kHz audio signal. As mentioned in the article, AM broadcasts will be pre-emphasized and "wideband" AM radios will have a corresponding de-emphasis curve, reducing noise while keeping audio response flat out to 10 kHz. Although not quite the equal of FM radio's 15-kHz audio response, wideband AM comes very close to matching FM's sound, and will dramatically improve the public's enjoyment of music broadcasts on AM radio.

Although I am only 16 years old, I have devoted much time to the study of radio, especially AM radio.
MATTHEW BAILEY
Stone Mountain, GA

A VOICE OF EXPERIENCE

Radio-Electronics certainly fills a gap in the information world, not only for the novice who is anxiously pursuing the fascinating and useful study of electronics, but also for keeping more experienced readers posted. In addition, the magazine provides recreation in the form of construction projects, featuring unique and useful devices for us to build.

I have a suggestion to offer regarding the excellent series called "Introduction to Microwave Technology" by Joseph J. Carr. In the September issue, on page 69, it states that the three traditional methods for generating RF energy were spark gaps, Alexanderson alternators, and vacuum tubes. It appears that arc generators were omitted from that category, although they were commonly found on board ships where the principle power source was 115 VDC. The arc signals were characterized by a much smoother wave band than spark sets, and were preferred by ship operators. They also were much more efficient than spark sets. (A sketch of such a device appears in Fig. 1.)

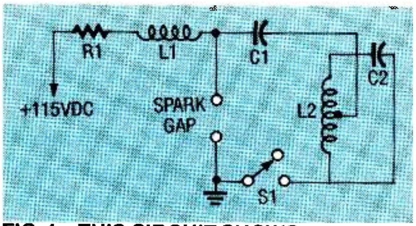


FIG. 1—THIS CIRCUIT SHOWS an arc-generator, which was used on-board ships where the primary power source was 115 volts DC.

Also on page 69 is a reference to using a Ford Model A ignition coil for a spark source of power. That is apparently an oversight, since the coils in demand were the vibrator-driven, type that were found on the Ford Model T.
FRANK J. BURRIS
Fallbrook, CA

BUILD A RESISTANCE STANDARD

A "standard resistance" value is a necessity for a calibration laboratory. However, those certified standards can represent a sizable investment. If you are performing calibration services in the field as a secondary function, buying a "standard" can be difficult to justify. However, there is a way in which a "resistance standard" can be designed, fabricated, and certified for a nominal sum.

First, select the value of resistance that you need most, and then obtain a precision resistor of that value. That resistor should be a 1%-or-better tolerance component. Verify the *true* resistance of the device on a certified instrument that is at least ten times the accuracy of the resistor. That reading, taken between 72°F and 78°F, becomes the "certified value."

For example, I made a 1.62-kilohm resistor standard. I used a Dale 50-watt, 1%, wire-wound resistor as a "standard" value, and verified its true value with a 4½-digit DMM certified to have a 0.1% ±2 LSD (least significant digit) error factor on the 0–2-kilohm range. The test leads were "zeroed" to eliminate their resistance from influencing the readings. The ambient temperature on the surface of the component was verified to be 75°F. I made a series of 10 individual resistance measurements at 10-minute intervals, which prevented the component's value from changing due to internal heating caused by current from the measuring instrument flowing through the resistor. That change could be 1–2 ohms in a less expensive resistor but, since we are building a "certified standard," the marked value should be as accurate as possible. The ten readings were identical: The resistor proved to have an value of 1617 ohms. That is within the 1% tolerance specified.

The value derived by the use of the precision ohmmeter is the "true" or "certified" resistance of the component. The "nominal" value is 1620 ohms. Now that the numerical values have been established, we can package the unit.

Because it is a "traveling standard" we cannot always control the environment in which it will be used. We must provide a thermal mass to surround the resistor, and thereby act as a temperature stabilizer. Encasing the resistor in a thermal insulating compound prevents a sudden change of environmental temperature from affecting the measured value of the resistor.

I soldered two #16 insulated leads soldered to the resistor, and lowered it into a mold cavity (an empty Spam can sprayed with mold release). I placed the resistor in the center of the cavity and used a casting resin to fill the mold. The resin took two hours to set and 24 hours to cure.

Once the casting was removed form the mold, I repeated the initial resistance readings to ensure that the value of the resistor had remained constant. After performing the second resistance verification, I drilled two mounting holes through the casting. I bolted the casting into a small cabinet and sealed the enclosure with rivets. My new traveling resistance "standard" is marked:

"RESISTANCE STANDARD."

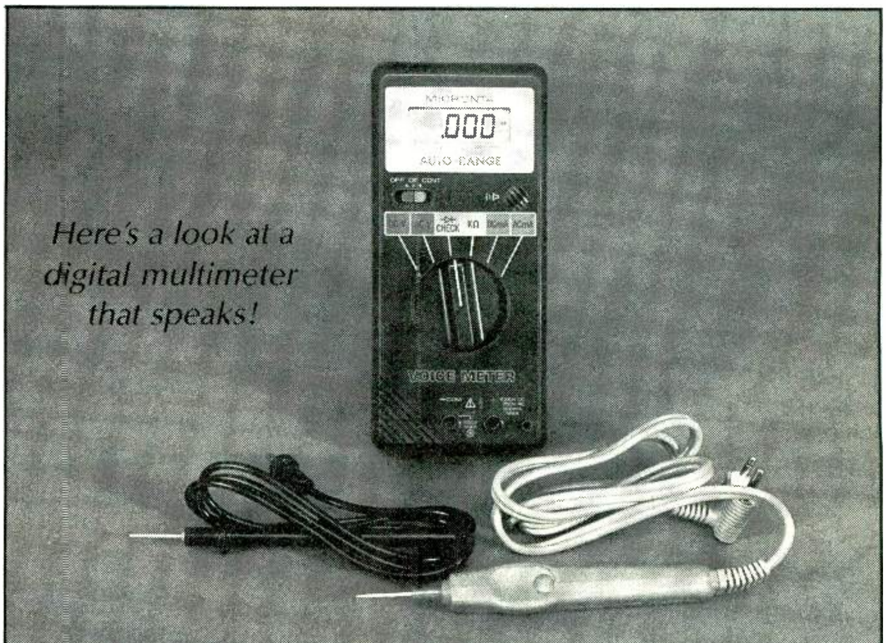
"NOMINAL VALUE—1.62K @ 1%"

"CERTIFIED VALUE—1,617 OHMS @ .185%"

"(Certified in thermal isolation mass at 75°F)"
CHARLES H. STURKEY
Newhall, CT

EQUIPMENT REPORTS

Micronta's Voice Meter Digital Multitester



Here's a look at a digital multimeter that speaks!

CIRCLE 10 ON FREE INFORMATION CARD

Using a digital multimeter isn't a difficult thing to do—or at least it shouldn't be. On a benchtop, that may be true. But in the real world of field measurements, using a multimeter can often try your patience—and your balance. Some of us have not-too-fond memories of measurements made on top of a ladder or catwalk, with half of our bodies reaching for the test points and the other half simultaneously stretching toward the meter to read its display. Others can relate to making underdash automotive measurements where it's difficult to get your head positioned to see where you put the multimeter probes, let alone see the display.

Of course, multimeter manufacturers are more than happy to find solutions to the problems that their users encounter. We've seen several techniques that are used to freeze the display and hold a reading of interest. While they work well, and are a perfect solution for many situations, they all share one feature that is a failing in other situations: You have to look at the display to determine the reading.

Radio Shack (700 One Tandy Center, Fort Worth Texas 76102, and more than 7000 locations nationwide) has come up with a different solution: their Micronta *Voice Meter*. At the push of a probe-mounted button, the meter announces the measurement in a clear voice.

The *Voice Meter* doesn't look much different from many other digital multimeters. Its gray plastic case measures roughly 7 × 3 × 1¼ inches, and features a 3⅔-digit (3000-count) LCD readout, a power switch, and a six-position rotary function-selector. The six measurement functions are: DC volts, AC volts, diode check, resistance, DC current, and AC current.

DC and AC voltages are measured in five and four ranges respectively: 3000 volts with a resolution of 1 volt; 300 volts with a resolution of 0.1 volt; 30 volts with a resolution of 0.01 volt; 3 volts with a resolution of .001 volt; and (for DC only) 300 millivolts with a resolution of 0.1 mV.

Resistance is measured over six ranges, from 300 ohms through 30 megohms, with resolutions that range from 0.1 ohms in the 300-ohm range to 10K in the 30-megohm range. DC and AC current are measured in a single range of 300 milliamps, with a resolution of 0.1 milliamp.

Using the *Voice Meter* isn't significantly different from using standers multimeters. In fact, you don't have to use the voice feature if you choose not to. If you do choose the voice feature, getting the meter to speak is as simple as pressing a button on the positive probe. Unfortunately, if you need the voice capability, you must use the probe supplied with the meter.

While we initially found the voice to be a novelty, it quickly got on our nerves when we made repeated measurements. Despite the *Voice Meter*'s clear, slow, easy-to-understand voice, we preferred simply glancing at the meter when making most measurements because it was faster and quieter. (No volume control is provided on the meter). However, for our tests where we couldn't see the meter's face, the voice, of course, proved invaluable.

The *Voice Meter* is powered by four "AA" batteries. When the batteries are low, a BATT annunciator makes you aware of the fact. If you don't notice it, you will be prompted by an insistent "Replace batteries" announcement when you try to get a voice reading.

Our overall impression of Radio Shack's talking multitester was favorable. The only feature we didn't like was that the test probes don't offer sheathed banana plugs—an important safety consideration when you're making high-voltage measurements.

Although we liked the meter, we doubt it will find favor in professional circles. Most professional users—except those who really need voice capability—will want more features, ruggedness, and higher accuracy. However, most of those professionals will find the $99.95 *Voice Meter* a perfect addition to their home workbench. **R-E**

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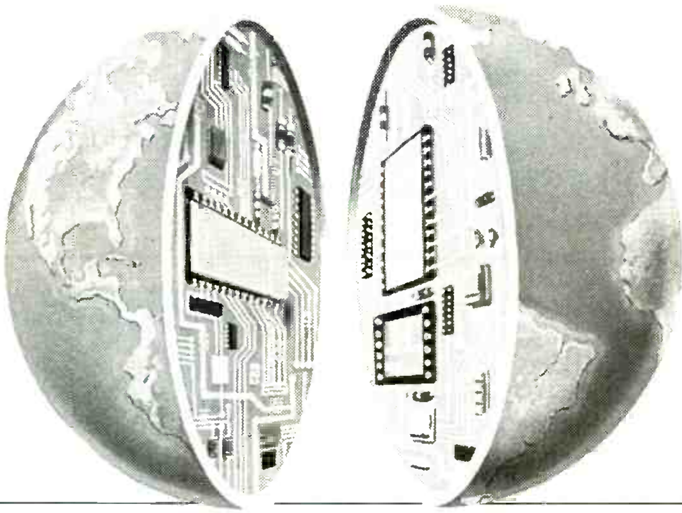

Look at the world as it was 20 years ago and as it is today. Now, try to name another field that's grown faster in those 20 years than electronics. Everywhere you look, you'll find electronics in action. In industry, aerospace, business, medicine, science, government, communications— you name it. And as high technology grows, electronics will grow. Which means few other fields, if any, offer more career opportunities, more job security, more room for advancement—if you have the right skills.

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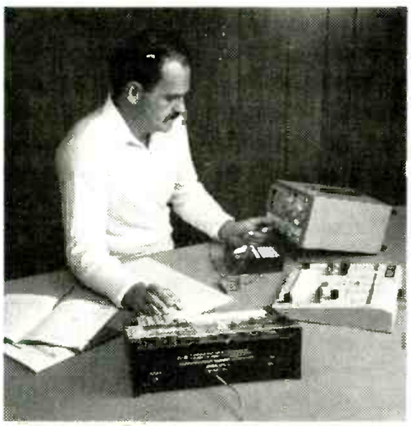

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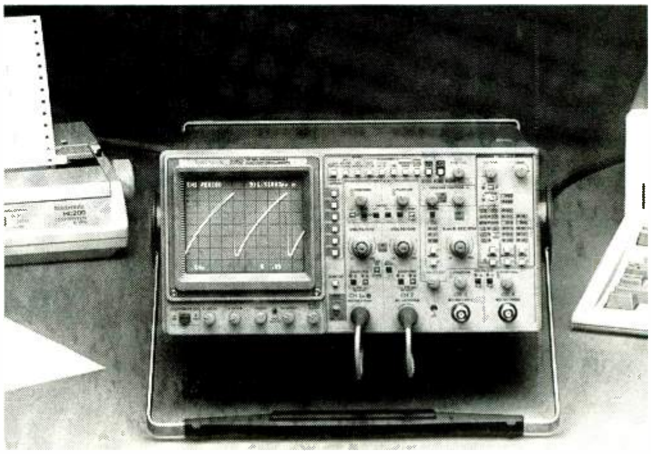
PORTABLE REAL-TIME OSCILLOSCOPE. The model *2252* programmable 100-MHz-bandwidth oscilloscope from *Tektronix* provides the precision, versatility, and ease-of-use of an analog scope, plus the ability to record the displayed signal on paper at the push of a button. The fully automated oscilloscope ensures measurement accuracy with its integrated digital voltmeter, "Smart Cursors," and precision counter/timer. The scope also features four channels, automatic setup, and dual time bases. Fully programmable over the standard IEEE-488.2 interface bus, the instrument can be controlled remotely from a PC.



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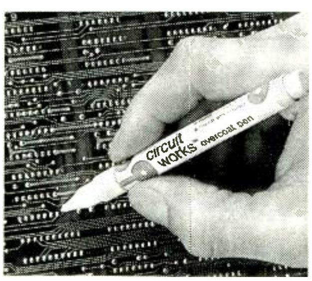
A unique sequential-sampling technique digitizes a repetitive signal for hardcopy output on an Epson-compatible printer. All displayed channels, scale factors, and active measurements can be transferred to the printer via a Centronics interface. Test results can be quickly documented, or unknown signals can be recorded for later review.

All oscilloscope functions, including instrument setup, signal acquisition, and measurement controls, are accessible over the standard GPIB. The interface and computer analysis make automated and repetitive testing applications easier and less time consuming than many other methods. The scope is supported by test-development software from Tektronix.

The *2252* provides a full complement of automatic measurements. The voltmeter includes "Smart Cursors," which automatically track changes in voltage measurements and visually indicates where measurements are being made on the waveform. The 200-MHz counter/timer delivers crystal-controlled, 10 parts per million accuracy for timing measurements such as automatic rise/fall time and propagation delay calculations. All measurements are made on the real-time analog signal. With its time-averaging counter, the scope is capable of up to 10-picosecond timing resolution at any sweep speed. Voltage measurements made using the voltmeter have better than 10-bit vertical accuracy. Gated measurements can be made on any portion of the signal.

The *2252* real-time oscilloscope, including both Centronics and GPIB interfaces, has a list price of $3,495.00—**Tektronix**, P.O. Box 1700, Beaverton, OR 97075; Tel: 1-800-426-2200.

SOLDER-MASK REPAIR PEN. An easy way to insulate, protect, and repair circuit boards, components, and delicate electronics is provided by the *3300 Circuit Works Overcoat Pen*. The pen applies a tough, conformal coating to insulate against shorting, arcing, and static discharge while it protects against moisture, abrasion, chemicals and other environmental hazards. Particularly useful in the design, prototyping, and repair of PC boards, the overcoat pen improves the reliability and safety of modifications when used to repair solder masks.



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The pen is easy to use. Normal writing pressure opens the tip and starts the flow of overcoat. Traces as narrow as 1/16 inch are possible, and the pen contains enough coating material—a polymer that is available in several colors and clear—to insulate and protect approximately 60 feet of exposed traces. The material dries in 5–10 minutes and can be heat cured at 50°C–100°C for enhanced performance. Maximum working temperature is 200°C. The wide temperature range permits both spot solder mask for in-line soldering operations and a durable overcoating for solder-mask repair of open traces and exposed connections after soldering. The overcoating is safe for gold, silver, copper, and solder alloys, and is flexible when cured.

The *3300 Circuit Works Overcoat Pen* costs $9.95 plus shipping ($1.00 U.S. Mail or $2.50 UPS)—**Planned Products**, 303 Potrero, Suite 53, Santa Cruz, CA 95060; Tel: 408-459-8088; Fax: 408-459-0426.

AUTORANGING DIGITAL MULTIMETER. Designed for convenient testing and troubleshooting, *B&K-Precision's* model *2701* autoranging DMM has a belt-clip and test-lead clips built into its case for hands-free use and safe storage of probes. The compact, hand-held multimeter allows single-handed operation in hard-to-reach locations. It can be used to test AC and DC voltage and current, as well

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as for resistance, diode, and continuity checks. The *2701* has a 3½-digit LCD. Its functions include autoranging, "High" and "Low" power ohms, and data hold. A 9-volt battery provides 800 hours of continuous operation.

The *2701* autoranging digital multimeter costs $69.00.—**B&K-Precision**, Maxtec International Corp., 6470 West Cortland Street, Chicago, IL 60635; Tel: 312-889-1448.

FREON-GAS ANTI-DUST SPRAY. Containing no CFC's, *Dust-A-Way* from *Jensen Tools* removes dust, lint, and other foreign particles from delicate equipment with no risk to the ozone. Depressing the trigger valve on the 12-ounce can delivers a quick burst of dry, inert freon gas precisely where it is needed. The spray is recommended for use on electrical, electronic, optical, and delicate mechanical devices.

Dust-A-Way freon gas spray costs $7.95 for a 12-ounce can.—**Jensen Tools Inc.**, 7815 South 46th Street, Phoenix, AZ 85044.

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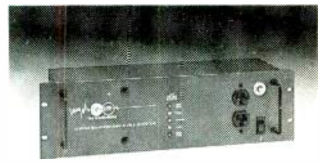
RACK-MOUNT LINE CONDITIONER. Providing affordable, effective voltage regulation in a compact unit, the *Tripp Lite LCR-2400* rack-mount line conditioner is designed to meet the needs of recording studios, testing labs, and industrial settings where 19-inch racks are used. With a 2400-watt output (20 amps maximum) and 14 AC outlets, the *LCR-2400* can simultaneously run a wide variety of equipment, test instruments, or appliances. Various input voltages from 87 to 140 VAC are controlled to 120-VAC output within ANSI C84.1 specifications to protect equipment from brown-outs or over-voltages. Built-in surge suppressors protect sensitive devices from spikes, line noise, and RFI/EMI interference. Two isolated filter bands prevent connected equipment from interacting with each other. The *LCR-2400* has a multi-color LED readout that indicates the level of line-input voltage and reacts to changes as they occur.



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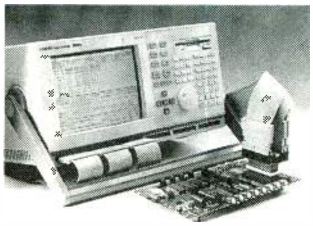
The *LCR-2400* rack-mount line conditioner has a suggested retail price of $459.00.—**Tripp Lite**, 500 North Orleans, Chicago, IL 60610-4188; Tel: 312-329-1777; Fax: 312-644-6505.

LOGIC ANALYZERS. *Philips' PM 3580/PM 3585* family of logic analyzers feature quick set-up time—users need less than 30 minutes to get an instrument up and running. Pop-up menus and VGA graphics offer a simple interface for new users, and provide experienced users with short cuts for quick operation. Faster analysis is obtained by reducing state and timing measurements to one probe connection, requiring only one set-up to be learned, and providing fully-integrated state and timing triggering. All measurements are time tagged with up to 5-nanoseconds resolution.



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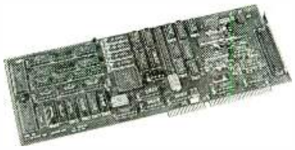
The logic analyzers feature a unique dual-analyzer-per-pin architecture that allows both state data (relating to software functioning) and timing data (relating to hardware performance) to be acquired from the system simultaneously on up to 96 channels, using just a single set of probes. Performance specifications are 50-MHz state, up to 200-MHz timing, and 2 kilobytes of memory per channel. Windows allow the display of state and timing or two views of state or timing data.

Other features include a large, high-resolution screen, a video-output socket for connection to an external large-screen VGA monitor, and a parallel-printer port for hardcopy output. Also provided is an RS-232 serial port for diagnostic testing and future options, and BNC trigger connectors for easy trigger of other instruments, or for external triggering of the logic analyzer from another instrument.

The PM 3580/PM 3585 family of logic analyzers ranges in price from $4,250 for the *PM 3580/30* with 32 channels of 50-MHz state recording and 32 channels of 100-MHz timing and 1K deep memory, to $10,950 for the *PM 3585/90* (pictured), which offers 96 channels of 50-MHz state and 96 channels of 200-MHz timing recording with 2K memory.—**John Fluke Mfg. Co., Inc.**, P.O. Box 9090, Everett, WA 98206; Tel: 800-44-FLUKE, ext. 77.

DIGITAL SIGNAL PROCESSING BOARD. *Dalanco Spry's* model *250* digital signal processing (DSP) board has analog and digital inputs and outputs for the PC/AT and bus-compatible microcomputers. The board is based on the 40-MHz Texas Instruments' TMS320C25 DSP, and can accommodate the faster TMS320C25-50, the EPROM-based TMS320E25, and the newer TMS320C26. The model *250* can be used in stand-alone mode in embedded systems when equipped with the TMS320E25. The DSP board provides data acquisition for eight single-ended channels at 12-bit resolution and a maximum 300-kHz sampling rate. Two analog-output channels are provided, as are a buffered digital I/O expansion connector and the serial (codec) interface of the TI DSP. The board can be populated with up to 64K words of zero-wait-state program RAM and up to 128 words of one-wait-state data RAM. The data RAM is simultaneously available to both the PC



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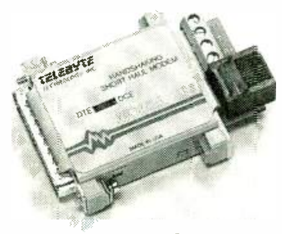
and the TMS320 DSP through the use of an on-board memory controller.

The model *250* features high throughput and is easily accommodated in multiple-board systems. PC-to-data RAM-transfer speeds may be as high as 3 megabytes per seconds. The maximum continuous throughput to disk is thus limited only by the capabilities of the host PC's disk system. Software that is bundled along with the model *250* includes assembler, debugger, FFT's, signal and spectrum display, digital filter examples, record and playback to and from disk, and a waveform editor.

The model *250* digital signal processing board is priced starting at $1095 (40-MHz TMS320C25, 4K words of program RAM, and 32K words of data RAM).—**Dalanco Spry**, 89 Westland Avenue, Rochester, NY 14618; Tel: 716-473-3610.

HANDSHAKING MODEM. Offering full-duplex data transmission at rates of up to 19.2 kiloband and a bi-directional control signal—all over two twisted pairs—*Telebyte Technology's* model *204 Handshaking Modem* can provide a "hardware handshake" for devices such as laser printers and various terminals.

The "handshake" is typically used when terminals are connected to a PBX switch, which uses the handshake to determine if the terminal is active or if its power has been turned off. Housed in a small plastic case, the full-duplex modem measures only 2 × 2¾ × ¾-inches.



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The model *204* samples clear-to-send (pin 4), request-to-send (pin 5), and transmit data of the RS-232 serial interface, and derives its operating power from them—no battery or external power supply is required. The standard-data I/O occurs on pins 2 and 3 of the RS-232 connector. The control signal uses DTR (data terminal ready) as the handshake input and DCD (data carrier detect) as the handshake output. The input and output are switchable, to accommodate connection of the modem to either a DTE or DCE device. The control signal input also controls the data flow from the modem. Data can be transmitted when the control signal is high. The modem requires no separate power inputs.

Data transmission between modems uses differential baseband signaling techniques, and common-mode signal rejection capability is greater than 20 volts. Those features are there to allow error-free operation in all kinds of noisy environments.

The model *204* costs $89.00 in unit quantity and $68.00 in quantities of 100.—**Telebyte Technology Inc.**, 270 East Pulaski Road, Greenlawn, NY 11740; Tel: 1-800-835-3298 or 516-423-3232; Fax: 516-385-8184. **R-E**

NEW LIT

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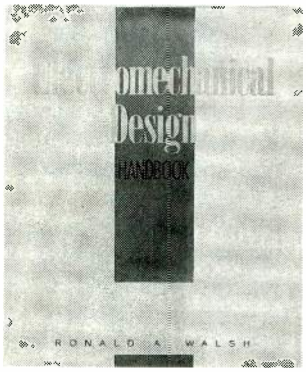
ELECTROMECHANICAL DESIGN HANDBOOK; by Ronald A. Walsh. TPR, Division of TAB Books Inc., Blue Ridge Summit, PA 17294-0850; Tel. 1-800-233-1128; hardcover; $49.50.

The fields of electrical and mechanical engineering are closely linked in the design and development of today's manufactured products. This book fills an important gap in the libraries of engineers and designers whose work requires them to cross the boundaries between electrical and mechanical design. Including information about both disciplines, this well-organized book provides practical product-design data, working procedures, and formulas in one comprehensive volume. The broad range of subject matter covered includes the following: spring design; standard fasteners and bonding methods; prototype construction; product liability, testing, and patents; basic pneumatic, hydraulic, air-handling, and heat equations and their uses; sheet-metal design and layout; and the selection of bearings and gears. In-depth treatments of frequently encountered topics are also presented, including descriptive geometry statics and dynamics, the fundamentals of circuit design, electronic components, fabrication techniques, drives, and linkages and mechanisms. The book provides real-world examples and more than 500 detailed illustrations. The emphasis throughout the pages of



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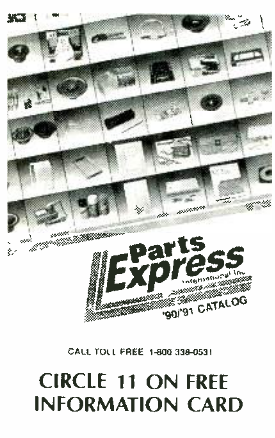
this handbook is on the practical design data needed in the day-to-day development of parts, mechanisms, and assemblies.

'90/'91 CATALOG; from Parts Express International Inc., 340 East First Street, Dayton, OH 45402; Tel: 513-222-0173; Fax: 513-222-4644; free.

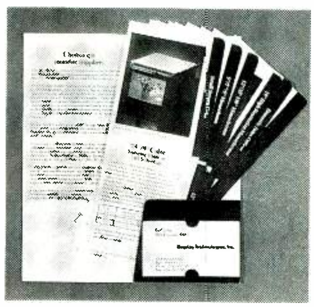
Packed full of electronic parts and accessories, this catalog will interest both professionals and hobbyists. In its pages are capacitors; resistors; speakers and accessories; semiconductors; connectors; wire and cable; TV, CATV, and VCR repair parts; technical books and schematics; alarm equipment; tools; chemicals; switches; and computer accessories. (Customers outside the U.S. and its territories must send $5.00 for postage to receive the Parts Express catalog.)



CIRCLE 11 ON FREE INFORMATION CARD

MONITOR POCKET GUIDE; from Display Technologies, Inc., 1355 Holmes Road, Elgin, IL 60123; Tel. 708-931-2100; Fax: 708-931-2120; free.

This 4 × 9-inch brochure contains complete information on 7½- and 9-inch color monitors and monochrome models that range in size from 5 to 21 inches. The guide includes easy-to-reference tabbed cards that list specifications such as CRT size, video and power inputs, horizontal

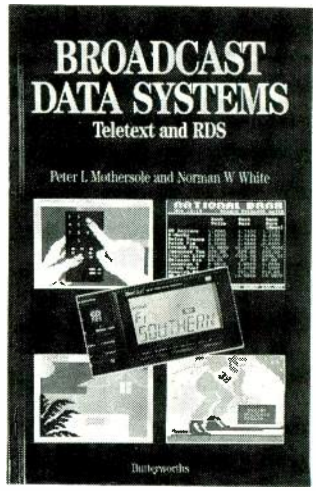


CIRCLE 12 ON FREE INFORMATION CARD

and vertical frequencies, and bandwidth, for each of Display Technology's products. Available options are also listed, and mechanical drawings of the products appear on the back of the cards. Highlighted in the brochure are the Color Pix.L monitors, which feature Sony Trinitron CRT technology. In addition, the pocket guide contains a listing of sales offices and guidelines for choosing a monitor supplier.

BROADCAST DATA SYSTEMS: TELETEXT AND RDS; by Peter L. Mothersole and Norman W. White. Butterworths, 80 Montvale Avenue, Stoneham, MA 02180; Tel: 617-438-8464; hardcover; $39.95.

Data transmission over TV and radio channels—commonly called teletext

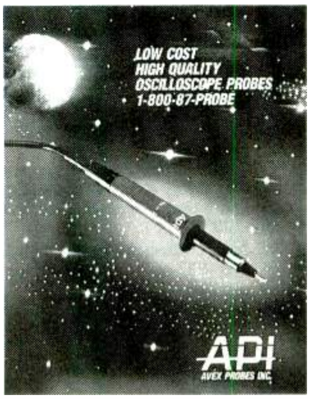


CIRCLE 13 ON FREE INFORMATION CARD

and Radio Data System (RDS), respectively—are becoming important aspects of modern broadcasting technology. This book covers both established television and radio practices and the computer technology that is used in the teletext and RDS systems. Background information concerning the development of teletext is presented, along with the data-signal format and coding methods used. The various components required to form a complete system are described. Other chapters cover such subjects as preparing and recording subtitles, the networking of teletext data signals and regional service requirements, teletext decoders, and the re-transmission of decoded teletext signals as a video signal. The measuring techniques required to maintain broadcast networks and to test decoders for both teletext reception and data distribution are described. The recent development of RDS, which allows digital data to be combined with a VHF radio signal, is discussed. The necessary techniques for both coding and decoding the signal are explained, and various applications are detailed—including the use of RDS to provide a local traffic-information service by interrupting network programming.

LOW-COST HIGH-QUALITY OSCILLOSCOPE PROBES; from Avex Probes Inc. (API), 1683 Winchester Road, P.O. Box 1026, Bensalem, PA 19020; Tel: 1-800-87-PROBE; Fax: 215-638-9108; free.

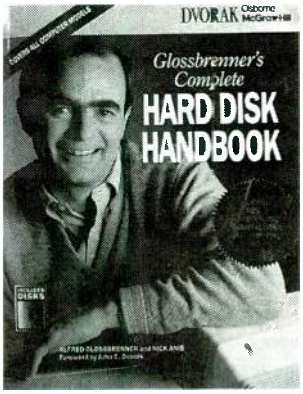
A variety of monolithic and modular oscilloscope probes are featured in this six-page brochure. Product descriptions are accompanied by photographs and specifications, and a handy cross-reference chart is included. Also highlighted in the catalog are a wide variety of probe accessories, and a 40-piece connector/adapter kit.



CIRCLE 14 ON FREE INFORMATION CARD

GLOSSBRENNER'S COMPLETE HARD DISK HANDBOOK; by Alfred Glossbrenner and Nick Anis. Dvorak Osborne McGraw-Hill, 2600 Tenth Street, Berkeley, CA 94710; softcover with diskettes; $39.95.

This encyclopedic volume is filled with clearly presented information on hard-disk drives for computer users of all levels of expertise. The book includes practical advice and convenient tips about selecting, buying, and installing a hard disk; loading and organizing the hard disk for maximum efficiency; restoration and recovery techniques; networking; and special formatting procedures. The first section of the book is dedicated to a "Quick-Start Guide" to get readers painlessly started using their hard-disk drives. The ins and outs of using DOS are explained in detail. The book describes how to avoid problems by following guidelines for maintenance, security, back-up techniques, and file recovery. Included with the book are two 5½-inch floppy disks that contain nearly 50 programs, including tutorials, software tools, and utilities. Money-saving coupons for many items are also provided in the back of the book. **R-E**



CIRCLE 15 ON FREE INFORMATION CARD

BUILD THIS BENCHTOP FREQUENCY COUNTER

Add frequency-measurement capabilities to your workbench with this inexpensive counter.

CARL BERGQUIST

THE INTERSIL ICM7216 frequency-counter IC's (models A–D) have an impressive array of functions. All have a high-frequency oscillator, decade time-base counter, 8-decade data counter and latches, 7-segment decoder, digit multiplexers, and 8-digit multiplexed LED-display drivers.

There are four models; the 7216A and 7216B are universal counters, capable of measuring input frequency, oscillator frequency, frequency ratio, period, and time interval, and can perform unit counting. The frequency counter discussed here uses the 7216C with a common-anode display (the 7216D is similar). It'll become one of the most versatile pieces of test equipment on your bench, and simply fun to use. You can build it for about $80.

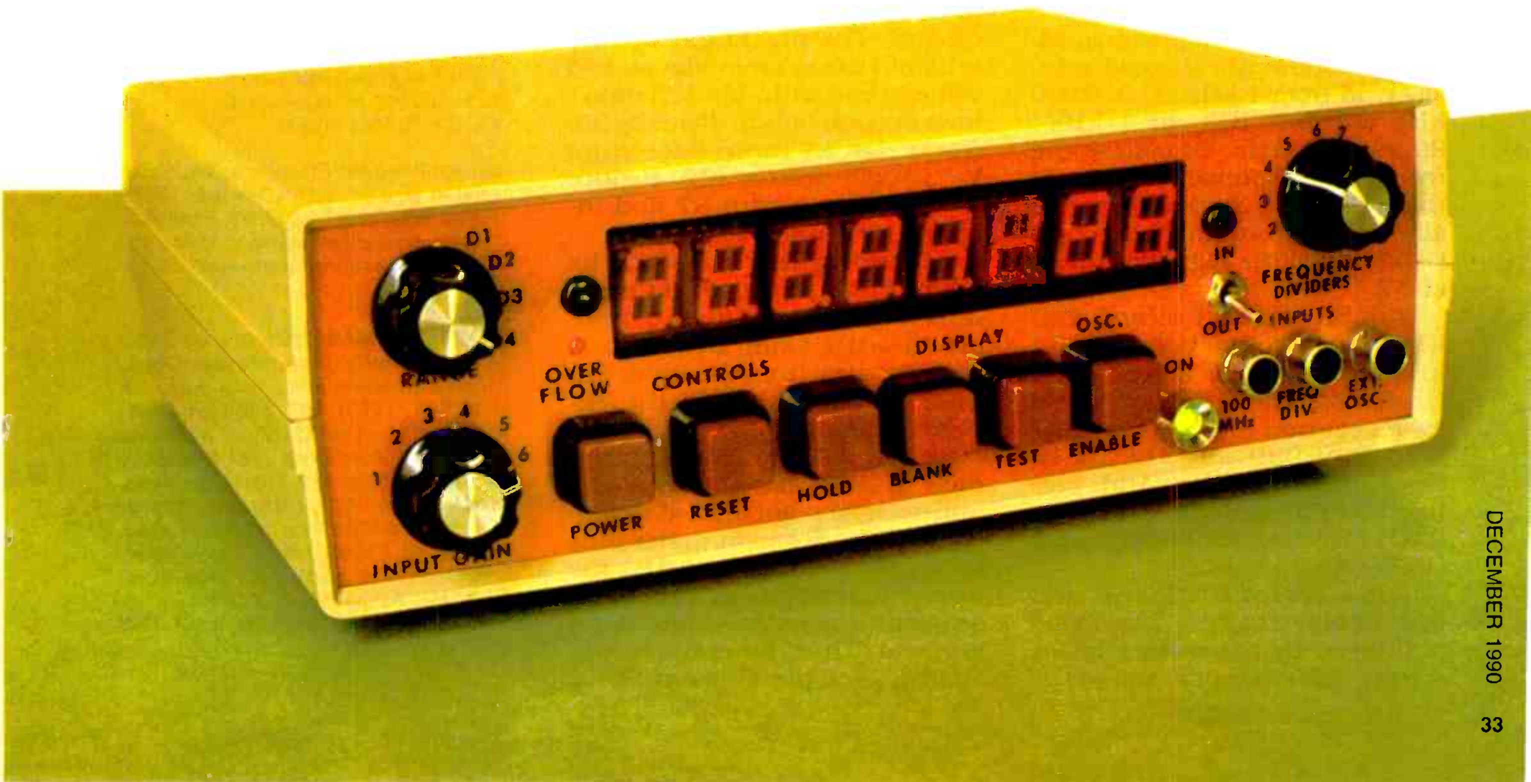
Circuit description

Figure 1 shows the pinouts for all four 7216 versions; the 7216A/B use two inputs for measurements like the ratio of two frequencies. The 7216C/D use single inputs, but have external decimal point (EX DP INPUT) inputs (pin 13), and MEASUREMENT IN PROGRESS outputs (pin 2).

The frequency counter schematic is shown in Fig. 2. IC2 decade counts the input frequency, stores the result in latches, drives an 8-digit multiplexed LED display, and blanks all leading zeros. While the internal oscillator normally uses 10-MHz crystal XTAL1, an external source can go on J3 to pin 24 of IC3 (EXT OSC INPUT). Some other 7216C features are display blanking, measurement holding, and display test-reset.

Since IC2 is designed for a maximum reading of 10 MHz, IC1, a 7490 decade counter, expands the range to 100 MHz by connecting pin 1 (B_{IN}) to pin 12 (Q_A) for the maximum count period. Pin 8 (Q_C) is tied to pin 28 (INPUT A) of IC2 for measurement. For more expansion, IC3, a CD4017 decade counter, is an adjustable divide-by-N.

As mentioned earlier, there are four ranges, and operation is possible with or without IC3. When S8 is set to OUT, IC3 isn't used, and the display reads 1:1, showing the actual undivided frequency of the input on J1 or J2 in kHz. Obviously, if the frequency of the input goes below the nominal minimum possible for any given range, the display will read zero.



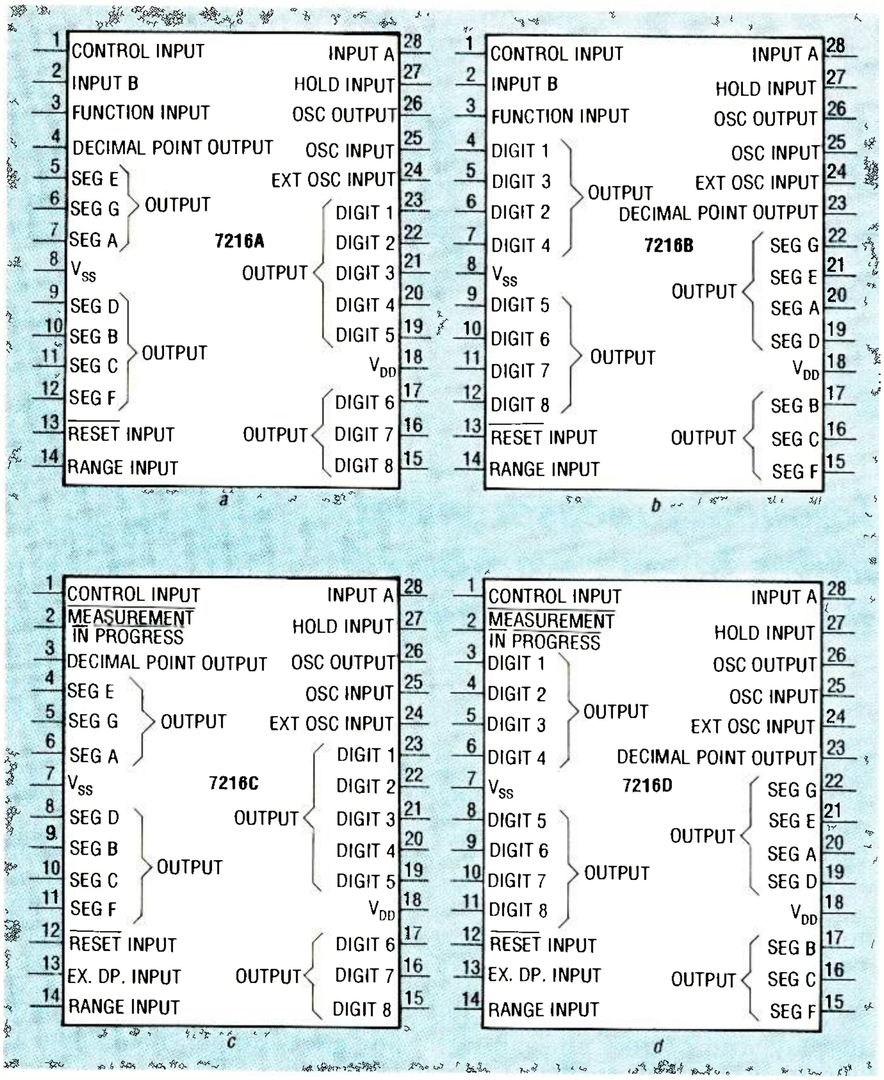


FIG. 1—THE PINOUTS OF ALL FOUR VERSIONS of the 7216. The 7216A/B both take two inputs, for measurements like the ratio of two frequencies, while the 7216C/D have single inputs.

If the frequency counter had adequate bandwidth, it could actually read from 1 kHz–99,999,999 kHz without IC3, or 1 kHz–99.999999 GHz. Of course the frequency response isn't nearly that good, and the counter actually works up to only about 1.8 GHz (using IC3), regardless of S6 or S7.

With S6 set to 0.1 second with IC3 out, the counter displays 0.1 kHz–9,999,999.9 kHz, or 100 Hz–9.9999999 GHz. Setting S6 to 1 second, it displays 0.01 kHz–999,999.99 kHz, or 10 Hz–999.99999 MHz. And, setting S6 to 10 seconds, it displays 0.001 kHz–99,999.999 kHz, or 1 Hz–99.999999 MHz.

If S8 is set to IN, IC3 is on, and the display reading has to be multiplied by the divider factor setting of S7 to get the actual frequency. The maximum divider ratio of 18 may seem like an odd value to end with, but IC3 didn't have enough taps to divide by 20. *Never* use an input exceeding V_{DD}; you'll destroy IC2. Reduce the input gain with R7 and increase for a stable reading.

Regarding DSP1–DSP4, the MAN6710 2-digit, 7-segment LED displays, the digit drivers are in order along the bottom, with the view from the front. Pin 14 is the digit driver for the left-hand digit, and pin 13 is for the right-hand digit. The left-hand digit in DSP4 has the segments and decimal point labeled for reference. The segment driver pins go on the left side in pairs; the former in each pair is a left-hand segment, the latter a right-hand segment. Thus, for example, pin 16 is A_L, and pin 11 is A_R.

PARTS LIST

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

R1—3300 ohms
R2—100,000 ohms
R3, R5—10,000 ohms
R4—22 megohms
R6—22,000 ohms
R7—500,000-ohm front panel potentiometer
R8—470 ohms
R9—1-megohm PC-board potentiometer
R10—1000 ohms

Capacitors

C1—100 pF, ceramic disc
C2—27 pF, ceramic disc
C3—6-50-pF PC-board trimmer
C4, C8—0.1 µF, ceramic disc
C5—3300 µF, 25-volt electrolytic
C6—1 µF, 10-volt electrolytic
C7—100 pF–1 µF PC-board trimmer

Semiconductors

D1–D4—1N914 diode
BR1—1.5-amp bridge rectifier
DSP1–DSP4—MAN6710, 2-digit, red, common-anode, 0.506-inch, 7-segment LED displays
IC1—7490 BCD counter
IC2—Harris 7216C frequency counter (Digi-Key ICM7216CIJI)
IC3—CD4017 decade counter
IC4—7805 5-volt DC regulator
IC5—555 timer
LED1—miniature red T-1 light-emitting diode
LED2—standard green, jumbo, diffused, T-1-¾ light-emitting diode

Switches

S1, S5—SPST momentary push button
S2–S4—SPST ON/OFF push button
S6—SP4T rotary switch
S7—SP9T rotary switch
S8—DPDT toggle switch
S9—SPST ON/OFF push button

Other components

J1, J2—RCA jack
T1—120-to-12.6-volt, 1.2-amp, AC power transformer
F1—1.5-amp fuse with holder
PL1—120-volt AC power cord
XTAL1—10-MHz crystal

Miscellaneous: Plastic cabinet (minimum size 8 × 6.25 × 3-inches, 7805 heat sink, bezel for LED2, 5-pin cabinet-mounted terminal strip, knobs, dry transfer lettering, hardware, solder, wire, etc.

NOTE: The MAN6710's are available from Quality Technologies Corp., 3400 Hillview Ave., Palo Alto, CA 94304, (415) 493-0400 or (800) 533-6786. The 7216C is available from Digi-Key Corp., 701 S. Brooks Ave., P.O. Box 677, Thief River Falls, MN 56701-0677, (218) 681-6674 or (800) 344-4539. The cabinet is available for $14.95, from Chaney Electronics, 932 North 94th Way, Scottsdale, AZ 85258, or P.O. Box 4116, Scottsdale, AZ 85261, (602) 451-9407 or (800) 227-7312.

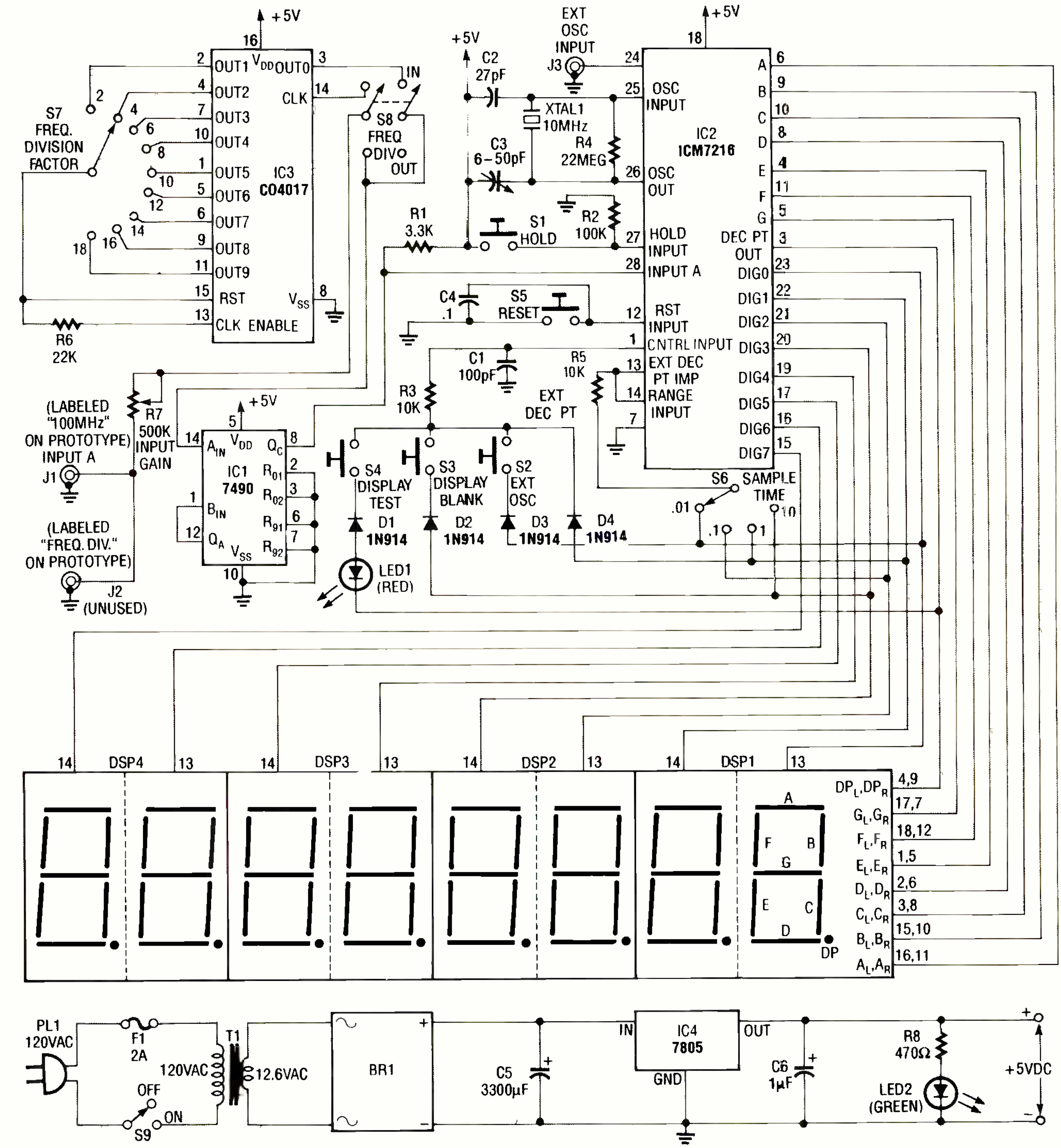


FIG. 2—THE FREQUENCY COUNTER SCHEMATIC; IC2, the 7216C, counts input frequency in decades, stores the result in latches, and drives an 8-digit multiplexed LED display, with leading zero blanking. While the internal oscillator normally uses with 10-MHz crystal XTAL1, J3 takes an external source. Other 7216C features include display blanking, measurement holding, and display test/reset.

Construction

The parts-placement diagram for the main PC board is shown in Fig. 3, and the display board is shown in Fig. 4; the foil patterns are also provided in this article. The prototype version omitted the power supply now incorporated in the main PC board. Use 18-pin DIP sockets for the LED-display PC board, and appropriate sockets for the main PC board. The wire groups for both the segments and the digits are indicated in both Figs. 3 and 4, and are omitted for clarity.

The Monsanto MAN6710's are 2-digit, 7-segment, multiplexed, common-anode LED displays; their pinouts are shown in Fig. 5. The B, D, F, and DP segments were connected by PC-board foils, and the A, C, E, and G segments using jumpers; the G jumpers criss-cross the display PC board as they progress. Use multi-colored wire to identify the various segments and digits; digit drivers D1–D8 go to the top of

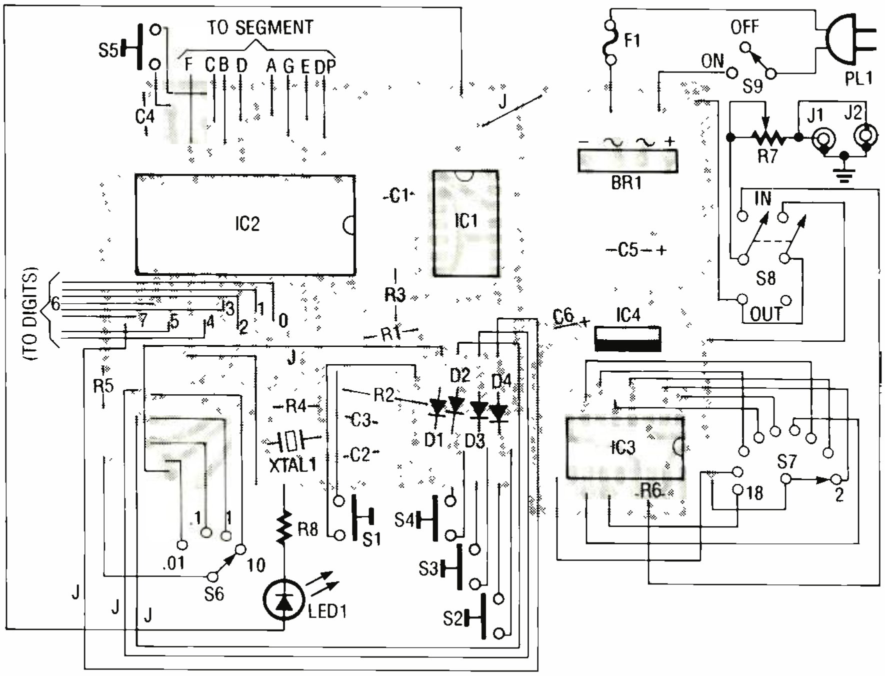


FIG. 3—THE PARTS PLACEMENT DIAGRAM for the main PC board. Use sockets for the IC's. The wire groups for both segments and digits are shown.

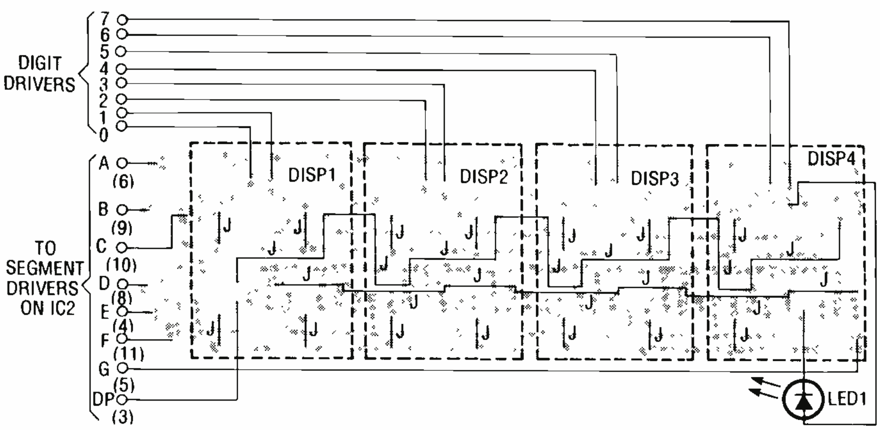


FIG. 4—THE PARTS PLACEMENT DIAGRAM for the LED-display PC board. LED1 goes on the right end of the PC board as shown, with the cathode tacked to the foil itself (not a pad), and the wire groups for the segments and digits are shown. Most jumpers don't have separate foil pads, and are tacked onto pads used for other wires.

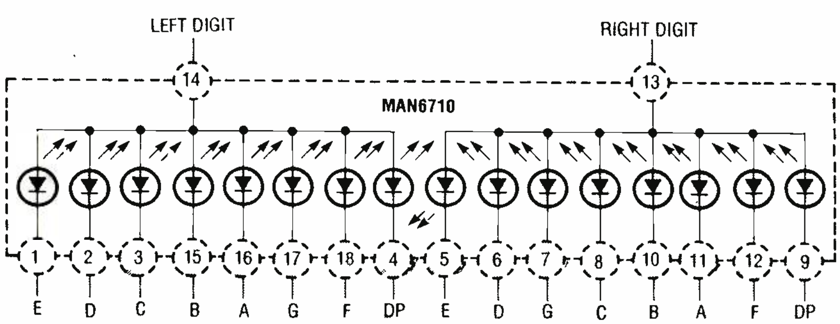


FIG. 5—PINOUTS FOR THE MAN6710 2-DIGIT, 7-segment, common-anode, multiplexed LED display.

the display board. Several jumpers must be tack soldered to the pads on the foil side of the display board.

The reason J1 and J2 are connected together is because in the prototype, the original plan (later abandoned) was to make a universal counter, needing two inputs to make full use of available IC functions. The parts distributor the 7216C was obtained from thought version C was a universal counter. By the time the mistake was discovered, the front-panel holes on the cabinet had already been drilled. To avoid an empty panel hole, dummy RCA jack J2 was placed there, in parallel with J1.

Although Fig. 2 indicates that J1 is the one that's actually used rather than J2, either was usable, but only one at a time. Obviously, you wouldn't need both jacks on yours, and should only drill one panel hole. The inputs on J1 and J2 were to have been "100 MHz" and "FREQ DIV," purely arbitrary titles stemming from personal preference. In the originally planned version, two 7490 decade counters were to have been used, one for each input. The finished frequency counter is shown in Fig. 6.

Figure 7 shows an overhead view with the top open. A 470-ohm resistor was installed for R8, slightly above the center on the left side of the main PC board, but never used in the prototype. Instead, another 470-ohm resistor was placed off-board, in series with LED2, behind where LED2 and its bezel fit into the front panel. The prototype really used four boards, but only the main and display boards had foils.

The IC4 heatsink is of sheet aluminum, bent to fit in the cabinet, with silicone grease used for good heat transfer, and C6 underneath. In the prototype, 24-pin DIP sockets were used. The rightmost piece was cut from a whole one, and has only six pins. Since the three sockets and the cut piece at right fit flush against one another, there's an unused hole between individual displays. To avoid cutting a socket, use 18-pin versions in yours. The 5-pin terminal strip is used as a feed point for the +5 volts from IC4.

Figure 8 shows a closeup view of the LED-display PC board from the foil side. Since three holes were needlessly drilled for J1–J3, there wasn't enough room left for S8, so a notch was cut in the lower left corner of the display PC board, clearly visible in Fig. 8. The wires to LED1 are at upper

FIG. 6—THE FINISHED FREQUENCY COUNTER, shown in display-test mode, with all digits and decimal points lit. J1 and J2 are wired together, but one is unnecessary (see text).

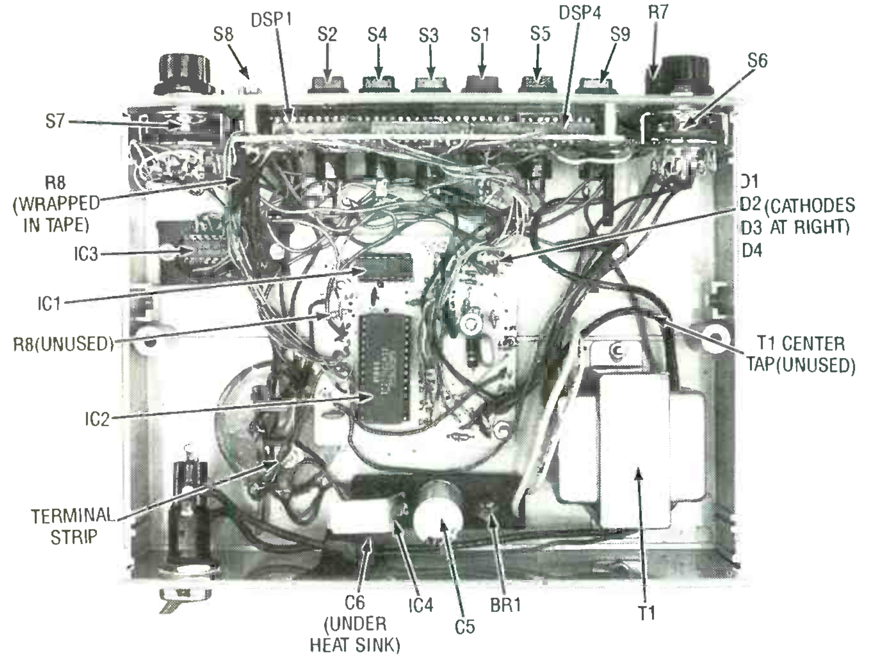


FIG. 7—AN OVERHEAD VIEW OF THE PROTOTYPE; R8 on the main PC board wasn't used. Another off-board 470-ohm resistor is in series with LED2, and IC3 and IC4 were later added to the main PC board. The IC4 heatsink is sheet aluminum with silicone grease; C6 is underneath. The prototype had three complete 24-pin DIP sockets for the LED displays, and part of another, with an unused hole between displays; use 18-pin sockets in yours. The markings shown on D2 and D4 are wrong; the cathodes all point right. The terminal strip is a feed point for the +5 volts from IC4.

right: normal polarity is reversed, with black going to the anode, and white to the cathode. Note the unused pads between individual LED displays, where they fit against one another on the component side.

The prototype cabinet is 8 ×6.25 ×3-inches; drill the front panel holes, and do the labeling before installing the switches, jacks, and display. Use dry transfer lettering with a light coat of clear enamel to prevent damage. The prototype has the labels of the digit drivers used on S6 for setting the display decimal point; instead, use the sample times shown in Fig. 2. Mount T1, anchor the PC boards, and check for wiring errors.

Power-up, test, and calibration

When you apply power, LED2 should glow. Press S4 (DISPLAY TEST), and the display should show all 8's and decimal points, and LED1 should light. If not, disconnect the power and recheck the wiring. With S8 in the OUT position, IC1 is off; set R7 for maximum gain, and apply a signal of known frequency no more than 5 volts in magnitude to J1 or

TABLE 1—IDEAL FREQUENCY COUNTER DISPLAY RANGES FOR ALL S6/S7 SETTINGS

Frequency Divider Setting (S7) / Sample Time Setting (S6), s	1	2	4	6	8
0.01	1–99,9999.999	2–199,999,998	4–399,999,996	6–599,999,994	8–799,999,992
0.1	0.1–9,999,999.9	0.2–19,999,999.8	0.4–39,999,999.6	0.6–59,999,999.4	0.8–79,999,999.2
1.0	0.01–999,999.99	0.02–1,999,999.98	0.04–3,999,999.96	0.06–5,999,999.94	0.08–7,999,999.92
10.0	0.001–99,999.999	0.002–199,999.998	0.004–399,999.996	0.006–599,999.994	0.008–799,999.992

Frequency Divider Setting (S7) / Sample Time Setting (S6), s	10	12	14	16	18
0.01	10–999,999,990	12–1,199,999,988	14–399,999,986	16–1,599,999,984	18–1,799,999,982
0.1	1.0–99,999,999.0	1.2–119,999,998.8	1.4–139,999,998.6	1.6–159,999,998.4	1.8–179,999,998.2
1.0	0.10–9,999,999.90	0.12–11,999,999.88	0.14–13,999,999.86	0.16–15,999,999.84	0.18–17,999,999.82
10.0	0.010–999,999.990	0.012–1,199,999.988	0.014–1,399,999.986	0.016–1,599,999.984	0.018–1,799,999.982

Note: The actual frequency response is limited to approximately 1.8 GHz for all S6/S7 settings; all values shown here in kHz.

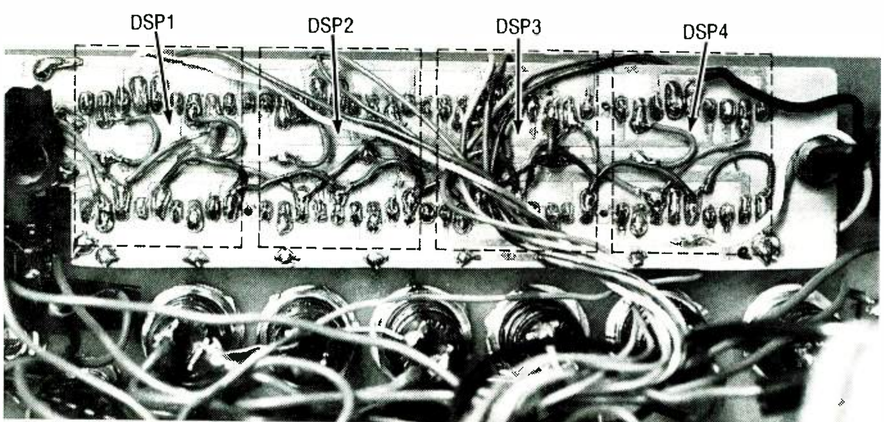


FIG. 8—A CLOSEUP OF THE FOIL SIDE OF THE LED-display PC board. Most jumpers go directly to the foil-side pads; there are no separate holes. Since holes were drilled for J1–J3, there wasn't room for S8, so a notch was cut in the lower left corner. The wires to LED1 (beneath the PC board) are at upper right, black to anode, white to cathode. The pads between the displays are unused, where they fit against one another on the component side.

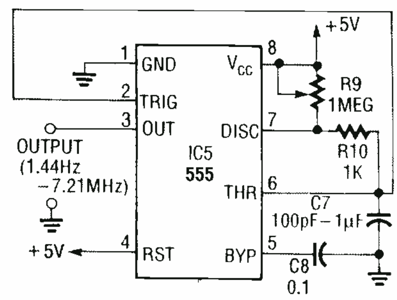


FIG. 9—AN OPTIONAL 555-TIMER ASTABLE square-wave generator for debugging the frequency counter. Both R9 and C7 are variable, to vary the output frequency from 1.44 Hz–7.21 MHz. The breadboard with this circuit on it appears in the lead photo.

J2 from a digital pulse generator.

Tune C3 until the display shows the same frequency as your standard, and the counter is calibrated. Switch S6 controls the number of digits of resolution following the decimal point. The frequency is in kHz, so 1 kHz on the 10-second setting of S6 should show up as 1.000. As you increase the sample time on S6, the accuracy increases but so does the measurement interval. On the 0.1-second setting, the reading is to one decimal place but takes only 0.1 second, whereas on 10.0-second setting, there should be three decimal places, but the sample time also increases accordingly.

The setting on S7 is the factor an input frequency is divided by. Thus, a 100-MHz signal reads 50 MHz on setting S7 to 2, 25 MHz on setting S7 to 4, etc. Conversely, 100 MHz on the display on setting S7 to 10 implies a 1-GHz input. S5 resets the display to zero, S1 retains a readout as long as needed, S3 just blanks the display, S2 introduces clocking from an external source on J3, and LED1 indicates overflow.

A simple astable multivibrator square-wave generator is shown in Fig. 9 for calibrating the frequency counter. Adjusting R9 and C7 will vary the output frequency from 1.44 Hz–7.21 MHz. **R-E**

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2600	1MHz 2.4GHz		•	•	•	± .2ppm add $ 80.
2210A	10Hz 2.4GHz	•				± .5ppm add $ 75.
1300H/A	1MHz 1.3GHz	•				± .5ppm add $ 75.

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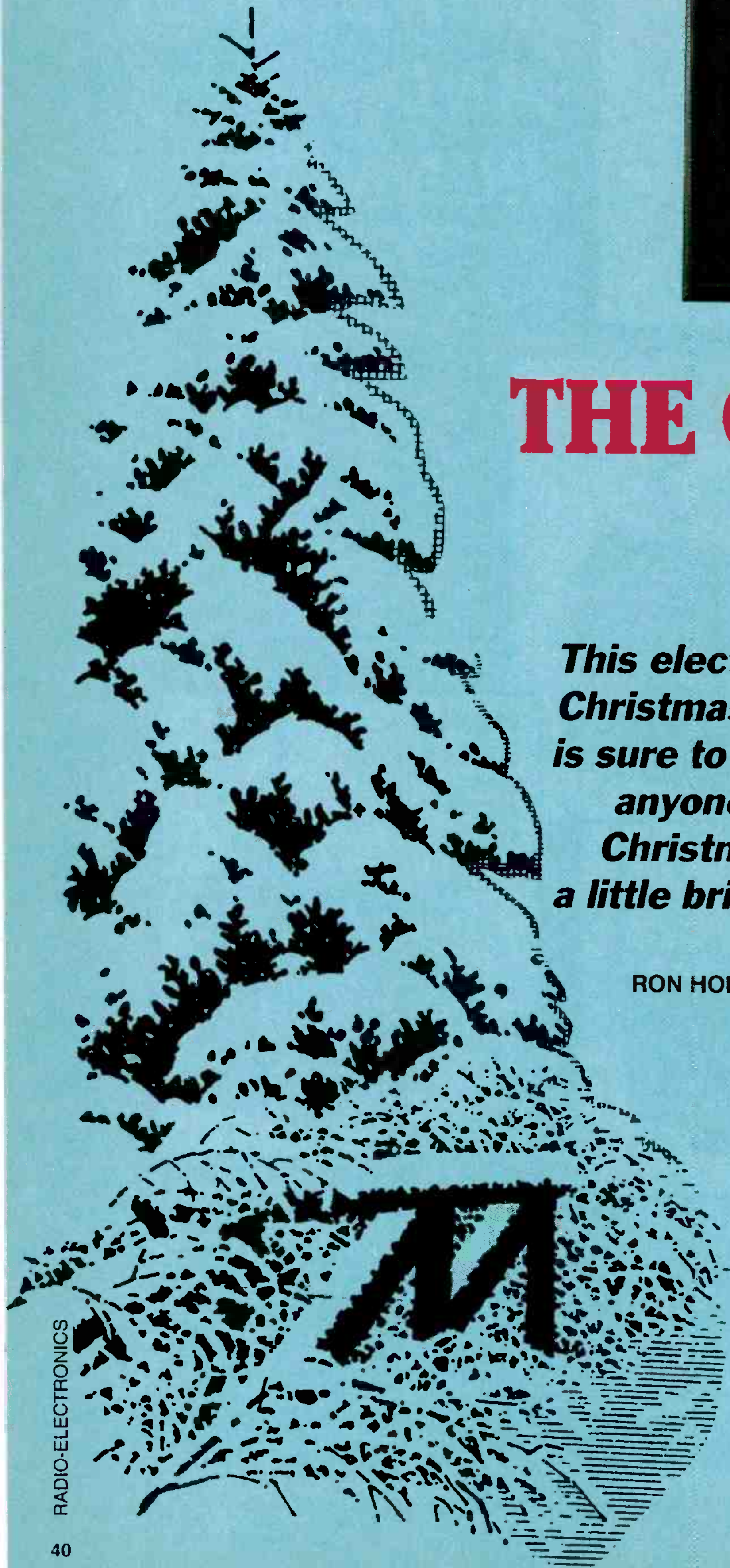


THE CHRISTMAS CARD

This electronic Christmas tree is sure to make anyone's Christmas a little brighter.

RON HOLZWARTH

HERE'S A PROJECT THAT YOU'LL BE happy to display in your front window this Christmas season—it also makes a great gift that anyone else would love to display in his or her window. The electronic Christmas tree is actually made from a printed circuit board with traces that form the branches of the tree. Different colored LED's mounted on the board simulate Christmas-tree lights. A built-in microphone picks up any audio signals—such as Christmas music—and different strings of LED's light according to the spectral distribution of the audio within a frequency band selected by the constructor. When installed in the custom metal frame, all of the electronics and the batteries are hidden behind the black mat and protected by the front glass. The end result is an attractive little Christmas tree whose lights will blink in unison with any kind of audio.

The photographs cannot convey the effect of the flashing lights, nor the vivid impression of seeing sound. Music becomes a quickly moving pattern of dancing lights. In fact, any sound becomes an interesting display as the microphone, which tops the tree, picks up any sound in the room. For the hearing-impaired, it opens up a new window to sound.

The project is also good for those who wish to learn about audio. For example, the tuning fork option only receives frequencies very near A440. But, it is hard to vocalize anything at any pitch without generating a display. In fact, singing notes far lower than A440 generates various displays. In addition, inflections, such as the rise in pitch that usually accompanies the conclusion of a question, are quite visible.

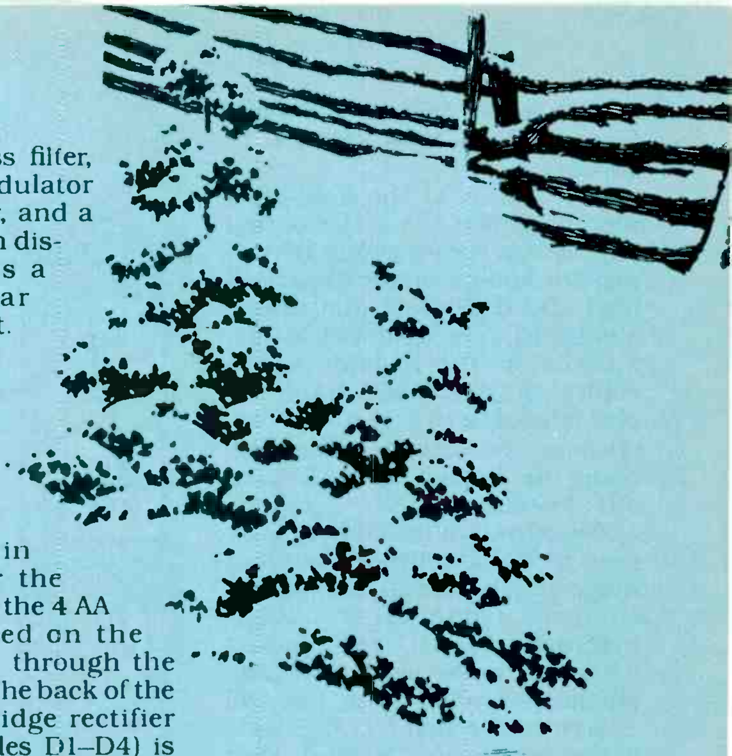
The unit is powered from four AA batteries, although an AC adapter jack is also included so that battery power can be conserved. It is a good idea to use an AC adapter whenever possible, as battery life is limited to about eight hours, depending on the volume level of the audio signal (more or less LED's will light), and the options selected.

The strings of LED's can be more accurately thought of as bar graphs. The device includes an amplitude-discrimination circuit that selects the harmonics of greatest amplitude and displays those harmonics in bar mode, at which time all others are in dot mode.

An interesting experiment would be to interface the board with other circuitry. The outputs of the drivers are TTL- and CMOS-compatible. Since most LED posts can be wire-wrapped, wiring selected outputs to an input port is easy. The device can then function as a front end to allow your computer to monitor sound waves without the complexity of digital filtering. The outputs can also be used to operate relays, allowing lights of any power level to be used.

Circuit operation

Although the circuit may at first seem complicated, it really isn't. Figure 1 shows a block diagram of the circuit. Signals from the microphone are amplified, filtered, and automatically adjusted for gain in the automatic gain control (AGC) section. The sections that follow are duplicated four times. All four sections are identical except for the frequencies that they handle. Each section has a level-adjust potentiometer, a bandpass filter, level shifter, demodulator and discriminator, and a display driver. Each display driver drives a separate LED bar graph at the output. Three of the bar graphs (A–C) contain ten individual LED's, and one of them (D) contains twenty.



Let's take a look at the schematic in Fig. 2. Power for the unit is supplied by the 4 AA batteries mounted on the board or supplied through the power jack (J1) on the back of the board. Since a bridge rectifier (consisting of diodes D1–D4) is used, DC of either polarity can be used, as well as AC. The batteries are disconnected whenever a plug is in the power jack.

Two large electrolytic capacitors, C19 and C20, damp any transients caused by power surges when a large number of LED's are lit. A voltage divider is formed by IC14, an LM336-2.5, which operates much like a Zener diode, but without nearly as much variation in reference voltage. The device has three terminals, and physically looks like a transistor. However, the third terminal is not needed in this application, so the device is drawn in the schematic as a Zener diode. The reference voltage from IC14 is divided and then wired to op-amp IC1-c which is in a buffer configuration. The output of IC1-c (pin 8) then serves as an analog ground for later portions of the circuit.

The output from the electret microphone (MIC1) appears as an AC waveform. It is amplified by IC1-b, which is configured as a non-inverting amplifier with an adjustable gain set by potentiometer R8.

The next stage is a bandpass filter (IC1-a), which selects the frequencies to be used by later portions of the circuit. Following the initial filter is the AGC that limits the signal when the output reaches approximately 1.1 volts peak-to-peak. The gain will increase slowly during periods of silence, reaching maximum sensitivity after approximately three seconds.

The AGC section consists of op-amp IC1-d configured as a non-inverting amplifier. When the output of IC1-d increases, Q2 turns on and allows a small amount of current to flow into C4. That will raise the gate voltage of Q1, effectively lowering the resistance of R12, thus decreasing the gain of the amplifier as a whole. In the rest of the discussion, only one filter (filter A which controls bargraph A) will be described, as the others are identical except for a few resistor values.

A level-adjust potentiometer (R17) is next, followed by a buffer (IC2-a). As the potentiometer setting is increased, the amplitude of the filter output increases, causing more LED's to light at the output.

The stage that follows is nothing more than a summing amplifier. The input signal is summed with a portion of the output from the filter that follows. With a little positive feedback from the filter output, the Q is increased. Within the feedback network is another filter which has a resistive divider attached to it that causes it to act as a unity-gain filter.

The next section is the level shift, which is necessary since the output of the filter appears as an oscillation about the analog ground. The display drivers require an input measured from true ground, hence the level shift section is needed to amplify the output as well as lower the waveform so that it is relative to ground.

The output of the level-shift section, which is a series of half sine waves, goes through D7 to a resistor and capacitor in parallel (R61 and C14). Note that this is similar to a conventional AM demodulator. The resistor values control the rate at which the display falls back to a zero state. Increasing the resistor values will make the display fall back (turn off) at a slower rate.

The output of the demodulator goes to the amplitude discriminator, which is an op-amp configured as a comparator. Germanium diode D11 will conduct whenever one of the filter outputs reaches 0.2 volts. Thus, C18 will charge and remain at 0.2 volts below the highest DC level. That causes the comparator for the filter output of the highest DC level to switch its output to a high state. That output connects to the control input of one section of a 4066 bilateral switch which connects power to pin 9 of the corresponding LED driver putting it in bar mode.

Resistor R65 is of a much larger value than R61–R64. Thus, when the filter output begins to decrease, the driver returns to dot mode and does not go back to bar mode until the output increases. The time constant is set so that the voltage has significantly decreased in about one second, so the rhythm of the music is displayed as the LED's shift to bar mode at each beat. Varying the RC time constant will make the device operate differently.

Bargraph D is driven by two drivers (IC12 and IC13) stacked end-to-end. They are made to function exactly as the others as far as the dot-to-bar mode transition is concerned. The display drivers (IC9–IC13) control the lighting of the LED's according to the input voltage. A databook should be consulted if you wish to know more about the operation of the display drivers.

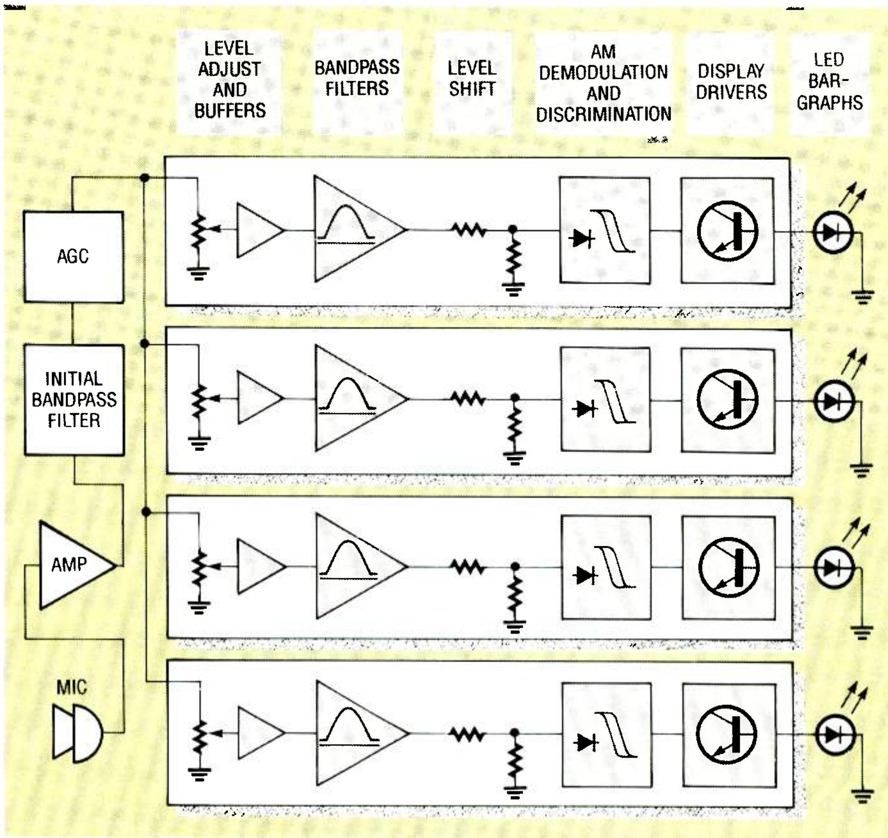


FIG. 1—BLOCK DIAGRAM OF THE CIRCUIT. Signals from the microphone are amplified, filtered, and automatically adjusted for gain.

Filters and Q

The Q of a filter defines how narrow the passband is. It is equal to the center frequency divided by the difference in frequency between the −3-dB points. The −3-dB frequency is the frequency at which the peak-to-peak voltage is attenuated by one half from that at the center frequency, assuming a constant voltage at the input.

Assuming we want a center frequency of 440 Hz, which is the American tuning standard for musical instruments, and we want A flat (415.3 Hz), one half step down, to be a −3-dB frequency, and A sharp (466.16 Hz), for the other −3-dB point, 440/(466.16 − 415.3) = 8.65. That would be the Q required for an attenuation of one half when stepping up or down one key on a piano.

Interestingly enough, the same Q is required to accomplish that across the entire keyboard. This is a necessary consequence of our tuning scale, which is now defined as the twelfth root of two multiplied repeatedly at each step. A logarithmic scale was thus developed by musicians centuries before mathematicians had opened their eyes, so to speak—17/18 has been used for the approximation of this factor, which results in an error of less than one percent. It has been used for the construction of guitars and similar stringed instruments for over three hundred years.

The Delyiannis-Friend bandpass filter (the type used in this project) was first described by T. Delyiannis in 1968. It has a number of advantages over some other filters, such as reduced sensitivity to component tolerances, minimal parts count, and a relatively easy-to-understand design algorithm. It has been described as a bridged-T RC circuit with an op-amp to provide negative feedback.

There are only two parameters needed to design a bandpass filter. They are the center frequency desired for the passband, and the Q, or quality factor. The bandpass filter in its simplest configuration is shown in Fig. 3. That filter has a bandpass center frequency of $1/2\pi$ Hz. The first step in designing is to assign numerical values—that is, substitute the Q required. Assuming a Q of 4, $1/2Q = 0.125$, and $4Q^2 = 64$.

After assigning numerical values for each of the components, the filter is scaled up in frequency by dividing the capacitor values

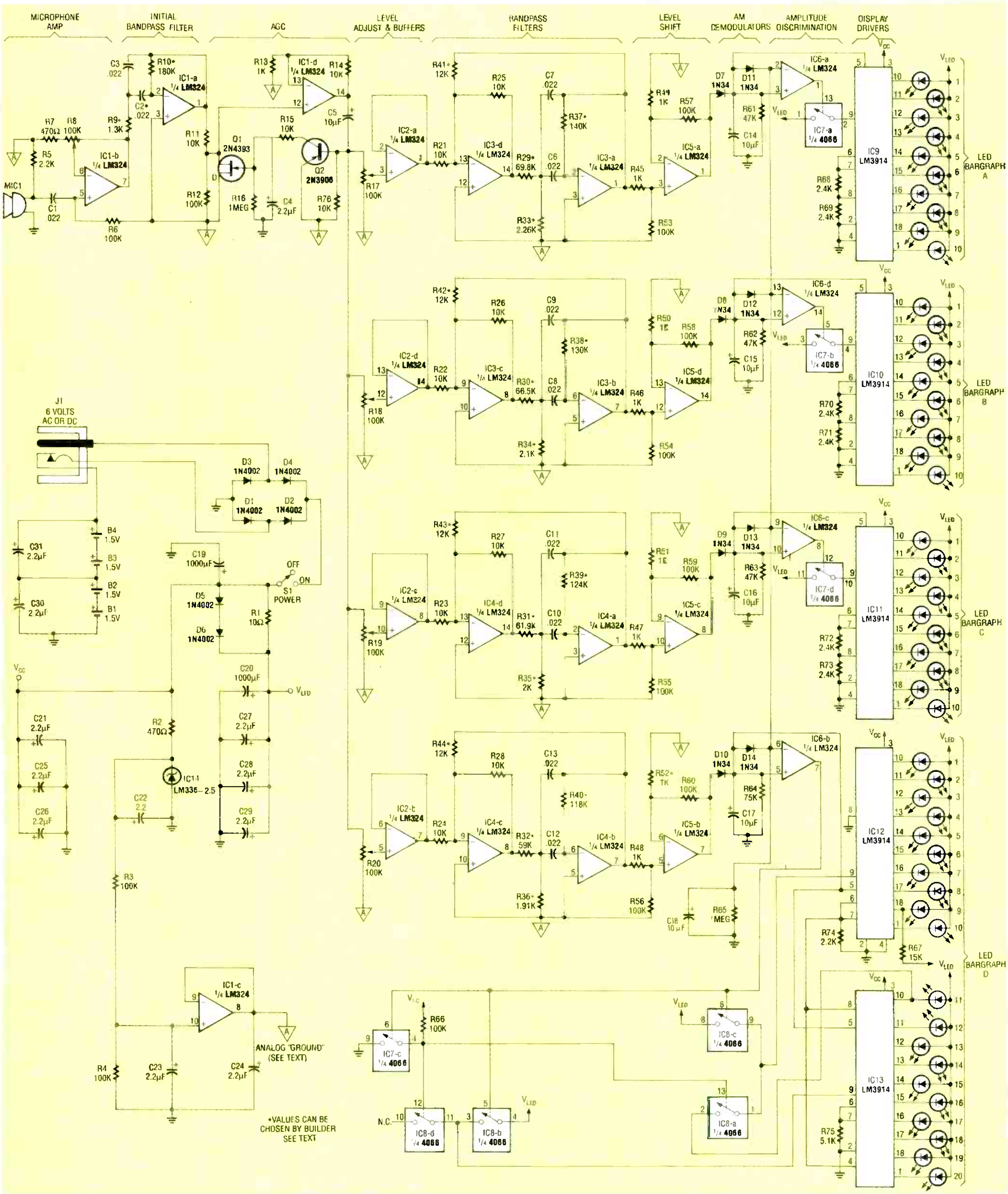


FIG. 2—CHRISTMAS TREE SCHEMATIC. Power for the unit is supplied by the 4 AA batteries or via the power jack on the back of the unit.

by the difference in frequency required. Assume the frequency required is 440 Hz. The difference in frequency required is equal to:

$$f_{NEW}/f_{OLD} = 440/(1/2\pi) = 880\pi$$

The capacitor value (0.125 F) is then divided by this number, giving 4.52×10^{-5}, the new capacitor value for our filter.

The next step, scaling to realistic values, is best described by an analogy. In an RC network, the time constant remains unchanged if the capacitor value is divided by any constant, just as long as the resistor values are multiplied by the same constant.

PARTS LIST

All resistors are ¼-watt, 5%, unless otherwise indicated.
R1—10 ohms
R2, R7—470 ohms
R3, R4,R6, R12, R53–R60, R66—100,000 ohms
R5, R74—2200 ohms
R8, R17–R20—100,000 ohms, multiturn potentiometer
R9, R10, R29–R44—option dependent, see text and Table 1
R11, R14, R15, R21–R28, R76—10,000 ohms
R13, R45–R52—1000 ohms
R16, R65—1 megohm
R61–R63—47,000 ohms
R64—75,000 ohms
R67—15,000 ohms
R68–R73—2400 ohms
R75—5100 ohms
Capacitors
C1–C3, C6–C13—0.022 µF, 5% metal film
C4, C21–C29—2.2 µF, tantalum
C5, C14–C18—10 µF, tantalum
C19, C20—1000 µF, electrolytic
Semiconductors
IC1–IC6—LM324 quad op-amp
IC7, IC8—CD4066 quad bilateral switch
IC9–IC13—LM3914 bar/dot LED driver
IC14—LM336Z-2.5-volt reference
Q1—2N4393 or 2N3972 MOSFET
Q2—2N3906 PNP transistor
D1–D6—1N4002 rectifier diode
D7–D14—1N34 germanium diode
Bargraph1–Bargraph4—50 LED's, assorted colors (3 groups of 10, 1 group of 20—see text)
Other components
MIC1—1-volt PC-mount electret microphone
J1—coaxial barrel-type power jack (Shogyo SJ-0202)
S1—C&K 7000-series right-angle SPDT switch
B1–B4—AA battery
Miscellaneous: PC board, two battery holders (Keystone 2223), metal frame and cover glass, six ⅝-inch spacers, solder, a bit of Christmas spirit, etc.
Note: The following is available from ART WORKS, Box 753, St. Francis, Kansas 67756: PC board, $35 each (three or more, $30 each); Partial kit, including PC board, all components including S1, J1, battery holders, and all 1% resistors listed (does not include LED's, frame, or spacers), $90 each (three or more, $80 each); Complete kit, including all of the above, plus 50 LED's in four colors, spacers, flat-black metal frame, front glass and mat, $125 each (three or more, $100 each). All prices include shipping and handling. Check or money order only. Please order early—we will do our best, but cannot guarantee delivery in less than 30 days. When making technical inquiries please include a SASE.

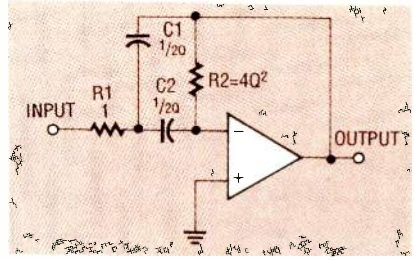


FIG. 3—A BANDPASS FILTER in its simplest configuration. It has a bandpass center frequency of 1/2π Hz.

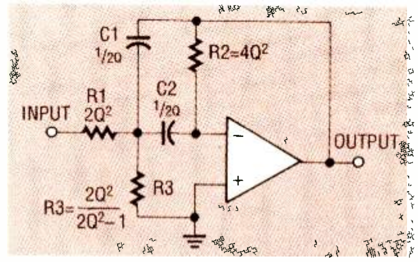


FIG. 4—WHEN DESIGNING a unity-gain filter, a voltage divider must be added to the input.

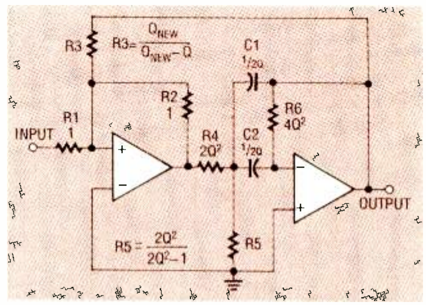


FIG. 5—TO RAISE THE Q, positive feedback is added to the filter input.

The same concept happens to be true in an op-amp filter. That is, the center frequency (and Q) will be unchanged when this step is taken.

A capacitor value of 0.022 µF results in realistic component values across the entire audio band, provided the Q is not too high. So, since the capacitor values will all be 0.022 µF, we can divide 4.52×10^{-5} by 0.022×10^{-6}, resulting in 2,055. Both of the resistor values in Fig. 3 are then multiplied by that constant, resulting in 2,055 and 131,533 kilohms.

At this point, it is a good idea to check your work. The values just obtained should be substituted into the following equation:

$$f = 1/2\pi C\sqrt{R1R2}$$
$$= 1/2\pi(0.022 \times 10^{-6} \times \sqrt{2.055K \times 131.533K})$$

The result should be the original frequency. That equation can also be used to check the variance in center frequency when standard component values are substituted, or to analyze an already existing filter.

In designing a unity-gain filter, a voltage divider must be added to the input, as shown in Fig. 4. Since the new R1 is one half of R2, that value is easy to calculate. For the new R3, the factor

$$2Q^2/2Q^2 - 1 = 2(16)/2(16) - 1$$
$$= 1.032$$

is then multiplied by the old R1, resulting in 2121.5.

To raise, or enhance the Q, positive feedback is added to the filter input, as in Fig. 5. The values for R1, R2, and R3 of Fig. 5 do not need to have the same scale factor as used before. A fine value for R1 and R2 is 10K; R3 will then be

$$10K(Q_{NEW}/Q_{NEW} - Q)$$

or, for our example,

$$10K(Q_{NEW}/Q_{NEW} - 4)$$

where Q_{NEW} is the desired Q of the complete filter. The last step is to determine the closest standard value for each resistor.

There are four versions of the unit that can be built without having to make any calculations. The four versions are the broadband option, the lower-four-guitar-strings option, the upper-four-guitar-strings option, and the tuning fork option. The tuning fork option is a good general-purpose version that will provide a nice display with most audio inputs.

To use any of those options, you must refer to Table 1; it shows the resistor values you'll need to use for the four filters to achieve the specified frequencies. Also, depending on which option you choose, the initial bandpass filter must be set up accordingly.

To use Table 1, first refer to the top section to determine the resistor values for the initial bandpass filter, the other four bandpass frequencies, and any special provisions for the particular option. Then, from the bottom section, determine the resistor values for the other four filters according to the frequencies listed in the top section. The resistor numbers shown (R29, R33, and R37) are for filter A. For filter B, add 1 to the resistor number (for example, R29 becomes R30, etc.). For filter C, add 2 to the resistor number, and for filter D, add 3.

Although you can assign any of the four frequencies to any of the four filters, the display will be most interesting if you use the lowest frequency for filter A, next highest for B, and so on. Note that where it says to delete a component, you should leave it out but DO NOT jumper the pads on the board. Where it says to jumper a component, you should leave it out and solder a jumper between the pads.

Construction

If you like, you can etch your own PC board since the foil patterns for the double-sided board are provided. However, an etched, drilled, plated-through, and silkscreened board is available from the source mentioned in the parts list. Keep in mind that the cosmetic effect of the green mask, silver branches, and white snow will be lost if you make your own board. Locating the components for installation is also easier using the pre-made silkscreened board. Complete and partial kits for the Christmas tree are also available.

Before beginning construction, you have to decide on how you want your LED's arranged. The author's intention was to make each detected harmonic a separate color. However, you are free to arrange the LED's in any pattern you choose, and you can also use whatever colors you like. In any case, the silk screening on the pre-made board indicates which bar graph each light belongs to; there are short white lines between the LED leads. The lines going up (from left to right) are for bargraph A, the horizontal lines are for bargraph B, and the ones going down (from left to right) are for bargraph C. Bar-

TABLE 1

Lower Four Guitar Strings Option: (E3, A3, D4, G4)
Initial Filter Q = 1.5 — Center Frequency = 270 Hz
R9 = 9.1K — R10 = 82K — R41–R44 = 11K

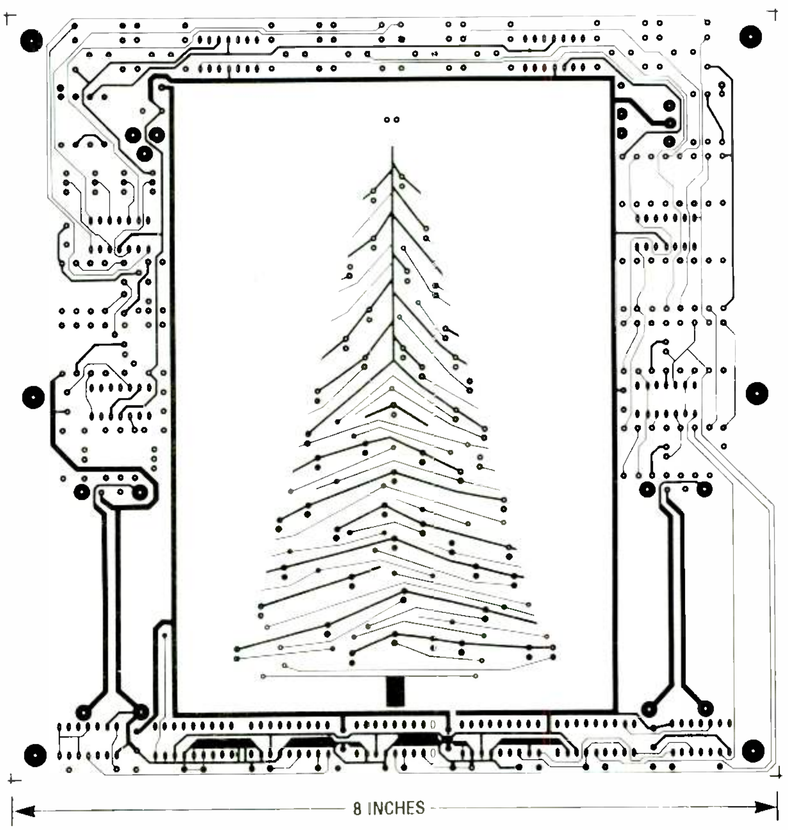
Upper Four Guitar Strings Option: (D4, G4, B4, E5)
Initial Filter Q = 1.5 — Center Frequency = 470 Hz
R9 = 5.1K — R10 = 47K — R41–R44 = 11K

Tuning Fork Option: (A4 flat, A4, A4 sharp, B4)
Initial Filter Q = 5.8 — Center Frequency = 470 Hz
R9 = 1.3K — R10 = 180K — R41–R44 = 12K

Broadband Option: (E2, A3, B4, F6 sharp)
(Jumper C2, delete C3)
R9 = 1K — R10 = 100K — delete R41–R44

Note	(frequency)	R29	R33	R37
E3	(164.81 Hz)	174K	5.62K	348K
A3	(220 Hz)	133K	4.22K	261K
D4	(293.66 Hz)	97.6K	3.16K	196K
G4	(392 Hz)	73.2K	2.37K	147K
A4	flat (415.3 Hz)	69.8K	2.26K	140K
A4	(440 Hz)	66.5K	2.10K	130K
A4	sharp (466.16 Hz)	61.9K	2K	124K
B4	(493.88 Hz)	59K	1.91K	118K
E5	(659.26 Hz)	44.2K	1.40K	88.7K
E2	(82 Hz)	11K	delete	680K
A3	(220 Hz)	4.22K	delete	261K
B4	(493.88 Hz)	1.8K	delete	118K
F6	sharp (1480 Hz)	620 ohms	delete	39K

NOTE: All versions except the broadband option require 1% resistors.



COMPONENT SIDE of the Christmas tree at half the actual size.

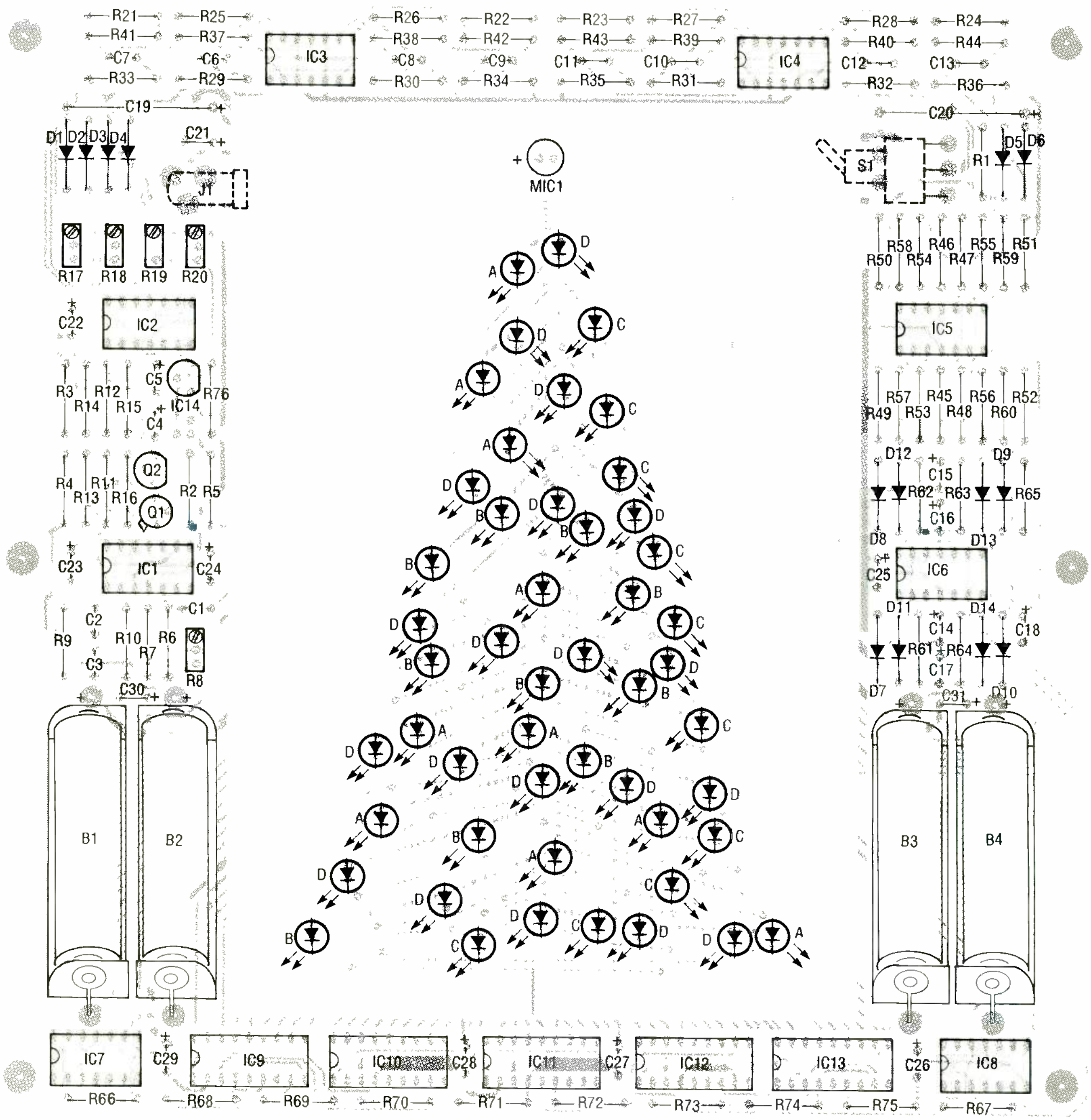


FIG. 6—ALL OF THE COMPONENTS mount on the front of the board, with the exception of J1 and S1; they mount on the solder side. Use a separate color for each LED bargraph.

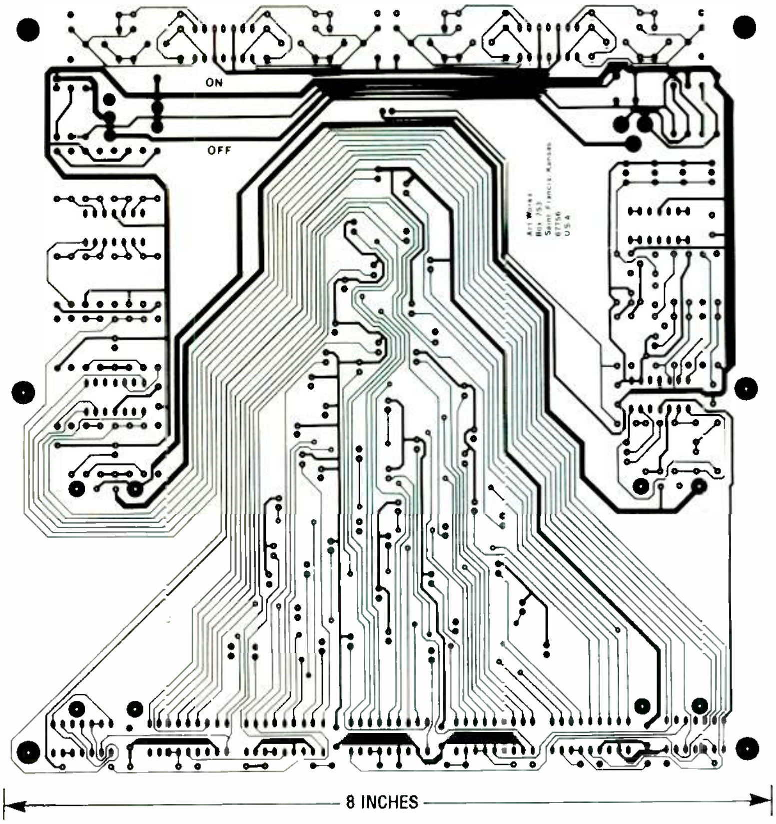
graph D is indicated by the absence of a short white line.

When installing the components, start with the LED's, as shown in the parts-placement diagram of Fig. 6. The letters next to the LED's indicate which bargraph they belong to. You should probably spend a minute or so looking at how the LED's are arranged on the printed circuit board because, once the device is assembled, the pattern becomes very confusing and the short white lines are covered by the LED's.

The LED's are installed with the cathode (the flat side) toward the bottom of the board. It's best to first solder one lead of each LED and then check for uniform positioning. Straighten them out where necessary, and then solder the other leads. Remember, that if you want to interface your tree to other circuitry later on, to leave enough extra lead on the back of the board to allow a wire-wrap connection to be made. Be sure to work carefully, so that you'll be able to bring out this project for many a Christmas to come. If you install all the components properly, it's very likely that the device will operate correctly right off the bat.

From the photo in Fig. 7, you can see the six spacers that are installed on the board to hold it in place within the metal frame. It's a good idea to install the spacers now, since they will protect the LED's from being damaged and can also support the board steadily. Now continue installing the rest of the components on the board.

You must now decide what fre-



SOLDER SIDE of the Christmas tree at half the actual size.

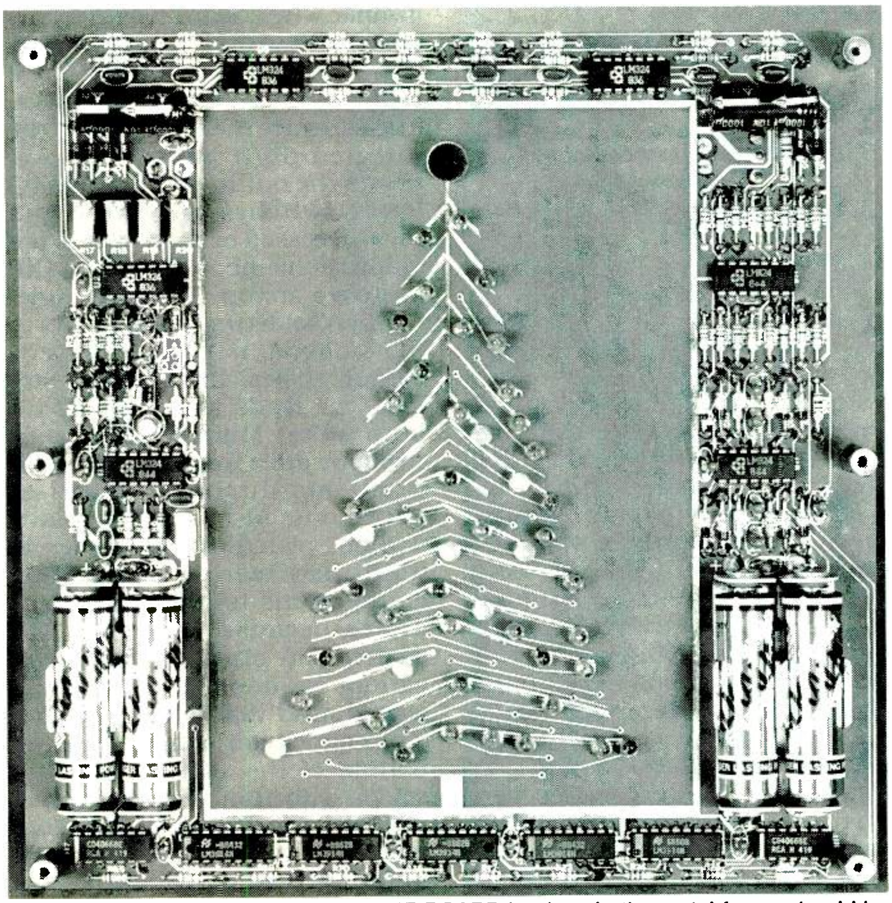


FIG. 7—THE SPACERS THAT HOLD THE BOARD in place in the metal frame should be installed early to prevent damage to soldered components.

quencies your Christmas tree will respond to. If your device is to be an assistance to the hearing-impaired, the broadband option will be the best, as both low frequencies and the high pitch of a police siren will be detected. For a musical version, you will have to make a decision based on your instrument of choice. Perhaps you can consult with a musician friend on this. You can re-tune the device at any time by simply changing a few resistors. All the components required for each suggested version are included in the kit. Remember that the initial filter must be "in harmony" with the other filters. They cannot detect frequencies that the initial filter doesn't pass. Refer to Table 1 when choosing frequency determining resistor values, or you are free to calculate your own values.

A word to the wise: put a set of batteries in the holders before soldering them. If you don't, the contacts on the battery holders are too close together which makes battery changing extremely difficult. Also, remember that the ON/OFF switch and the DC power jack mount on the solder side of the board as indicated by the dashed lines in Fig. 6.

Checkout

After checking for incorrectly installed components, poor solder joints, and shorts, and making sure to correct any problems, install a set of batteries or connect a 6-volt power source to the power jack. Turning the power switch on will cause many of the LED's to light. After which point, they will step down to position one, then go out. This is normal operation as the device approaches steady state. Slowly increase the gain of the initial amplifier by turning R8 clockwise. Go back and forth between one of the level-adjust potentiometers and R8, increasing them a little bit each time until one of the bargraphs responds to the sound of your voice. Make sure that none of the potentiometers are set too high, as troublesome oscillations may occur.

Alternatively, connect a voltmeter to the junction of R15 and R16 and increase the setting of R8 until speaking directly into

continued on page 90

BUILD THIS TELEPHONE CALL SCREENER

LAST MONTH WE COVERED ALL OF the operating theory concerning the CallScreen unit. This month we will finish up the story by building the unit.

Get ready to give out your access codes, but only to the people who you want to hear from!

JOHN G. KOLLER

Construction

Construction of the CallScreen essentially involves stuffing the two PC boards: the main board and the front-panel board. The use of PC boards with plated-through holes will greatly ease and speed up the assembly.

The main PC board includes circuitry for the call routing adapter (CRA). The parts-placement diagram for the main board is shown in Fig. 3. If that feature is not going to be used, the CRA corner of the PC board can be removed with a hack saw. Then the ringer transformer can be placed in the cutout space. That will result in a very compact unit if a wall-type power transformer is used. Also, the CRA can be connected as an outboard unit in its own project box; all you have to do is make the nine connections to the main board. You can combine CRA switches S101 and S102 into a single DPDT center-off toggle switch.

The telephone input/output connections to the main board are made using a standard telephone extension cord cut in half, with the cut ends soldered directly to the main board. That makes it easy to place the CallScreen out of sight. The CRA jacks, however, are mounted directly to the PC board. All parts on the main board are mounted on the component side.

The parts-placement diagram for the front-panel PC board is shown in Fig. 4. All parts mount on the component side of the board with the exception of the six DIP switches and the two screen-status indicators (LED1 and LED2); those parts mount on the solder side so they can protrude through the front-panel cutouts (see Fig. 5).

The builder may wish to simplify both the assembly and cutting out the front panel by eliminating the six DIP switches. You can simply hard wire your selected codes during assembly. Future code changes could be made but would require moving jumper wires. Hard wiring of access codes is done by soldering a 2-inch wire to the common foil of each of the six DIP-switch traces. The wires are then soldered to the selected digit pads. Figure 4 shows the outline of the code-selector switches and the digits (1–9) accessed by each switch position. Remember that as the DIP switches are on the solder side.

When soldering components to PC boards without plated-through holes, always make sure that the leads are soldered on both sides. Missed solder connections are a frequent source of problems during the initial check out. Also, if a PC board without plated-through holes is used, hard wiring of the code connections is recommended. That's because, with the DIP switches in place, top soldering cannot be done. However, one way around that is to use adhesive copper foil attached to the bottom of the switch body and soldered to the common row of connections. The end of the copper foil is then brought out from under the end of the switch and connected to the common foil. A copper pad without holes is provided on the foil for this purpose.

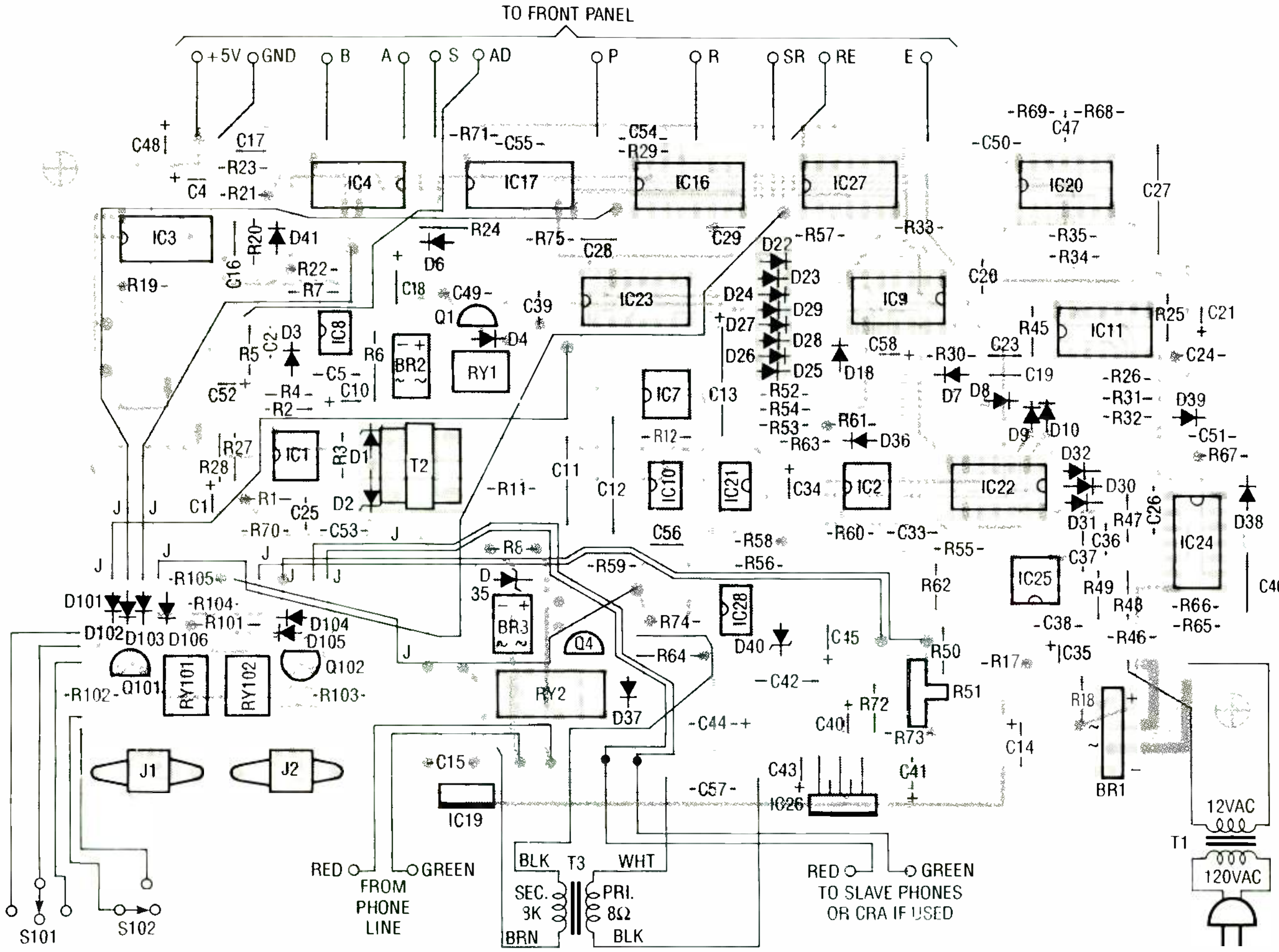
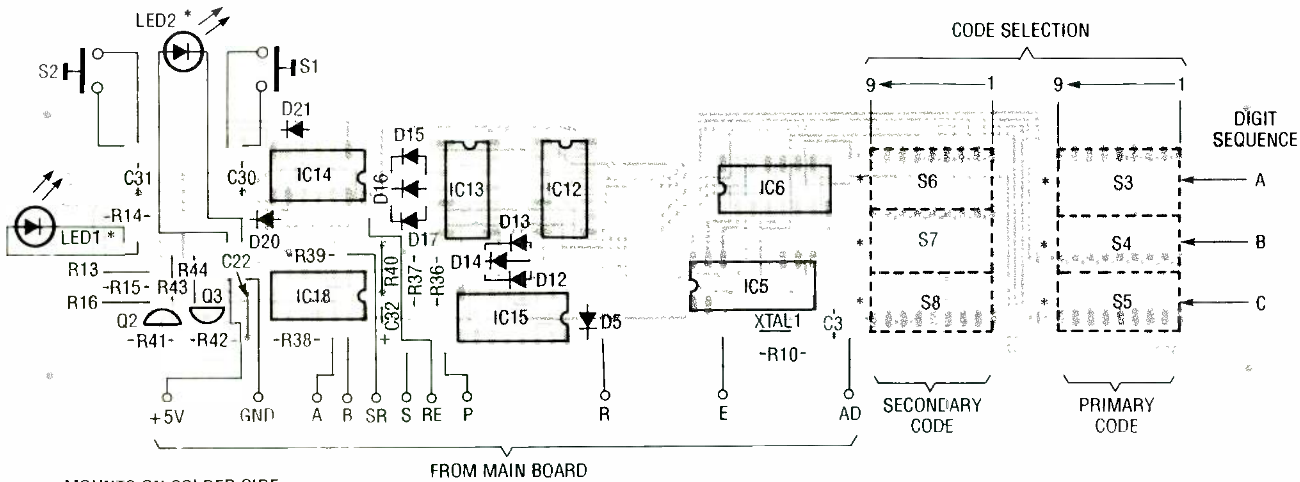


FIG. 3—PARTS-PLACEMENT DIAGRAM for the main board. Note that the CRA parts also mount on this board, although the two circuits are completely separate.

On the assembly drawing for the front-panel PC board (Fig. 4), leads are shown for the local screen-mode select switches. When used, they are simply SPST momentary pushbuttons. Typically, they are not used since most modern telephones are of the Touch-Tone® type, and screen-mode changes can be made from any such phone connected to the CallScreen output jack. When the CRA is switched on, remote screen selection from connected telephones is automatically disabled as a security measure in case an answering machine or FAX machine an-



*MOUNTS ON SOLDER SIDE

FIG. 4—PARTS-PLACEMENT DIAGRAM for the front-panel PC board. The DIP switches can be left out if you hard wire the access codes.

CALLSCREEN PARTS

All resistors are ¼-watt, 5%, unless otherwise noted.
R1, R10, R46, R57, R65, R68—1 megohm
R2, R5, R7, R17–R19, R23, R26, R32, R33, R36–R42, R52–R55, R58, R60, R63, R67, R70, R75—10,000 ohms
R3, R27—560 ohms
R4, R29, R71—47,000 ohms
R6—560 ohms, ½-watt
R8—metal-oxide varistor (MOV) surge suppressor, 130 VRMS, 15 joules
R9–not used
R11, R12—2200 ohms
R13–R16, R20, R24, R25, R30, R31, R34, R45, R61—100,000 ohms
R21—680,000 ohms
R22, R50—4700 ohms
R28—680 ohms
R35—51,000 ohms
R43, R44—180 ohms
R47–R49—200,000 ohms
R51—2000 ohms, potentiometer
R56—390,000 ohms
R59—100 ohms
R62, R74—470 ohms
R64—150 ohms, ½-watt
R66—82,000 ohms, 1%
R69—33,000 ohms
R72—220 ohms
R73—10 ohms

Capacitors
C2, C3, C16, C17, C19, C20, C23, C25, C28–C31, C39, C47, C56—0.02 µF, 20 volts, ceramic disc
C4, C10, C21, C52—22 µF, 16 volts, radial electrolytic
C5, C15, C22, C24, C26, C33, C49, C50, C51, C54, C55, C57—0.1 µF, 20 volts, ceramic disc
C6–C9—not used
C11—0.33 µF, 250 volts, polypropylene
C12—0.47 µF, 250 volts, polypropylene
C13—10 µF, 50 volts, axial electrolytic
C14—2200 µF, 25 volts, radial electrolytic
C18—100 µF, 10 volts, radial electrolytic
C27—4.7 µF, 10 volts, axial electrolytic, non-polarized
C1, C32, C34, C35, C40, C48, C58—10 µF, 10 volts, radial electrolytic
C36—0.039 µF, 20 volts, ceramic disc
C37—0.01 µF, 20 volts, ceramic disc
C38, C53—0.05 µF, 20 volts, ceramic disc
C41, C45—470 µF, 10 volts, radial electrolytic
C42, C46—0.22 µF, 50 volts, polyester
C43—1 µF, 35 volts, tantalum
C44—4700 µF, 16 volts, radial electrolytic

Semiconductors
IC1—LM1458 dual op-amp
IC2, IC25—LM741 op-amp
IC3—MC4001 quad NOR gate
IC4, IC12–IC14, IC22—MC4081 quad AND gate
IC5—SSI 202 DTMF receiver (Silicon Systems, Inc.)
IC6—MC4028 BCD-to-decimal converter
IC7—TCM1520 ring detector (Texas Instruments)
IC8, IC21—4N33 Darlington optocoupler
IC9—MC4071 quad OR gate
IC10, IC28—MCT-2 transistor optocoupler
IC11, IC20, IC24, IC27—MC4011 quad NAND gate
IC18—MC4013 dual D-type flip-flop
IC15–IC17, IC23—MC4017 decade counter
IC19—MC7805 5-volt regulator
IC26—LM383 7-watt power amplifier
D1, D2, D35, D40—5.1-volt Zener diode
D3–D10, D12–D18, D20–D32 D36–D39, D41—1N914 diode
D11, D19 D33, D34—not used
Q1–Q4—2N4401 NPN transistor
BR1—50-PIV 1.5-amp bridge rectifier
BR2, BR3—100-PIV 0.5-amp bridge rectifier

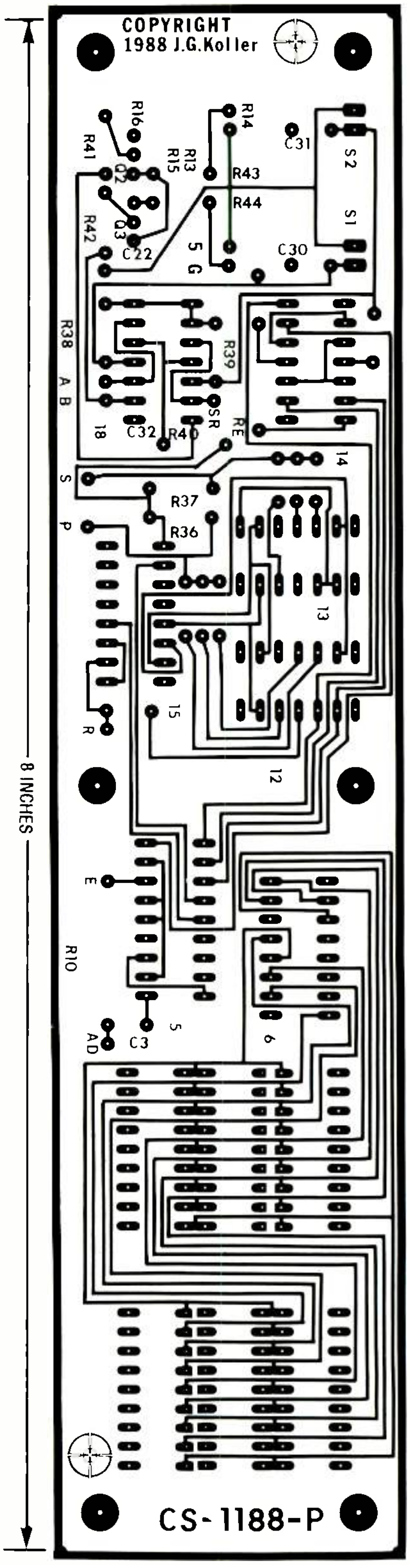
Other components
T1—120/12VAC 950 milliamp power transformer
T2—600/600-ohm telephone line coupling transformer
T3—8/8K ohm 10-watt matching transformer (use 8-ohm and 0.625-watt taps on a 70-volt line transformer)
XTAL1—3.58-MHz colorburst crystal
S1, S2—SPST momentary pushbutton switch
S3–S8—9-position DIP switch
RY1—SPST N.O. miniature relay, 5-volt, 70-ohm coil (or nearly any other 5-volt miniature relay)
RY2—DPDT miniature relay, 12-volt, 290-ohm coil (between 260–400 ohms)

CALL ROUTING ADAPTER PARTS

All resistors are ¼-watt, 5%, unless otherwise noted.
R101—150 ohms, ½-watt
R102, R103—10,000 ohms
R104—330 ohms
R105—1000 ohms

Semiconductors
D101–D106—1N914 diode
Q101, Q102—2N4401 NPN transistor

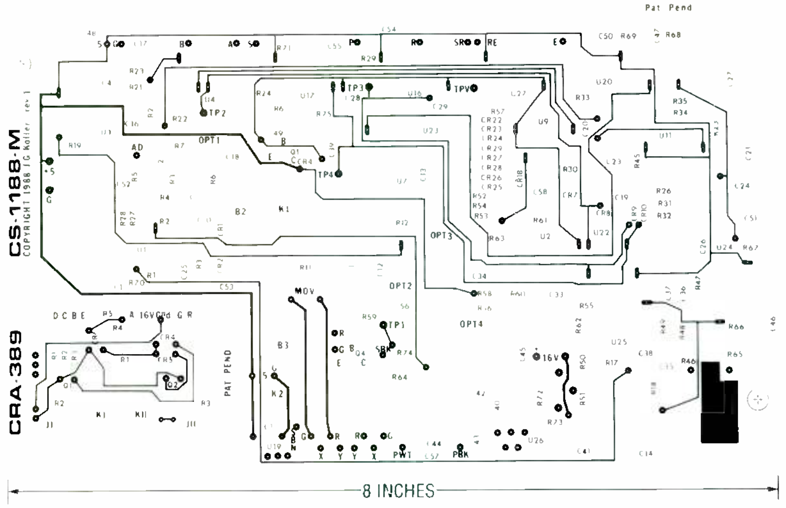
Other components
RY101, RY102—SPDT miniature relay, 12-volt, 320-ohm (nominal) coil
S101, S102—SPDT miniature switch (or use single DPDT center-off switch)



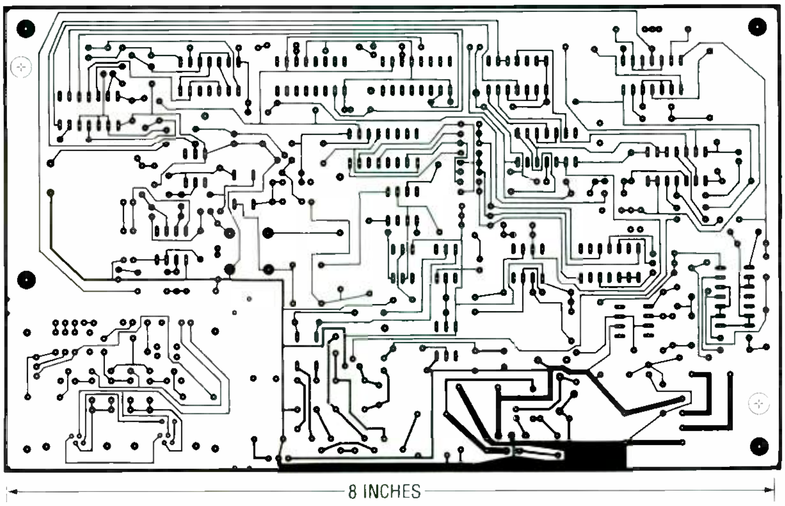
COMPONENT SIDE of the front-panel PC board, at full size.

swers a processed call. It is done so that the screen modes cannot be changed be the caller during the seven-second "window" when an off-hook is raised at the CallScreen/CRA output. If call routing is desired for telephones only, then the remote screen selection feature should remain available all the time. That is achieved by leaving out the jumper wire from the CRA terminal E to the main-board TPV.

When the two boards are



COMPONENT SIDE of the main circuit board, shown here at half of its actual size.



SOLDER SIDE of the main circuit board, shown here at half of its actual size.

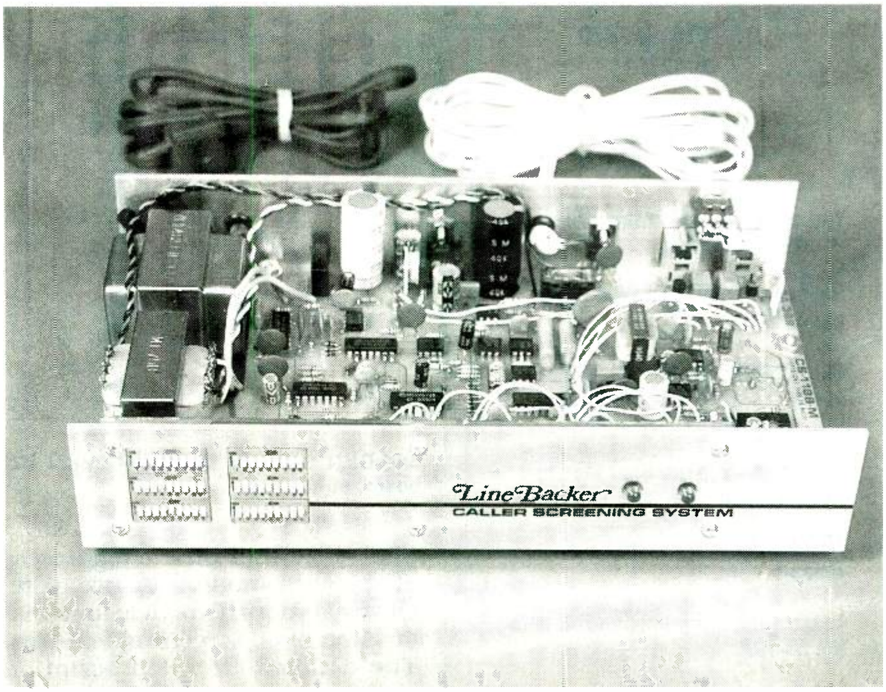


FIG. 5—THE SIX DIP SWITCHES and the two screen-status indicators (LED1 and LED2) must be mounted on the solder side of the front-panel board so that they can protrude through the cutouts on the cabinet.

ORDERING INFORMATION

Note: This information supersedes that presented last month. The following is available from Electronic Control Systems, R.D. 2 Box 3308, Wernersville, PA 19565: A set of two double-sided, plated-through PC boards for $39.95 (add $2.00 postage and handling); a complete kit including PC boards and all parts except the cabinet for $139.00 (add $3.50 postage and handling). Pennsylvania residents add 6% sales tax to all orders; check or money order only.

finished they are connected together and mounted at a right angle to each other in the cabinet. But remember to inspect all wiring and solder joints for poor or non-existent connections before doing so. All interconnections between the two boards should be made with fine gauge hook-up wire (AWG 30) to reduce mechanical stress on the boards during assembly. The boards may be installed in any type of cabinet the builder wishes. If the LED indicators are panel mounted and the code-select DIP switches are replaced with hard wire jumpers, then the front-panel board can be mounted anywhere inside the cabinet.

The two power IC's (IC19 and IC26) must be heat sinked. Their location on the PC board allows them to be bolted directly to the cabinet wall using 6-32 hardware. (Make sure that the nuts used are not so large that the IC cases crack when tightened against the tabs). Both IC heat-sink tabs are at ground potential so they do not require insulating. If a plastic cabinet is used, a strip of aluminum sheet metal may be mounted to the tabs as a heat sink. The majority of heat generated occurs when the screener is ringing telephones, so large sinks are not needed. A 1- × 5-inch strip of aluminum should be sufficient.

Power-up

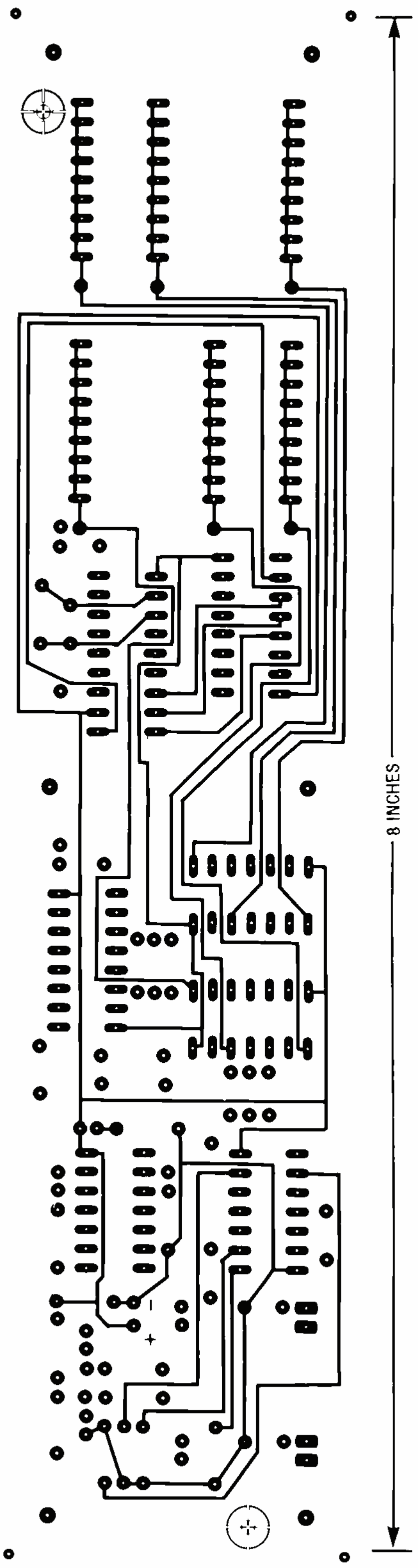
Set the ring-voltage potentiometer (R51) to an initial 10-O'Clock position. If possible, adjust the ring voltage to 90 volts using a DMM and an REN load of 1.0. If the CRA is used, make sure it is switched off. Connect the Call-Screen to a phone line. Lift the receiver and check for a dial tone.

Connect an ohmmeter across

the +5-volt supply line and make sure that no low resistances exist (less than 1K). Similarly, check the +16-volt supply line for any resistance under 15K. Connect a DC voltmeter across the 5-volt supply, power up the unit, and check for the proper voltage. Also check the 16-volt supply: under idle conditions it should read close to 18 volts.

Lift the receiver of the telephone and check for screen mode changes using the "#" and "*" keys. Leave the screen mode in "Limited Screen" (one LED lit). Note that screen mode changes via a connected phone are allowed for only seven seconds following an off-hook transition. Using two telephones connected to the CRA output jacks, have a caller enter each code, and also no code, with the CRA in each of its two modes. Verify that call routing occurs.

In a similar manner, cause one phone to ring but answer the call through the non-ringing phone. Verify that the incoming call is properly answered. Repeat the step using the other telephone. Verify that outgoing calls can be made by either phone regardless of the CRA mode. Be sure to review last month's article for a discussion of all screening features. The detailed circuit description should help you to troubleshoot any problems. Then you're ready to give out your access codes! **R-E**



SOLDER SIDE of the front-panel PC board, at full size.

SUSIE simplifies digital design, and makes breadboards a thing of the past.

TJ BYERS

DESIGNING DIGITAL CIRCUITS MAY look like child's play, but the journey from inspiration to a functional circuit is fraught with peril. Propagation delays, glitches, timing violations, and bus conflicts can turn a simple idea into a nightmare.

The traditional method of testing a digital design is to breadboard the circuit, then drag out the logic probe, oscilloscope, and logic analyzer to find out why it doesn't work. The modern method is to simulate the design on an IBM-compatible PC using a program called SUSIE (standard universal simulator for improved engineering), made by a company called Aldec.

If you knew SUSIE

SUSIE is a simulation program that graphically depicts the timing and logic events of a digital circuit. Although SUSIE uses software to verify the design, the results are the same as if you had built the circuit and used an ultra-sophisticated logic analyzer to test and debug it.

SUSIE simulates the operation of logic IC's using mathematical models stored in a library. IC models include algorithms for setup and hold time, pulse width, edge-to-edge transfer delay, and other propagation parameters.

There are different libraries for different types of components, with one library for TTL devices, another for CMOS, yet another for ECL, and so on. SUSIE comes with those three libraries, plus two additional libraries containing switches and other passive components. Aldec's Model Builder Compiler (MOBIC) allows you to model IC's that are not included in the libraries. You can also purchase extra libraries for devices including memory IC's, microprocessors, gallium-arsenide (GaAs) logic, programmable logic devices (PLD's), and gate arrays, plus libraries for computer interfaces and industrial components like stepper-motor controllers. The optional libraries cost between $800 and $2,000. However, you can do a lot with the nearly 6000 devices that come standard with the basic SUSIE package.

PRODUCTS MENTIONED

SUSIE
Aldec Co.
3525 Old Conejo Rd. #111
Newbury Park, CA 91320
(805) 499-6867
OrCAD
OrCAD Systems Corp.
1049 S.W. Baseline St.
Suite 500
Hillsboro, OR 97123
(503) 640-9488
SuperCAD
Mental Automation
5415 136th Place S.E.
Bellevue, WA
(206) 641-2141

A SUSIE example

To understand how SUSIE works, let's take an example. The circuit shown in Fig. 1 is a divide-by-five counter with a 50% duty cycle. Ordinary divide-by-5 counters produce an asymmetric output with a 20/80 timing ratio, but by using a negative edge-triggered flip-flop and half-state timing, we can make a divide-by-five counter with a 50/50 timing ratio.

Three counter stages are needed to divide by five, with one driven on the inverted clock to compensate for the odd number of states. That is, to achieve the sixth state needed to produce a 50% duty cycle, IC1-b must change state on the negative edge of the clock at $t = 2.5$, and that can be forced by timely triggering of the flip-flop's PRESET input (pin 10).

Debugging a circuit like that in hardware could get quite thorny. Let's see how SUSIE handles the situation.

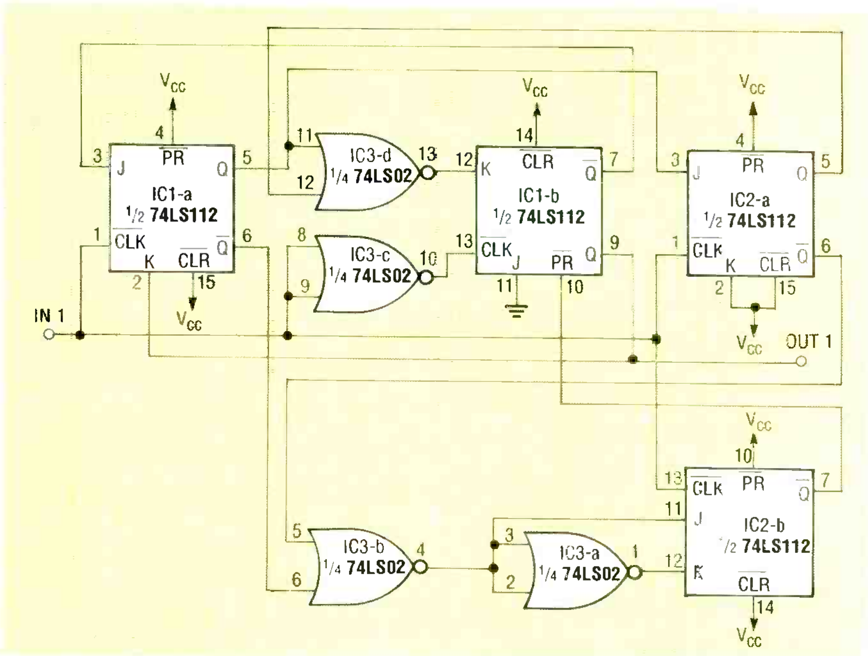


FIG. 1—DIVIDE-BY-FIVE counter with a 50% duty cycle output.

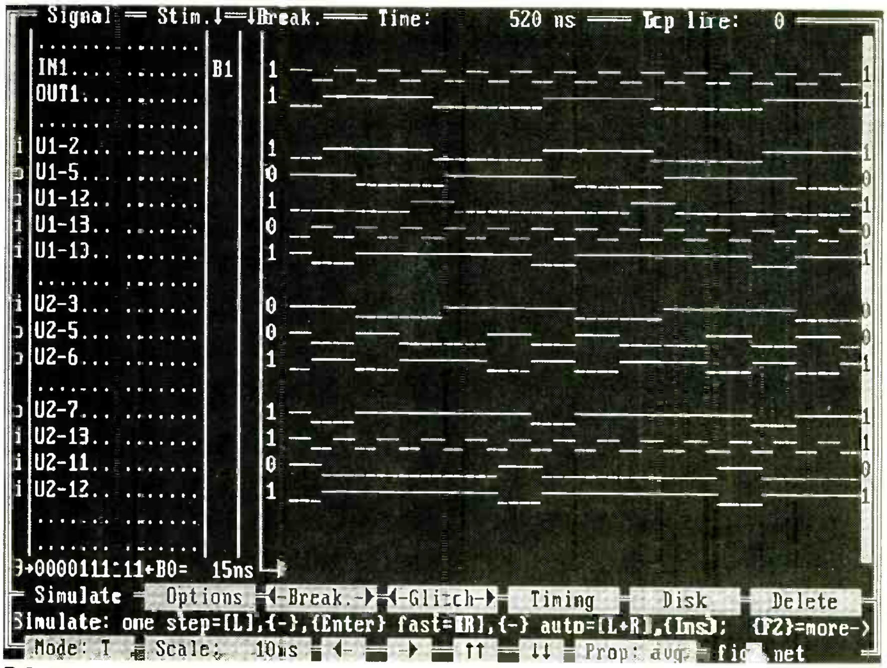


FIG. 2—SUSIE SIMULATION of the divide-by-5 counter shown in Fig. 1.

Design entry

SUSIE's design verification process is divided into three steps: design entry, test vectors, and simulation. During design entry you load and define the section or sections of the circuit you want to display on the screen. SUSIE can show as much or as little of the design as you wish. You can zoom in on a single IC or display waveforms for every point in the circuit.

Design entry begins with a *netlist*. The netlist contains a list of all the components in the circuit and their connections to one another. SUSIE reads the netlist, downloads the specified components from their libraries, and "builds" the circuit in RAM. (See the sidebar, "Writing A SUSIE Netlist," for more information about netlists.)

After SUSIE loads the netlist, you define which part(s) of the design you want to view by listing pin numbers or node names in the signal column on the left side of the display screen. For example, in Fig. 2, we defined several nodes (IN1, OUT1) and various pins of IC1 and IC2 for display.

Note that we selected no pins from IC3, and only some from IC1 and IC2. The reason is that too much information can be more confusing than not enough. The point is that, regardless which nodes are displayed, the entire circuit is tested during simulation, and all questionable timing events (glitches, etc.) are brought to your attention.

Of course, after creating a design, you can save it to disk and load it again later.

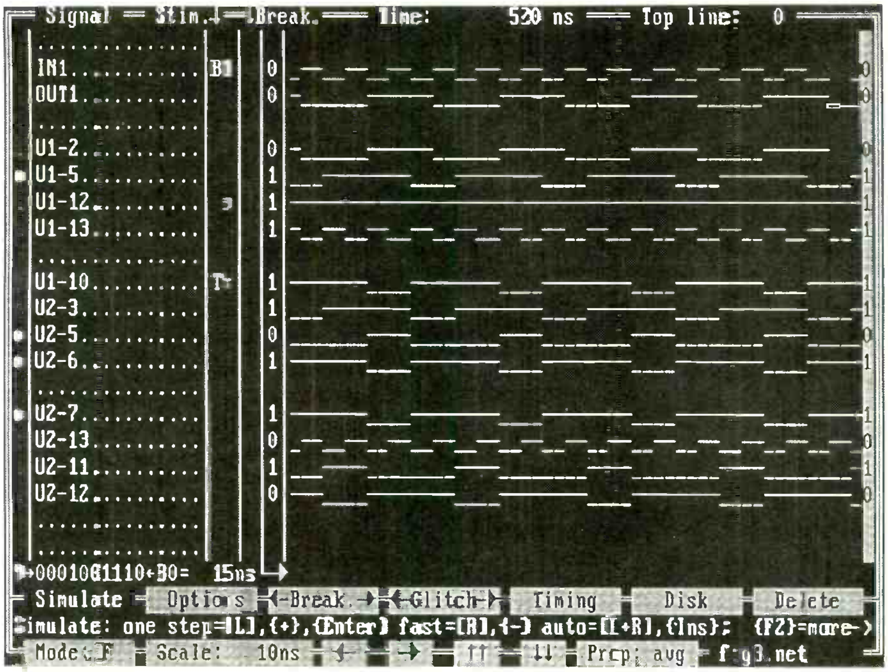


FIG. 3—DIVIDE-BY-THREE counter created by changing the test vector on pin 10 of IC1 to pull pin 12 high. The original circuit (Fig. 1) becomes a divide-by-3 counter with a 50% duty cycle.

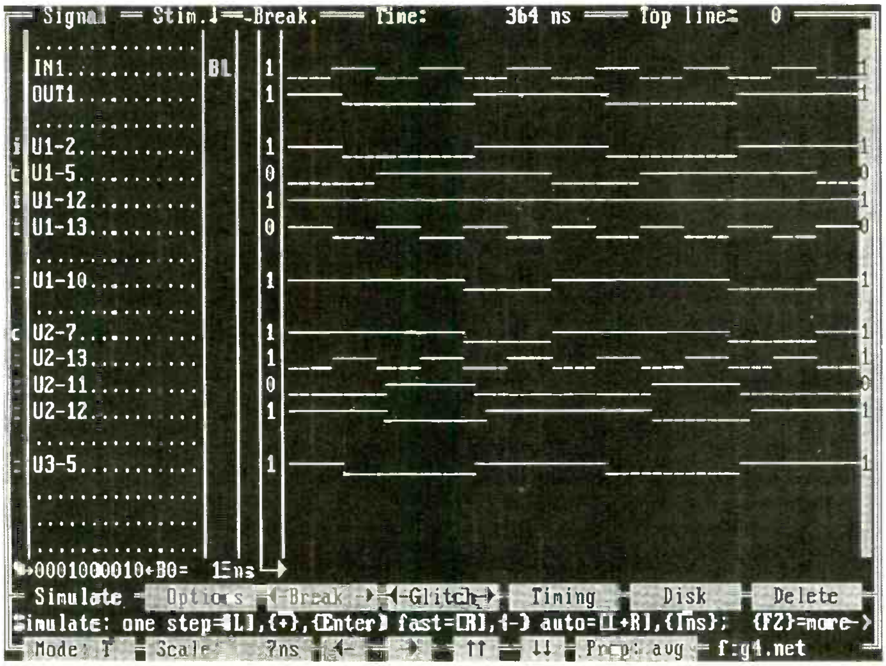


FIG. 4—SUSIE SIMULATION of the complete divide-by-3 counter.

Test vectors

For a design to function, it must have some kind of input; SUSIE's inputs come from *test vectors*. A test vector is nothing more than a waveform that, when applied to an input, causes something to happen in the circuit. SUSIE can serve up an almost limitless variety of test vectors.

You create test vectors using either an ASCII text editor or SUSIE's built-in test-vector editor. Test vectors may be stored in either a compressed binary format or one of three ASCII formats. The ASCII versions differ both in the format of the file and in the way it is used.

- The *line version* is formatted as a string of 1's (high) and 0's (low) that establishes the timing and shape of the waveform. Each line in the file represents one waveform, and you may describe and load as many lines (waveforms) as you wish.
- The *bus file* is similar to a line file, except that it is written in hexadecimal notation, and is used primarily to define waveforms for an entire bus.
- The *waveform file* consists of statements written in Aldec's proprietary high-level language, and it can be used to create waveforms too complex for the other methods.

To use SUSIE's built-in editor, you simply place the cursor over the signal to be edited and manually key in the desired waveform. After the test vector appears satisfactory, you can save it to a line or bus file directly from the screen. However, test vectors created on the screen using Aldec's programming language cannot be saved to a file; you can retain such files only by creating them first with a text editor.

After defining and naming a test vector, you can load it into any netlist design entry. Although a test-vector file may contain any number of waveforms, only one file may be loaded at a time.

SUSIE also has an internal ten-stage binary counter that can be used along with a test-vector file

OBTAINING SUSIE

As digital circuit-simulation programs go, SUSIE is a real bargain. But at $995 (optional libraries not included), it's too pricey for the average hobbyist.

Fortunately, Aldec offers a free SUSIE demo disk that does everything the full-blown SUSIE package does, but on a smaller scale. Instead of 6000 devices, the demo contains 26 logic devices and seven PLD's, plus a full complement of switches and passive components.

Although the demo disk can't simulate every digital design situation, the logic types are varied enough that, with prudent part selection, you can test a wide variety of design types—for free. Table 1 lists the IC's supported by the demo disk. The letters *xx* stand for any logic technology, ie. LS, AS, F, etc. IC models include setup and hold time, pulse width, edge-to-edge and other propagation delay parameters. **R-E**

TABLE 1—DEMO DISK SUPPORTED COMPONENTS

74xx00	Quad 2-input NAND gate
74xx02	Quad 2-input NOR gate
74xx04	Hex inverter
74xx05	Hex inverter (OC)
74xx07	Hex buffer (OC)
74xx08	Quad 2-input AND gate
74xx10	Triple 3-input NAND gate
74xx11	Triple 3-input AND gate
74xx20	Dual 4-input NAND gate
74xx30	8-input NAND gate
74xx74	Dual D-type flip-flop
74xx85	4-bit magnitude comparator
74xx86	Quad 2-input XOR gate
74xx90	BCD decade counter
74xx138	3-of-8 decoder
74xx151	8-input multiplexer
74xx153	Dual 4-input multiplexer
74xx157	Quad 2/1 multiplexer
74xx161	Presettable binary counter
74xx175	Quad D-type flip-flop
74xx193	BCD up/down binary counter
74xx244	Octal driver Three-state
74xx245	Octal bus transceiver
74xx279	Quad S-R latch
74xx373	Octal transparent latch
74xx374	Octal D-type flip-flop three-state
10H8	PLD
16L8	PLD
16R4	PLD
20L8	PLD
20L10	PLD
22V10	PLD
32VX10	PLD

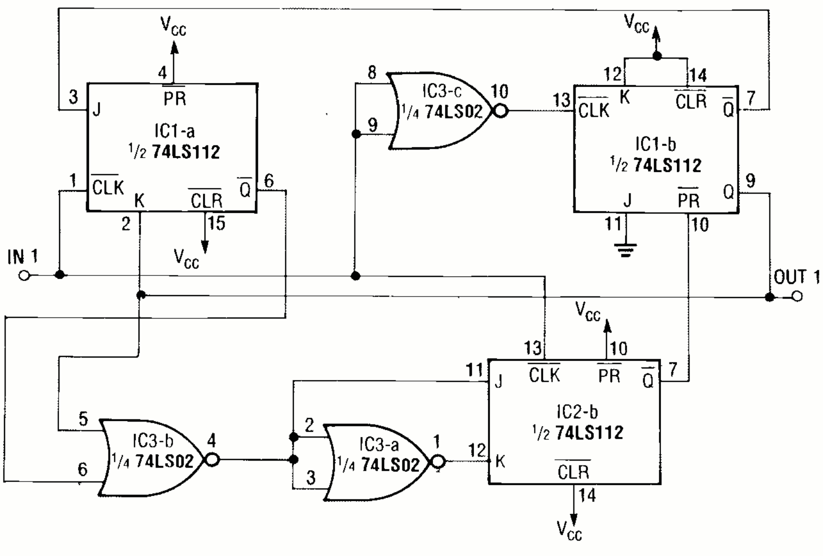


FIG. 5—FINAL SCHEMATIC of the divide-by-3 counter.

as a square-wave signal generator or as a frequency divider for other test vectors.

Simulation

Circuit simulation is the third and final step in the simulation process. It is where you get to see what happens in the circuit as a result of the applied inputs. It's also where you learn whether or not your design will fly.

The simulation mode provides numerous features that simplify analysis. You can preset any design element to an initial logic state, search for timing glitches, and set breakpoints for incremental timing measurements.

Most simulations use the internal binary counter for the signal source, as we did for our test design in Fig. 1. The counter has ten stages (B0 through B9), each of which is half the frequency of the preceding stage. The pulse width of B0 is adjustable between 10 picoseconds and 999 seconds. For our simulation, we set B0 at 15 ns and used B1 (30 ns) as the clock. The resulting display is shown in Fig. 2, which we will now use to verify our design.

At power up ($t=0$), the output of IC1-b (pin 9) is set high. On the first clock pulse, the input to pin 13 goes negative, causing the flip-flop to toggle and force pin 9 low and pin 7 high. That sets the stage for IC1-a to reset on the falling edge of the same clock pulse, which in turn causes pin 12 to go low and prevents further clock pulses from affecting IC1-b.

However, IC2-a continues to toggle, sending signals to IC2-b until its inputs reach a logical combination (pin 11 high, pin 12 low) that causes the inverted output (pin 7) to go low on the falling edge of the third clock pulse. That forces IC1-b's preset input (pin 10) low and output (pin 9) high. A half state later, IC1-b's new logic state forces IC2-b's pin 11 input low. That releases the hold on IC1-b and enables the counter to function as a normal state machine until the forced state is reached again. The resulting waveform at OUT1 shows us that our design does indeed work as predicted.

Using SUSIE to modify a design

Unlike many analog and digital simulators, SUSIE doesn't need to compile the netlist before it can do a simulation, and that makes it possible to change test vectors and circuit connections without having to change the netlist.

For example, let's say that we wanted to modify our design so that it was a divide-by-3 counter instead of a divide-by-5 counter. That is easily done using SUSIE's on-screen editing features.

Looking at the timing screen in Fig. 2, we see that in order to pull

LISTING 1—NETLIST OF DIVIDE-BY-3 COUNTER

```
sockets u1 = 74LS112
sockets u2 = 74LS112
sockets u3 = 74LS02

/in1, u1/1, u2/13, u3/8, u3/9          ;signal input
/out1, u1/2, u1/9, u3/5                ;divide-by-3 out
u1/3, u1/7
u1/6, u3/6
u1/10, u2/7                            ;U1b preset
u1/13, u3/10
u2/11, u3/2, u3/3, u3/4
u2/12, u3/1
/GND, u1/8, u2/8, u3/7, u1/11
/VCC, u1/16, u2/16, u3/14, u1/4, u1/15, u1/14, u1/12, u2/10, u2/14
```

WRITING A SUSIE NETLIST

Like all circuit-simulation programs, SUSIE uses a netlist to define the circuit. However, unlike many circuit simulators, which require special tools to create the netlist, SUSIE's netlist is in pure ASCII, which means all you need to make a SUSIE netlist is a text editor.

The process begins with a schematic of the design. (Refer to Fig. 1 in the text for this discussion.) First, the circuit's inputs, outputs, and components are identified by name and number. Those labels are then entered into the netlist using the format: *sockets schematic label = device type*. The order of the parts is really immaterial.

Next, connections between devices are listed by component label and pin number, with a comma separating each entry. Again no special order is necessary, and comments (placed after a semicolon) can be inserted in the netlist to help describe large designs. Signal inputs, outputs, and power-supply connections are preceded by a slash.

A separate line is required for each node in the circuit (a node is any point where two or more pins or wires connect). However, if the number of connections to a node is greater than will fit on a line, the listing can extend to the next line by ending the first line with an "&" character. There is no limit to the number of lines you can use for a single node, provided the lines are in sequence and linked via the "&" character.

That's all there is to it. The netlist shown in Listing 2 is ready for simulation. Several schematic-capture programs, including OrCAD and Super-CAD, can generate a SUSIE netlist directly from a screen schematic. **R-E**

LISTING 2—NETLIST OF DIVIDE-BY-5 COUNTER

```
sockets u1 = 74LS112
sockets u2 = 74LA112
sockets u3 = 74LS02

/in1, u1/1, u2/13, u3/8, u3/9, u2/1    ;signal input
/out1, u1/2, u1/9                      ;divide-by-5 out
u1/3, u1/7
u1/5, u2/3, u3/11
u1/6, u3/6
u1/10, u2/7                            ;U1b preset
u1/12, u3/13
u1/13, u3/10
u2/5, u3/12
u2/6, u3/5
u2/11, u3/2, u3/3, u3/4
u2/12, u3/1
/GND, u1/8, u2/8, u3/7, u1/11
/VCC, u1/16, u2/16, u3/14, u1/4, u1/15, u1/14, u2/4, u2/15, u2/2, u2/10, u2/14
```

this off we have to force the break at $t = 1.5$ instead of at $t = 2.5$. We can test our theory by applying a custom-made test vector to pin 10 of IC1-b.

The test vector can be created in several ways, but the best method for our situation is to use the Aldec programming language. First we look at the display to determine where the changes must occur. For our application, the test vector must have eight high pulses followed by four low pulses. The Aldec equation for that waveform is (H8L4)100, where H8 specifies eight highs, L4 specifies four lows, and 100 indicates that the preceding pattern should be repeated one hundred times. The repeat gives us plenty of time to play with the circuit before running out of signal.

To perform the modified simulation, we load the original design into SUSIE and apply the test vector to pin 10 of IC1-b (Fig. 3). Analysis of the timing display shows that pin 12 of IC1-b needs to be tied high so that IC1-b isn't affected by IC2-a. You could go into the netlist and change pin 12's connections, but SUSIE's editor lets you assign IC pins or nodes to keyboard keys that manually override the design stimulus. In our case, we assigned the *a* key to pin 12, then toggled the input high for the simulation. The result of this simulation, shown in Fig. 3, shows that our assumptions were correct and that the new design does work: For every three input pulses, the circuit produces one output pulse, and the duty cycle is 50%. The netlist for that circuit is shown in Listing 1.

The next step is to alter the circuit so that it generates the test vector itself. This can also be done in SUSIE using *connectivity markers*—screen notations that tell SUSIE to make a connection between like markers. As it turns out, the only change we have to make in the original design is move pin 5 of IC3 from IC2-a to pin 9 of IC1-b using the "aa" connectivity markers shown in Fig. 4. The rules for connectivity are: If you mark an input for screen connectivity, all previous connections to the input are severed; if you mark an output for screen connectivity, it serves the new source plus all the original sources.

Next we disconnect the Aldec test vector and run a new simulation, as shown in Fig. 4. Once again, the simulation verifies the circuit changes. A revised schematic of the new divide-by-three counter is shown in Fig. 5.

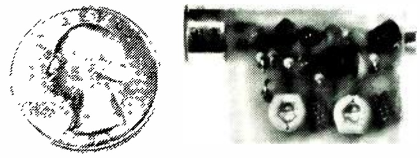
Advanced features

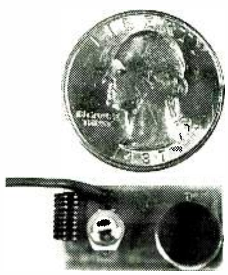
SUSIE also has a host of advanced features that are used to pinpoint design defects, test for worst-case conditions, and input data from or output it to the real world. Here is a brief description of each advanced feature.

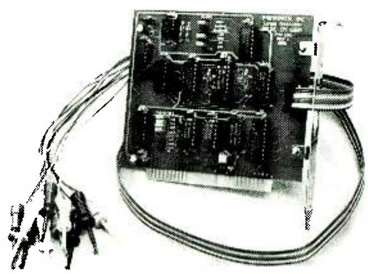
- Switches placed in the circuit can be opened and closed from the simulation screen, making "what-if" and alternate-configuration designs a snap to verify.
- The timing selection allows you to set IC propagation delays to any value for worst-case evaluation. You can also change IC technology (for example, from LS to AS), save and load IC propagation data files, and include the effect of temperature and loading on the simulation.
- Glitches that occur as a result of propagation delay, timing violations, or floating inputs are automatically displayed and pinpointed—even if the pin involved isn't part of the simulation display.
- Bus conflicts, where two or more outputs vie for simultaneous use of the bus, automatically produce a warning message that can be used to pinpoint the conflicting signals.
- Fault simulation, which shows all stuck inputs and outputs, is available as an option. To speed the lengthy process of fault simulation, SUSIE lets you divide the job among an unlimited number of unconnected PC's.
- Hardcopy printout of screen simulations can be made using either a dot-matrix or laser printer. The logic analyzer option lets you feed test vectors from a hardware design (breadboard or PC board) to SUSIE for analysis and debugging.

While SUSIE's simulation powers make it an attractive alternative to breadboarding, its real strength is that it lets your creative talent run free—without any physical restrictions. **R-E**

Radio Electronics® mini-ADS



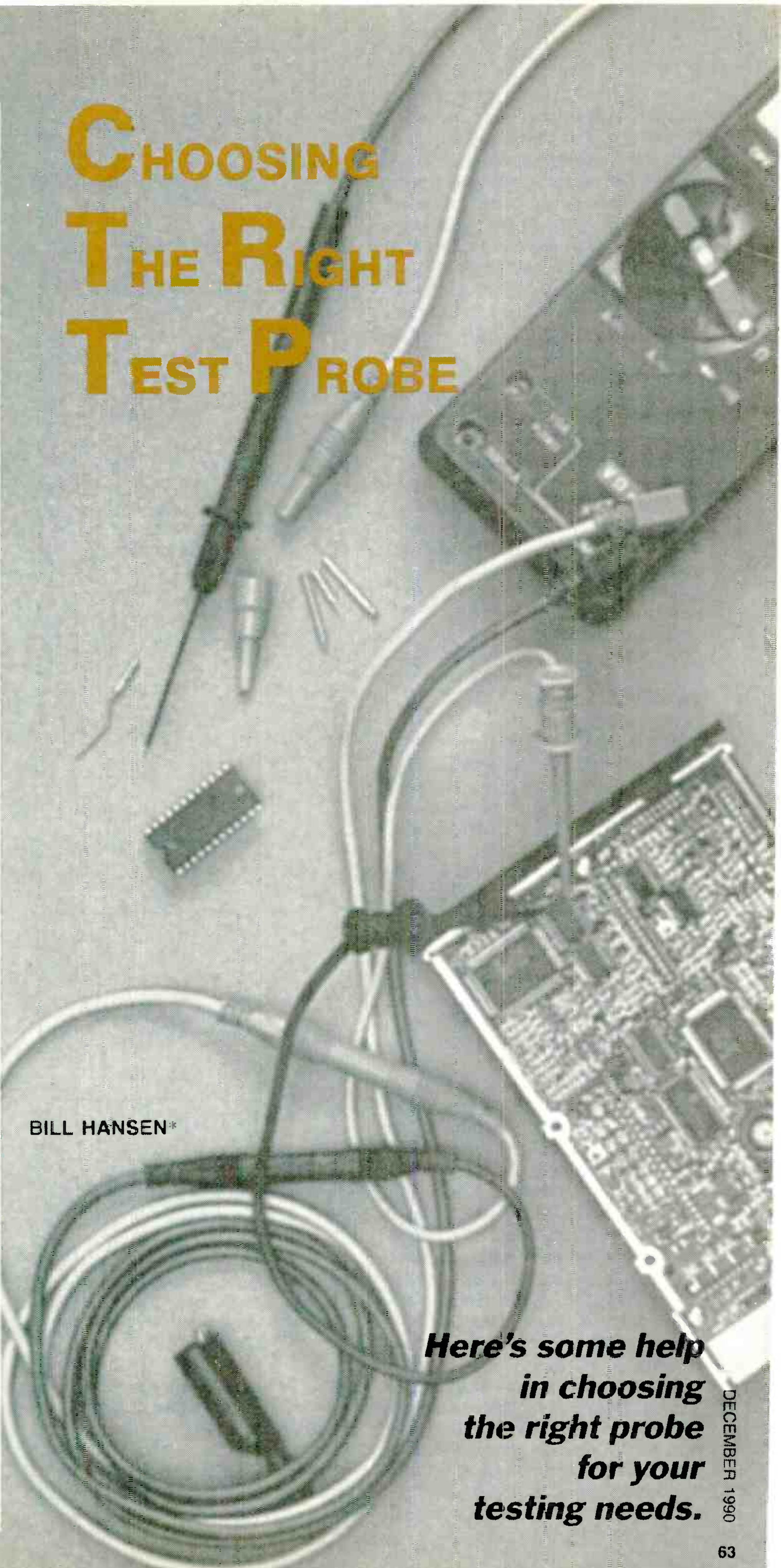




CHOOSING THE RIGHT TEST PROBE

Here's some help in choosing the right probe for your testing needs.

BILL HANSEN*



FOR A TEST TECHNICIAN OR ENGINEER, using test leads with a multimeter may be an everyday experience. Those of you who use multimeters on a consistent basis know how important it is to use the right kind of test lead, probe and probe tip. Those less experienced might be inclined to use any old probe. We'll show you why that's not a good idea, and then we'll take a look at what's currently available to help you make the right decision in choosing your test probes.

The basics

There are four basic requirements that determine the quality of a good test lead. Those requirements are:

- Reliability—the test lead should bite through the oxide, dirt, corrosion and insulation or conformal coating to make good contact with a lead, test point or wire.
- Hold the connection—the test lead should keep a continuous, nonintermittent contact.
- Dependability—the test connection must be insulated from other devices or equipment, and the connections shouldn't pull loose. That's a particularly frustrating problem, especially when you're forced to stop testing several times to reconnect the leads. A "hot" lead swinging loose can also be a danger, which leads us to the next point.
- Safety—testing can be inherently dangerous in many cases, so it's important that the equipment be as safe as possible.

Those four points aren't listed in order of priority; they are interdependent necessities. A good contact doesn't accomplish anything if you have 1500 volts hanging loose! With those four basic requirements in mind, we'll take a look at different probe tips, which actually make the test contact, as well as body design and interconnections.

Types of probe tips

One of the most commonly used tips is the brass-notched type, shown in Fig. 1-*a*. That type of tip is normally a 0.08-inch diameter brass rod, an inch or less

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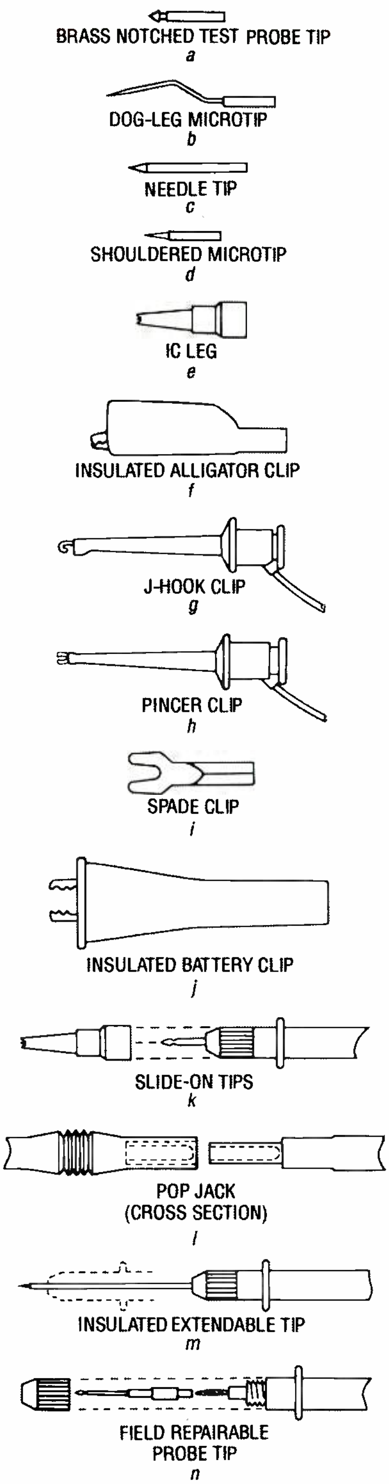


FIG. 1—EACH OF THESE PROBE TIPS HAS THEIR OWN distinct advantage when used in a specific testing application. All of these probe tips should meet most of your testing needs.

in length, with a conically-shaped arrow-head on the end. Brass is a good current conductor with a very low voltage drop across the contact point. It's relatively soft so it can conform to the test point with some grab, and not slide away too easily. In addition, the notch can lock onto a lead or wire, if that's what you're testing. The notched tip is small enough to fit into tight spaces and can handle most loads it's subjected to.

A dog-leg microtip, shown in Fig. 1-*b*, is useful for probing high-density PC boards that use surface mount technology (SMT). It lets you dodge around components and provides a "springiness" that enables you to move the probe handle slightly without losing your contact point. Extendable versions allow you to reach several inches down into a circuit, perhaps to get around a power supply or other object. Since these long, thin tips are insulated, they are not likely to cause shorts.

A sharp needle-point tip, shown in Fig. 1-*c*, offers a lot of advantages. A sharp tip can penetrate oxides or insulation easily and makes a good connection. It's made of stainless steel so it's strong, even springy, and easy to handle. The sharpness of the point digs in and grabs hold of the test point, and tends to stick and not slide off. One drawback is that steel is not the best conductor, and the sharp point means you can't drive too much current through it or it will burn up.

A shouldered microtip, shown in Fig. 1-*d*, provides a very small needle point, which is ideal for piercing insulation, while leaving only a very small hole.

The IC leg, shown in Fig. 1-*e*, is a specialty tip, which is a sharp needle point protected by insulating plastic on each side. As with the needle points, it digs in and holds in place while the insulation protects against shorts. This is an excellent probe tip for contacting IC leads.

Alligator clips, shown in Fig. 1-*f*, are perhaps the most common. Nobody likes alligator clips but everyone uses them. Because of their size, they don't fit into tight spaces very well. The clip's weight acts as a lever that tends to pull itself loose. Their jaws tend to be out in the open, contributing to inadvertent contact with neighboring objects, unless they are sheathed. Alligator clips come in different sizes and, in the right applications, they are useful.

J-hooks, with a spring-loaded insulation sheath, can really grab a component lead or wire and hold on well. That type of probe tip is shown in Fig. 1-*g*. They come in maxi, mini, and micro sizes to adapt to different jobs. Gold-plated beryllium-copper alloy makes an excellent contact. Don't accept J-hooks of base metal; the savings aren't worth it. The spring-loaded sheath is a safety factor as well as a mechanical aid for a good hold. Their advantages are obvious. The disadvantage is a slightly higher price than straight tips. In very close quarters, with tightly spaced component leads, J-hooks can also present a size problem.

Pincers, shown in Fig. 1-*h*, were designed as a J-hook replacement for use in tighter spaces. The "U" shaped tips are gold-plated beryllium copper and are heat treated to act as a spring. They reach around and grab onto component leads. Again, a spring loaded sheath provides a safety advantage and protects against shorting to adjacent leads. The disadvantage of a pincers tip is that they are more expensive then simpler straight tips.

Spade lugs, shown in Fig. 1-*i*, can be screwed down at a binding post, giving you the advantage of hands-free operation to turn on power, throw your switches and make your measurements. In specific applications they let you hook one or both sides of your multimeters and not worry about making or keeping contact.

The battery clip, shown in Fig. 1-*j*, was not really designed for batteries, but is the common descriptive name used in industry. It lets you grab onto large nuts or bolts and holds on strong.

Probe design

Many of the tips we have described are available permanently installed in special purpose probes. Some are available as "slide on" tips (Fig. 1-*k*), which allow a common probe body to be interchanged with a variety of probe tips and some with "pop-jack" connections (Fig. 1-*l*) to plug into a common probe body.

Permanently connected probe tips offer advantages to anyone who often or repetitively performs the same test step. You just pick up your sturdy probe and do the job. The disadvantage is a lack of versatility. Either you'll have to try and "make-do" with the wrong probe occasionally or you'll have to buy a number of different probes to meet each situation. In fact, if you do a large amount of testing, having a collection of probes to meet each situation is a wise decision. A number of kits of probes selected to match various applications are available at good prices.

Slide-on tips give you versatility. You can use a needle-sharp tip when you need it, and a spade-lug when your need changes. They provide big advantages to anyone that usually works with high-voltage equipment and only occasionally with low voltage.

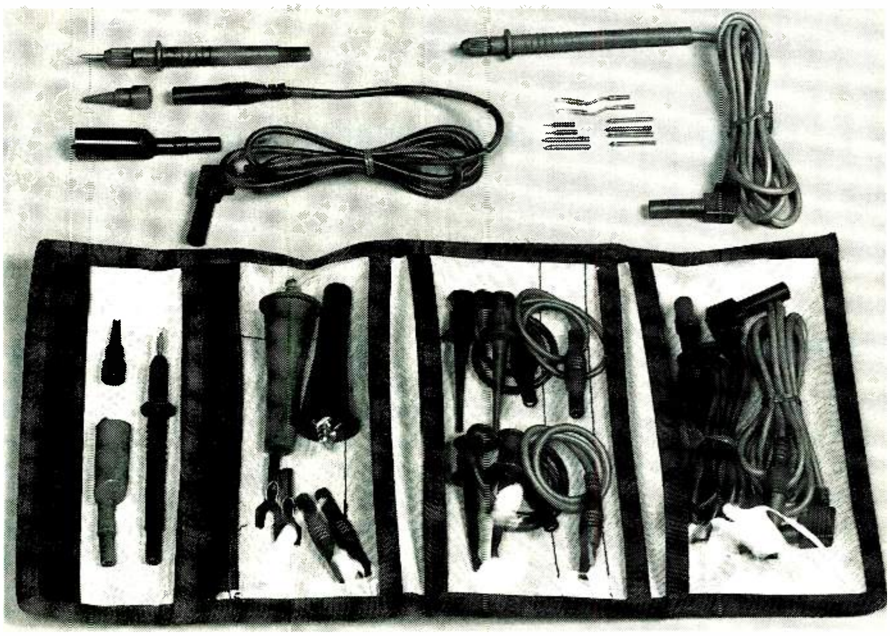
A particularly useful slide-on tip is the insulated extendable tip shown in Fig. 1-*m*. The extendable tip is able to get into those deep, hard-to-reach spaces without the worry of shorting of nearby components.

The disadvantage of slide-on tips is an outgrowth of the advantage—the slide-ons can also slide off. The pop-jack connection offers a solution to that problem. It allows you to interchange probe tips but holds them in place tighter. It offers a metal male-female connection with a friction grab, plus the plastic insulating sheaths actually deform and create a seal. The pop-jack connection requires five or more pounds of pull to dislodge it, although if you twist it first, it parts easier. It's somewhat like a Chinese finger puzzle in its holding ability.

Field repair

Test probes that are field repairable have a distinct advantage over those that are not. Most test probes that are non-field repairable are insert molded, with the test leads permanently embedded in the handle. That method of construction can present several problems. Most problems occur when the lead wire frays where it enters the handle. Once that happens, the probe must be discarded and replaced.

There can also be a safety hazard during the manufacturing process. A stray wire can sometimes occur at the tip-and-lead junction on the test probe, which is usually a crimp. When molded into a handle, that stray wire can be very close to the surface of the probe and, particularly at high voltages, presents a serious shock hazard.



POMONA'S *MAXI-KIT* CONTAINS a wide assortment of probes for the professional DMM user.

At Pomona, the tip-and-lead-wire assembly is threaded into a hollow handle and the tip is then held in place with a screw-down chuck. Therefore, it will never short through to the probe handle, and the probe is actually field repairable. If the lead wire is bent, broken or frayed, you cut it off and re-solder the wire to the tip, insert it back into the handle and chuck it in place. Figure 1-*n* shows a drawing of a field repairable probe tip.

Connections

Connection of the probe to the multimeter is through wire and a standard banana plug. The wire must be properly insulated and have a low enough resistance to adequately pass signals. Pomona test leads use double-insulated, 18-gauge wire, which more than meets all product safety requirements. Various insulating materials include: standard PVC, a superior PVC that's more flexible, or silicone, which is both more flexible and much more resistant to high temperatures, which is usually a problem when using a soldering iron.

There's more to a banana plug than you might think. High-quality banana springs are made of a single piece of heat treated, spring quality, beryllium copper. Most banana plugs on the market, however, are made of materials with bus spring retention, which makes less dependable and less reliable connections.

Uninsulated banana plugs are still available for multimeters, but the move is away from them, which is all for the better. A bare, uninsulated plug swinging loose while "hot" is just too dangerous to accept. For safety reasons, we urge you to use insulated plugs.

Most users, after they finish testing, wrap the leads around the meter and put them away until the next time. That means the leads are getting bent at a 90° angle, banged against a drawer or shelf, and eventually tend to break or fray. Leads that are molded at 90° from the sheathed plug will prevent that problem.

Wrap up

Multimeter manufacturers have a bad reputation for test leads. The fact is, your meter probably doesn't come with the best selection of leads for your specific needs. Typically, you should plan on investing some money on additional test leads.

Testing can be inherently dangerous, particularly at higher voltages. The closer you get to having the correct tool for each task, the safer and easier it is to perform your testing. **R-E**

IC SPOTLIGHT

The '90s begin with power processing and not-so-dynamic memory.

MIKE MULLIN

This year brought us lots of activity in IC and systems development. While much of that activity was in incremental process improvements to reduce geometries and increase densities, some new architectures and novel applications have surfaced. We will focus on three significant developments that you're likely to see in the future. Those important developments we'll talk about are: improved chip-level parallel processing architecture, a chip set that lets you incorporate a Sun workstation into your own design, and a new kind of memory that will be added between RAM and disk storage on system boards of tomorrow.

Second-generation transputers

The most significant development in microprocessor architectures this year is the new generation of transputers from Inmos, the developers of the original transputer. Dubbed the H1, these new chips overcome architectural limitations that kept the original transputers from being used in all but a few parallel-processing models.

For those of you who are unfamiliar with the transputer, it's a series of single-chip computers developed by Inmos which are used in parallel processing. The original transputers were well suited in implementing the communicating sequential processes (CSP) model of parallel-processing. In the CSP model, parts of the program are considered to be separate sequential processes that are assigned to different processing nodes. Those transputers came armed with a 32-bit central processing unit (CPU), some local memory, a hardware task scheduler and four serial links that communicated with themselves.

You can't get too much parallelism out of the earlier transputers because they're limited to four serial links. You're also limited to the CSP model of parallel processing, including systolic arrays for wavefront processing. Other architectures that have become very popular are the multi-dimensional hypercube and BBN's 8,000-node Butterfly processor architecture. If the transputer is to survive, it will need to be flexible enough to find its way into those processing models.

As a solution to the limitations we've just mentioned, Inmos has introduced the H1. Hardware improvements in the H1 include larger data and instruction caches, a separate arithmetic and logic unit (ALU), floating point unit (FPU), and workspace cache. It can perform 20 million floating-point operations per second (FLOPS) at a blazing 150 million instructions per second (MIPS). The H1's instruction set is also compatible with the existing T-series of transputers, specifically, the T805.

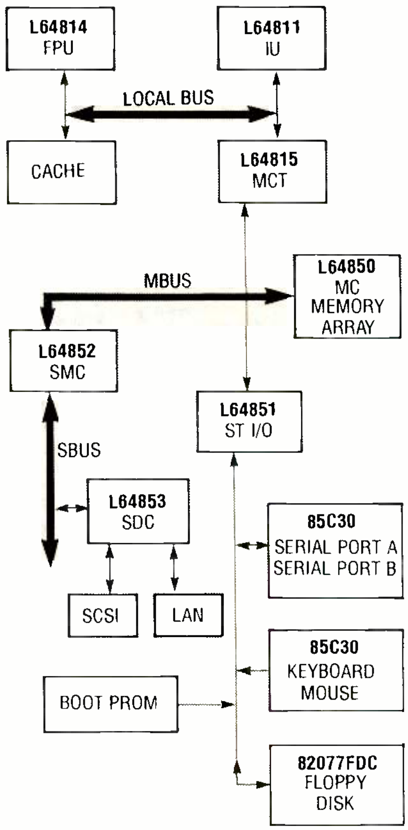


FIG. 1—THIS IS A BLOCK DIAGRAM of a SPARCstation-1 compatible workstation. LSI's 7-CHIP SparKIT family provides a highly integrated solution for producing Sun Microsystem SPARCstation-1 workstation compatibility.

The big news about the new transputer Irmos has designed, though, is that it introduces a new inter-processor control scheme. With the old transputers, you had to write a code to identify which physical serial link would carry data or instructions to which transputer in the model. If the target transputer was not directly connected to the source transputer, store-and-forward delays would build up, limiting the effective size of the parallel structure.

The new communication scheme, which Inmos calls small-area networks, or SAN's, actually uses many of the communications techniques found in local-area and wide-area networks. A key feature in SAN's is the use of virtual channels, in which transputers can talk to each other via a temporary direct connection, much like a telephone call is a temporary direct connection between two telephones in an international communications network.

The SAN's further supports flexible chip-to-chip communications by allowing you to write a code with the serial links as symbolic software links. The hardware works out the actual connecting path on its own. In addition, the H1 links pass messages of any length in 32-byte packets, unlike the byte-by-byte transfer of their predecessors. Each packet has a header and an end-of-packet marker, while each message has an end-of-message marker that denotes its last packet.

The actual message routing is performed by one of three separate chips: the C104 for routing H1 devices with each other; the C100 for routing H1 to T-series chips; and the C101, a universal link adapter.

continued on page 80

HARDWARE HACKER

Discrete cosine transforms, digital sine-wave generator, more video compression, Santa Claus machine update, and an audiovisual switcher circuit.

DON LANCASTER

Did I really do that? Well, I will admit I thought I had made an error once, but it turned out I was mistaken. At any rate, most of the op-amps in my October 1990 column on active filters seem to be upside down.

All op-amps in *all* figures should have their (−) or inverting input on the *top* and the (+) or non-inverting input on the *bottom*. Figure 3 was correct; Figs. 2, 4, and 5 need revising. All of the illustrations in my *Active-Filter Cookbook* are correct.

Sorry about that. Since all of my technical illustrations are submitted as "shoot-and-go" camera-ready Post-Script, I did it all by myself.

As all of you long-term *Hardware Hackers* already know, all the artwork you see in this column gets done with the *AppleWriter* word processor with my Apple IIe. No scanners or artwork-generation packages of any kind are used; everything gets done directly with "raw" PostScript. That includes all the schematics, pictorials, charts, text boxes, all printed circuit layouts, and all of the perspective and isometric stuff.

Our superb new PostScript PSRT RoundTable (M835) is going great guns on *GEnie*, and you'll also find some advanced *Hardware Hacker* and *Midnight Engineering* info there for your downloading. You could also contact me there via mail by using my Synergetics address.

You can give *Genie* a voice call at (800) 638-9636 for connect info. They recently reduced their rates and have expanded their many services. Nearly 100,000 library downloads are now available in one of the finest and highest quality shareware and public-domain collections in the world. Just about all computers get supported, major or minor.

My thanks to all of you perpetual-motion builders for your thoughtful suggestions on how to shield, time, or rearrange all the magnets to get my energy-producing gyroscope (**Radio-Electronics**, September 1990) to run, rather than simply latching up. And an extra special thanks to the few of you that sent me all of those super-strong magnets to try.

There's lots of goodies this month. Let's start off with a...

Santa Claus machine update

The science fiction authors called them *Santa Claus* machines. Instant replication devices that, on command, could reproduce just about anything from a machine part to a computer to a new girlfriend to a roast beef on rye sandwich.

Today, this emerging industry goes by the names of *Desktop Prototyping* or *Instant Modeling*. So far, all these machines are limited to producing quite costly and somewhat crude solid models in a rather limited range of materials. And you'll still notice a rather acrylic aftertaste to your roast beef sandwich.

But the hacking opportunities here do boggle the mind. First off, today's machines really do seem obscenely overpriced. Second, the best possible prototyping method clearly does not exist in any of the crude approaches in use today. Third, and finally, there are all sorts of service bureau, rental, and franchise opportunities emerging.

The reasons for desktop prototyping are obvious. Just as you can now instantly produce a *Book-on-Demand* published volume, you should eventually be able to create virtually any object on a desktop, at pretty much the same cost and speed—but with development expenses and a time-to-market that are only a tiny fraction of traditional machine-shop approaches.

And you should even be able to fake teleportation, simply by sending the replication codes to a remote machine over a satellite, modem, or fax line. Or, someday, a *Playmate of the month* on CD ROM. Yes, the real thing—no holograms need apply.

Our *Santa Claus Machine* resource sidebar for this month can show you where to go for more information on this exciting new field.

There are several dozen approaches to desktop prototyping, but those with the most commercial success so far are limited to *lower-end* CAD/CAM, *ultraviolet stereolithography, visible-light stereolithography,* and *laser sintering*. Let's look at each in turn.

The low-end CAD/CAM can involve miniature computer-controlled milling machines or lathes, and the parts are produced in the usual way by using a cutting program. Today, most of these machines are aimed at the educational market. Sources include *masterCAM, Roland Digital,* and *Light Machines,* while others advertise in *Industrial Education* and *School Shop.*

One material often used is a special *machinable wax* now available from *Freeman Supply.* This product is low-cost, does not wear out your tools, and can be recycled.

The pioneer in ultraviolet (UV) stereo-lithography is *3-D Systems*. The 3-D system uses a tank of UV-sensitive photopolymer. An elevator sits in the tank and is initially just below the surface. Their ultraviolet laser will selectively harden the photopolymer above your elevator. Then the elevator gets lowered a few mils, and the process is repeated.

Pancake style, a composite object gets built up on a layer-by-layer basis. Compound curves and tricky undercuts that are impossible to do the old

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way are easily created.

While the UV photopolymer normally used is both expensive and hard to get, a possible hacker substitute could be the *Merigraph* photopolymer used for rubber stamps, and available by way of *Gratham* or *R.A. Stewart*.

A second generation *visible light* photopolymer is being developed at *Dupont*, and one major system which uses these is *Quadrax*. Advantages of the visible photopolymer include its lower viscosity, the ability to use a cheaper laser, and (with proper safety precautions) being able to see what you are doing. Because of the lower viscosity, you can also *raise* the liquid level, rather than actually moving what you have already produced.

While these liquid-vat methods do work, they are limited in accuracy to several mils, are rather costly, and end up severely restricting your choice of materials. A fresh, different, and totally dry approach to desktop prototyping gets used by *DTM*. Here a granular powder of certain waxes or any of a number of plastics is selectively hardened by an infrared laser in a process known as *sintering*. Sintering simply melts the surface of the granules so they stick together.

In addition to being cleaner and simpler, you have a wide variety of possible material options, including real metals. Many powders can be reground and recycled, and they are far cheaper than the photopolymers.

Let's see, a few loose ends: Other approaches to Santa Claus machines include photochemical machining of thin layers and various other "gasket" techniques that get bonded together to produce composite objects. One think tank doing active instant prototype development is

NAMES AND NUMBERS

Alltronics
2300 Zanker Road #D
San Jose, CA 95131
(408) 943-9773
CIRCLE 301 ON FREE INFORMATION CARD

Castolite
PO Box 391
Woodstock, IL 60098
(815) 338-4670
CIRCLE 302 ON FREE INFORMATION CARD

C-Cube 399A West Trimble Road
San Jose, CA 95131 (408) 944-6300
CIRCLE 303 ON FREE INFORMATION CARD

Circuit Design
1790 Hembree Road
Alpharetta, GA 30201
(404) 475-1818
CIRCLE 304 ON FREE INFORMATION CARD

Circuit Cellar Ink
4 Park Street S20
Vernon, CT 06066
(203) 875-2751
CIRCLE 305 ON FREE INFORMATION CARD

Circuit Works
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GEnie
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Rockville, MD 20850
(800) 638-9636
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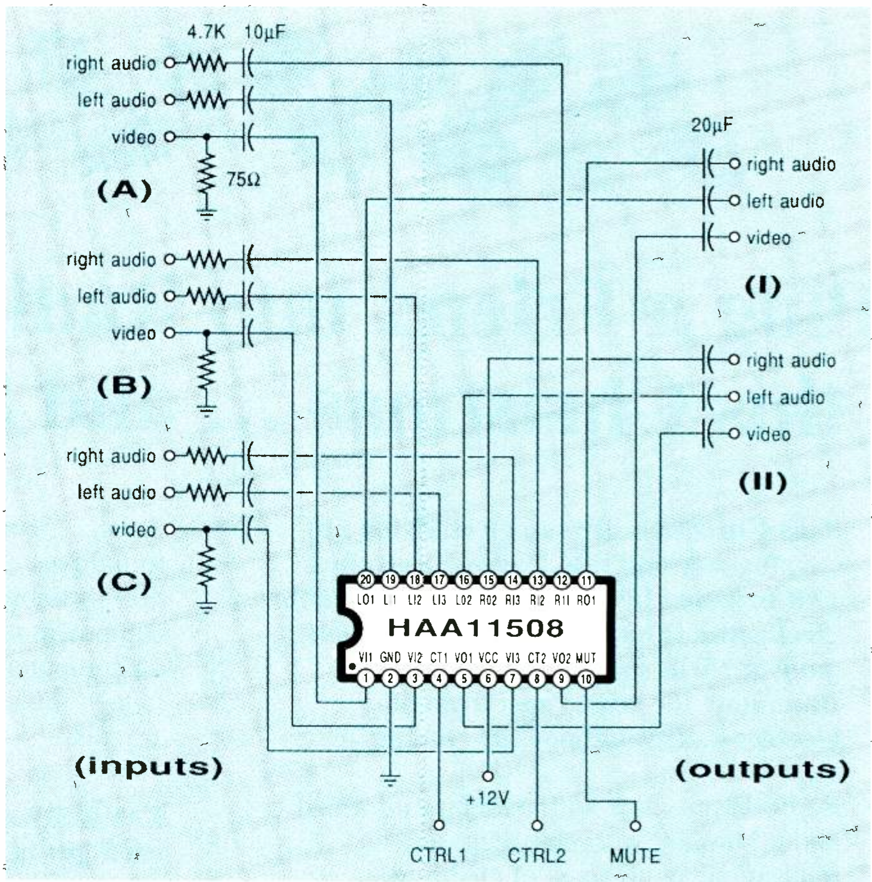

FIG. 1—THIS TRIPLE AUDIOVISUAL SWITCHER uses the Hitachi HAA11508 to simultaneously select video and two-channel stereo audio from any one of three sources and then route them to one of two selected outputs.

Batelle, while conventions and seminars are sometimes done by the *CAD/CIM Roundtable*. One of the many sources for traditional CAD/CAM support software appears to be *Control Automation*.

One thing that's totally obvious to me is that the PostScript language will play a major role in the future of desktop prototyping. Obvious reasons here are PostScript's nearly total device independence, its incredible graphical performance (especially for three dimensions), and its ability to let your favorite el-cheapo word processor completely and totally blow away virtually *any* of today's costly CAD/CAM packages.

For our contest this month, just add to our Santa Claus machine dialog in some useful way. There will be all of the usual *Incredible Secret Money Machine* book prizes going to the dozen or so top entries, with an all-expense-paid (FOB Thatcher, AZ) *tinaja quest* for two going to the very best of all. As usual, please send your written entries to me here at *Synergetics*, instead of **Radio-Electronics.**

An incredible data book

Certainly one of the most beautiful, largest, and most impressive data books I've ever run across is the incredible new *ASSP for Audio and Video Applications* data book offered by *Hitachi*. It is crammed to the rafters with unique new hacker integrated circuits.

Picking a sample more or less at random, Fig. 1 shows an *audiovisual* switch using their new HA11508 chip. This beast is hard to describe. It *simultaneously* switches one video and two stereo audio channels from your choice of three sources. As Fig. 2 shows, there are two separate triple outputs, selected per the CTRL1 and CTRL2 lines. The audio on the second triple output can get muted using the *mute* input.

This dude is intended to select three audiovisual sources inside a TV set and route them to two possible destinations. But it cries out to be used as part of a home- or low-end-studio control center *or* a switching bay.

The quality specs seem fairly impressive. While a 12-volt supply is

CTRL1	CTRL2	OUT I	OUT II
0	0	A	A
0	1	A	C
1	1	B	B
1	0	B	C

FIG. 2—THE TRUTH TABLE for the triple audio switcher. Logic signals on the control inputs decide which input gets selected. An optional mute input turns off the audio only on output II.

recommended, anything from 8 to 13 volts can be used. All the inputs and outputs are supposed to be capacitor-coupled. Since the switching times and all the overlaps are not specified, this chip appears to be mainly intended for use in static switching or source selection. Instead of being applied to chroma-key or picture-insertion applications. Naturally, for any higher-quality switching, full double-sided PC boards with lots of ground plane are an absolute must.

More on data compression

There sure was plenty of ongoing hacker interest in all of that data-compression stuff we looked at a few months back and in the *Hardware Hacker II* reprints. Much of the action today centers on the new *Discrete Cosine Transform*, especially in high-resolution color computer and TV displays.

Figure 3 is a bibliography of some of the heavier duty papers on the DCT. Start out with Chris Ciarcia's introductory tutorial in *Circuit Cellar Ink*, and then go on to the fancier stuff shown through *Interlibrary Loan* at your local library.

To compress any video image, individual 8×8 pixel blocks have their discrete cosine transform taken, by using either hardware or software. The result of this transform is a list of frequencies and amplitudes. Any change so minor that the eye can't see it anyway gets replaced with a zero, leaving a sparse data set. Put another way, what you don't know (or see) won't hurt you.

The sparse data set then gets further compacted using *Huffman* or similar techniques. The net result is a video compression in the 30:1 range without causing significant visual degradation.

The reasons for compression is to reduce your disk storage time and your communication time Far more important, this sort of data compression is essential to squash an HDTV image down into reasonable bandwidth channels. So knowing and understanding video compression is an essential part of the new multimedia revolution which is combining video and computing.

Two sources of DCT chips include *C-Cube* and *SGS*, while some useful (but very much slower) do-it-yourself software routines are shown in the Ciarcia article.

Digital sine-wave generator

Hardware hackers interested in communications are really getting off on a great new integrated circuit from

A Fast Algorithm for the Discrete Cosine Transform
C.H. Smith, *IEEE Transactions on Communications* Sept. 1987 pp 1004-1009.

Image Compression for High Speed Network Transmission
C. Ciracia, *Circuit Cellar Ink*, Aug/Sep 1990, pp 19-26.

Teleconferencing
K. Rao, *Van Nostrand Reinhold Company*, 1985.

Digital Coding of Waveforms
N. Jayant, *Prentice Hall*, 1984.

A New Wave in Applied Mathematics
B. Cipra, *Science* 24 Aug 1990, pp 858-859.

Survey of Adaptive Image Coding Techniques
A. Habbibi, *IEEE Transactions on Communications*, Nov 1977, pp 1275-1284.

Advances in Picture Coding
H. Mussmann, *Proceedings of the IEEE*, April 1985, pp 523-548.

Progressive Transmission of Gray-Scale and Binary Pictures
K. Knowlonton, *Proceedings of the IEEE*, July 1980, pp 885-896.

Predictive Coding Based on Efficient Motion Estimation
R. Srinivasan, *IEEE Conf. Communications*, May 14 1984, pp 521-526.

DCT Processing of NTSC Composite Video Signals
A. Ploysongsang, *IEEE Trans. on Communications*, March 1982, pp 462-479.

FIG. 3—A FEW OF THE RECENT PAPERS on video-image compression and the DCT discrete cosine transform.

Micro Linear. This is their ML2035 Programmable Sine-wave Generator. Cleverly disguised as an eight-pin mini-DIP, this new chip is an $8, full performance, 16-bit digital sine-wave generator. It has a 21-bit phase accumulator and a 9-bit sine lookup table built into it!

The device can easily produce any sine wave from 1 Hz to 25 kHz in 1-Hz steps, and its serial interface mates beautifully with virtually any computer or microcontroller. Figure 4 shows the extremely simple circuit. A split supply of +5 and −5 volts is needed. The output frequency resolution will be:

$$f_{OUT} = f_{XTAL}/8{,}388{,}608$$

Thus, you would use the 8.388608-MHz crystal to get a 1-Hz resolution. Or you could apply any external frequency up to 12 MHz.

Your output sine-wave frequency is determined by the 16-bit digital word you last selected. For instance, a digital "1" would get you 1 Hz, while a "5623" (or a hex $15F7) will get you 5.623 kHz. Your output is a clean and low-distortion sine wave of around 12-volts peak-to-peak.

In order to save on package pins, your digital control word is entered serially. There are three pins involved. The SERIAL INPUT DATA (SID) pin accepts one data bit at a time, the least significant bit first. The SCK or SERIAL CLOCK accepts each new data bit on its rising edge. Finally, the LAT or LATCH pin stores the input serial data stream on its falling edge.

This should interface beautifully with the game-paddle port of an Apple IIe, or anywhere else you have three I/O lines available from a computer or microcontroller. There's also an ML2036 in a larger package with some extra features at slightly higher cost.

One obvious tip: You do enter the frequency in *binary* or in *hex*, and not in decimal! Don't laugh. That's a *very* common hacker mistake.

As a second contest for this month, just tell me something different you would do with this new ultra-cheap, ultra-simple, and ultra-precise digital sine-wave generator.

New tech literature

Schaevitz has a free *Handbook of Measurement and Control* that gives the fundamentals of LVDT positioning sensors. From SGS, there's a new data book on *Protection Devices* that includes surge and transient suppressors.

Texas Instruments has a new and free linear products sample packet on their *Excalibur* series of JFET operational amplifiers.

Two great surplus flyers include *Alltronics*, who are big on powerful magnets and computerized hamsters (their dead ones are cheaper); and *Marlin Jones*, who has some new tilt-angle sensors, parabolic mirrors, LCD displays, clutches, and regulators.

Our featured free trade journals for this month include *Circuit Design* on printed-circuit layout techniques, and *Nickel*, devoted to stainless steel and all other nickel applications.

Still at the same old stall after all these years, the *Castolite* people of-

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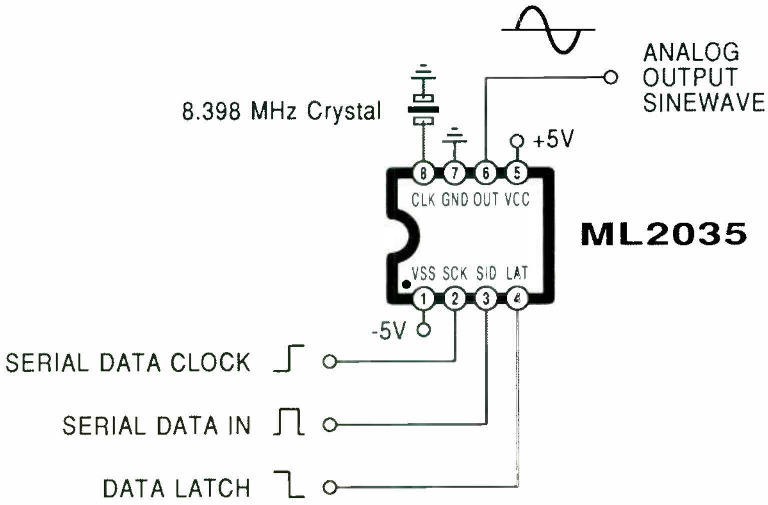


FIG. 4—A DECEPTIVELY SIMPLE DIGITAL SINE-WAVE GENERATOR. This $8 chip does a full 21-bit phase addition and a 512-level table lookup for an outstanding output quality. Resolution is 1 Hz over a 1-Hz to 25-kHz range!

fer all sorts of castable resins and mold products. One good way to get started with the castable resins is to pick up their $75 product sample and evaluation kit.

The *Circuit Works* people have an interesting conductive pen that writes in silver ink. The main use for this unusual gadget is for printed-circuit-board repairs.

For some additional mechanical stuff, 3M has an interesting brochure on microcapsule technology, while free plastic-tubing samples are newly available through *NewAge Industries*. And *PM Research* has a fine catalog on steam-engine kits.

Turning to my own stuff, I have combined my seven top hacking books into a *Lancaster Library* at a very special price. These include the *TTL Cookbook, CMOS Cookbook, Active Filter Cookbook, Micro Cookbook I, Micro Cookbook II, Hardware Hacker II*, and, of course, *The Incredible Secret Money Machine*.

Finally, I do have a new and free mailer for you which includes dozens of insider hardware-hacking secret sources. Write or call for info.

Our usual reminder here that most of the items mentioned appear either in the *Names and Numbers* or in the *Santa Claus Machines* sidebar.

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

Amplifier Transfer Functions: A Strange Audio Controversy

LARRY KLEIN

My IEEE dictionary defines transfer function as "a mathematical, graphic, or tabular statement of the influence that a system or element has on a signal or action compared at input and output terminals..." The somewhat stilted language refers essentially to whatever differences occur between the input and output signals of a circuit. It may seem strange that an innocuous technical term like "transfer function" could in another guise excite such passions in the audiophile community. It all began, as have several other audio controversies in the past decade, with the work of Bob Carver, former president of Phase Linear, and presently the president and chief engineer of the Carver Corporation.

The Carver Corporation

When Carver founded the company that bears his name, he produced two products that both excited audio consumers and rattled a few cages. The first to hit the market was a "sonic holography" preamplifier that provided an enormous extension of the sonic sound stage far beyond normal speaker spacing. In fact, on certain program material, the effect is as though two invisible side-wall speakers have been switched in. The holographic illusion is achieved by electronically nullifying the interaural crosstalk that occurs with conventional speaker setups. Normally, the sound from the right speaker reaches your left ear and the sound from the left reaches your right ear; the Carver circuit injects some out-of-phase left signal into the right channel and vice versa, thus electronically canceling, when you are properly located, the acoustic "leakage" between both channels.

Carver's sonic holograph prompted a host of "me-too" products, and variations on the idea are still found in the products of some companies. Not surprisingly, purist audiophiles complained in letters to audio magazines that Carver was illegitimately monkeying with the integrity of the audio signal, that the effects achieved were far from realistic, and that the recommended listener position was unduly restrictive. However, buyers of the Carver sonic-holograph preamp simply enjoyed its effect, untroubled by the objections of the purists.

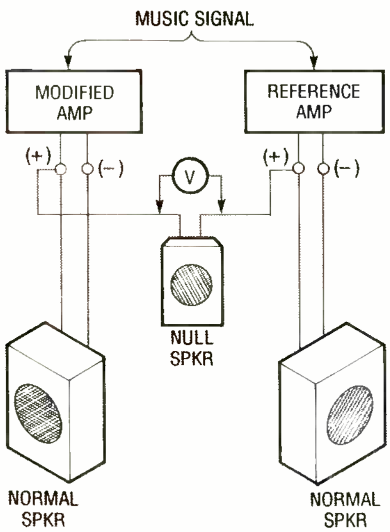


Fig. 1. CONNECTION FOR COMPARING one channel of a reference amplifier to one channel of the modified amp. The normal speakers, whose purpose is to provide a typical load, are placed out of earshot, The null speaker plays only the difference between the two channels. Theoretically, two identical channels will produce no sound from the null speaker. A meter connected across the null speaker has revealed nulls as low as – 70 dB.

The Carver challenge

Bob Carver's next project was the M-400 "magnetic-field" amplifier. Truly a revolutionary product, it was a 200-watt-per-channel amplifier embodied in a 7-inch cube weighing a mere 10 pounds. Once again, audiophiles who tended to judge an amplifier's quality by its cost—and the severity of the hernia you got trying to lift it— were outraged. Obviously, there had to be something wrong with the M-400's sound that did not show up in conventional testing, yet was surely audible to anyone with ears golden enough to hear it.

Bob Carver told me several times during that period how distressed he was by the self-selected audio esthetes who felt that he was, at best, a designer of mid-fi equipment. Carver set out to prove them wrong. He devised and demonstrated a nullification circuit (not unlike the Hafler circuit discussed in these pages several years ago) that would null out all similarities in the signal between any two amplifier channels leaving only whatever differences might exist in phase shift, frequency response, distortion, and/or noise to be heard.

I attended at least two of Carver's demonstrations and came away convinced that his amplifier was essentially perfect in respect to absence of any audible problems. In truth, I was not terribly surprised by Carver's test results since I believe that almost any well-designed amplifier when operated with a reasonable speaker load and within its power rating will sound like any other amplifier also operated under the same conditions. (That is also Carver's view, but he hesitates to propagate it for fear of further alienating the irrational self-appointed audio elite.) In any case, Carver made his point among those willing to be convinced. But Carver's test convinced none of the audio fundamentalists whose ultimate faith resides in what they think they hear under their own essentially uncontrolled listening conditions.

For this group, only prolonged listening to one amplifier and then the other will allow proper evaluations to be made. Anyone who has attempted to make scientific subjective assessments in any product area knows of the pitfalls of such a procedure, but nevertheless, that is the preferred audiophile evaluation technique.

Okay, thought Carver, let's approach the problem from a different direction. He issued a challenge to the editors of *Stereophile* magazine: You pick out an esteemed high-end power amplifier—tube or transistor—and I will duplicate its sound by minor modifications of one of my current $700 magnetic-field amplifiers. Carver flew out to *Stereophile's* Santa Fe, NM, offices and set up his equipment in a nearby motel, and *Stereophile* brought over a massive $5,000 tube amplifier to serve as the reference. Several days later, Bob emerged from his instrument- and parts-cluttered motel room with the modified Carver amplifier whose sound he claimed exactly matched that of *Stereophile's* audiophile tube amplifier.

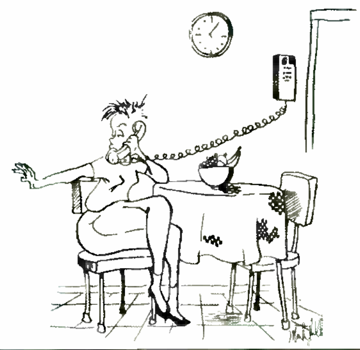
Here comes the surprising part: After hours of comparison listening, the flabbergasted editors of *Stereophile* reluctantly agreed that Carver had accomplished just what he claimed he would. The sound of the two amplifiers was *indistinguishable* even with the "best available" associated equipment and speakers! The implications of what Carver had done was not lost on those who had participated in the event. How could Carver's amplifier duplicate the sound of the reference, without the use of gold-plated connectors and circuit boards, oxygen-free copper wire, capacitors with special dielectrics, and metal-film resistors, and all the other magical elements—including tubes—that are found in audiophile amplifiers? Could it be, as Carver claimed, that the only thing necessary was to get the proper transfer function?

Now for the unsurprising part. Upon reflection, reconsideration, and relistening to the original modified Carver amp plus other samples that Carver had modified similarly, *Stereophile's* staff decided that the amplifiers really didn't sound alike after all. How could they, when the basic premise of the magazine (and high-end audio) suggests the existence of subtle, mysterious audible differences that differentiate audiophile equipment from that produced by the "mass merchandisers" such as Carver. You wipe out those differences and you obviously wipe out the justification for overpriced and overdesigned high-end audio equipment.

I asked Bob exactly what he does to match the sound of two amplifiers. Essentially, he said, the differences he's eliminating are all in the spectral domain. However, that involves more than simply matching the frequency-response characteristics of two amplifiers. Every amplifier has a characteristic complex input and output impedance that causes small frequency response variations when driving various speakers and when being driven by various input components. Matching the sound of two amplifiers consists essentially of matching those impedance characteristics. It isn't necessary to work out the reasons for the impedance characteristics of the reference amp, only to duplicate them.

Postscript

I thought that Carver's approach to amplifier matching would make an interesting story and I offered it to *Audio* magazine. The editor, whom I've known for years, turned me down flat. Why? His belief system, like those of the editors of *Stereophile*, would not permit him to accept that Carver's feat was possible. And a final note: Since *Stereophile* recanted, they have, in Carver's view, constantly attacked his products in editorial comments and reviews. That has led indirectly to a series of legal claims and counterclaims, which, are now being worked out in court. **R-E**



"I think he loves me... He let me touch his stereo."

Let's keep our DTMF generator circuit as simple and as elegant as possible.

ROBERT GROSSBLATT

Just about everyone who owns a computer has had to deal with plug-in cards at one time or another. Back in the old days, there were no such things as ASIC's (application specific integrated circuits), and it was even rare to see a board with PAL's (programmable logic arrays) on it. Most of the board designers and manufacturers produced products that were constructed entirely around recognizable hardware. That usually meant that you'd see lots of 74-series logic on the board with an occasional EPROM (a 2708) to handle unusual gating requirements, data tables, and so on.

Things aren't like that any more.

Modern boards, and most modern electronic products, are now built around custom silicon since the failure rate is a lot lower and the cost of production is less as well. This is good for the consumer since the products are a lot more reliable and less expensive. A VGA card is an extremely complex circuit but you'll find the parts count to be minimal.

The down side of all this is that it's next to impossible to fix any of the newer boards. You not only can't get the ASIC's that form the heart of the design but, even if you could, very few (if any) of such newer boards are delivered with a schematic and circuit description.

The reason I'm mentioning this is because the state of board design has led a lot of people to assume that discrete design is a thing of the past. That's just not true since even the most complex and custom designed boards start out in life as a load of discrete circuitry built around the same MSI (medium scale integration) stuff that, once upon a time, also existed on the final products.

The major contribution of the development of ASIC's has to do with economy, not electronics. The same sort of argument applies to component density. Not every product made to work with a computer has to be complex. As a matter of fact, Grossblatt's Fourteenth Law—Keep it Simple—tells you that things should be only as complicated as they have to be to get the job done. Not only that, but the more time you spend doing electronics, the more you'll appreciate the advantages you get when you keep things as simple as possible. If the word "simple" bothers you, think of it as being "elegant" instead.

The circuitry for the controller we're building doesn't have to be any more complex than is required by the job it's designed to do. We're building a telephone dialer and, although there are certainly an infinite number of things we can have it do, all we're looking for in the beginning is the ability to generate DTMF tones—and we've already talked about all the silicon needed to do that.

The DTMF generator we're designing is basically a two-chip circuit since most of the work is done by the 5088 that generates the tones. Although tone-generator chips are a far cry from an ASIC, it would take an impressive amount of silicon to replace them.

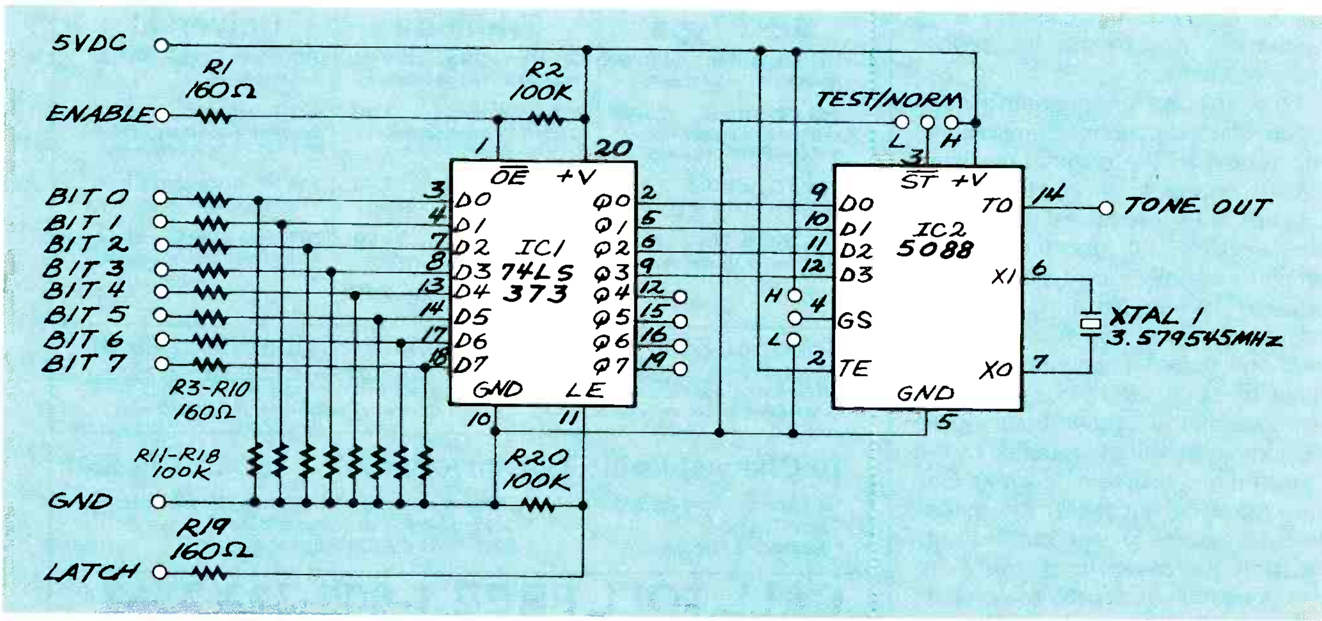


FIG. 1—THIS CIRCUIT COMBINES the latch layout we already developed with the 5088. With a bit of simple software, it will generate DTMF tones under keyboard or program control.

We've already laid out most of the circuit we need to implement our design, and all we have left to do (from the point of view of hardware) is to put it all together. The circuit shown in Fig. 1 combines the latch layout we already developed with the 5088 and, when we add a bit of simple software, will generate DTMF tones under keyboard or program control.

The first four data lines from the parallel port are used to talk to the 5088 through the latch. Even though the latch control of the 373 is brought out to the connector going to the parallel port, we can ignore it for a while by tying the enable line to ground. You can do this with a jumper on the breadboard or, if you want, seven of the pins on the parallel-port connector can be tied to ground. There were originally eight ground pins but remember that we modified one of them (I suggested pin 25) so that it would carry five volts and make it easier to power the circuit we're building.

The only thing new in the schematic is the colorburst crystal added across pins 6 and 7 of the 5088. That is the only component we have to add to the circuit to make it work. The jumper shown hanging off pin 3 allows you to tie the pin either high or low. Making it high will enable the chip to generate DTMF, and making it low will cause the IC to generate the high- and low-group tones separately. The selection of high or low group is made with the jumper at pin 4. If you tie pin 4 low, the chip will generate the low-group tones, and tying it high will generate the high-group tones. If you make pin 3 high by connecting it to +V, the chip generates DTMF regardless of the connection made at pin 4.

Although the circuit shown in Fig. 1 still has to have things added to it if you want to do practical things with it (connect it to the phone line, control a telephone, etc.), that doesn't mean it has no use at all. Since it's generating real DTMF, the output of the 5088 can be connected to any circuit that gets driven or controlled by DTMF tones. We'll talk about additional hardware later on but, for the moment, it's time to turn to the software part of the design.

Since this is the most basic hardware design we'll have for the circuit (other refinements will come later), it stands to reason that the software is going to be simple as well...at least at this stage of the game.

TABLE 1

5088 DTMF GENERATOR INPUT6 AND OUTPUTS

KEY PAD	D 3	D 2	D 1	D 0	HEX IN	OUT LOW	OUT HIGH
1	0	0	0	1	1	697	1209
2	0	0	1	0	2	697	1336
3	0	0	1	1	3	697	1477
4	0	1	0	0	4	770	1209
5	0	1	0	1	5	770	1336
6	0	1	1	0	6	770	1477
7	0	1	1	1	7	852	1209
8	1	0	0	0	8	852	1336
9	1	0	0	1	9	852	1477
0	1	0	1	0	A	941	1336
*	1	0	1	1	B	941	1209
#	1	1	0	0	C	941	1477
A	1	1	0	1	D	697	1633
B	1	1	1	0	E	770	1633
C	1	1	1	1	F	852	1633
D	1	0	0	0	0	941	1633

All we're interested in at the moment is writing a few lines of code to tell us whether the hardware is working or not. Since I want to keep things as broadbased as possible, I'll write the software in Basic.

Although you're free to drive the latch with any four of the many outgoing lines on the addresses that make up the parallel port, we can be nice and logical and use the data port. If the port you're working with is LPT1, the data port is at 3BCh or 956 decimal. Things aren't as clear with the other parallel ports, (LPT2, LPT3, etc.), since the addresses aren't fixed. LPT2, for example, can have its base address at 378h, 278h, or elsewhere.

As I talk about software, I'll be referring to LPT1. If you're using a different port, you'll have to substitute the proper addresses yourself. The hardware is set to pay attention to only the lower four bits of the data port and, as you can see from Table 1, the bit combination sent to the port will determine which one of the DTMF tones we generate.

The actual code we need to exercise the hardware is simple stuff since it's nothing more than a single OUT instruction. All we want to do is send the data shown in Table 1 on the

(Continued on page 90)

IC SPOTLIGHT

continued from page 66

Chips of a feather...

...come in sets together. Thanks to LSI Logic, you can now build an entire core of a workstation which is binary compatible with the SPARCstation-1, a reduced instruction-set computer (RISC)-based workstation made by Sun Microsystems, from a single 7-chip set. All that's needed to complete the system are peripherals and their controllers, boot PROM's, and the main and cache memories. Figure 1 shows a block diagram of the 7-chip system.

The chip set includes an integer processor, a floating-point processor, memory-management, direct memory access (DMA), standard I/O and bus controllers, and cache controllers and tags. At the heart of the system are two processors, the L64811 and L64815. The L64811 RISC-based integer unit (IU) has 136 general-purpose registers organized into eight-register windows. It has a four-stage pipeline, and can execute most commands in a single cycle, thus giving it 18–29 MIPS of performance. It also has two coprocessor interfaces, one for a user-definable coprocessor, and the other for the L64814 FPU. The L64814 performs double-precision operations at speeds of up to 6 megaFLOPS at 40 MHz. The FPU's controller section synchronizes the FPU with the IU and provides additional floating-point hardware support.

The L64815 is a cache memory-management controller that implements the SPARC Reference memory management unit's (MMU's) virtual address translation mechanism as specified by Sun and AT&T. Using a 64-entry translation look-aside buffer (TLB), this MMU implementation will be used in all future Sun workstations, and will support the next release of SunOS and UNIX System V, Release 4.

The L64815 also provides cache tagging, with the tag memory integrated into the IC. There are 2048 usable tags, giving the designer great flexibility in designing the memory subsystem. It can be made up of 32-, 64-, 128-, or 256-kilobytes of combined data and instruction cache memory, with line sizes of either 32, 64 or 128 bytes.

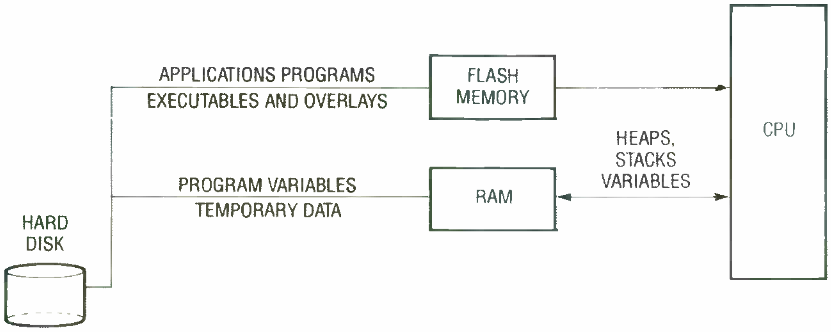


FIG. 2—FLASH MEMORY CAN BE used to store entire programs from disk. RAM is still needed, though, to store program heaps, stacks, variables, and other data that must change randomly throughout the program's run time.

The memory manager connects to the memory through a high-speed "M bus," which passes data to and from memory at a blazing 320-megabytes per second at 40 MHz. Peripheral controllers connect to both each other, as well as to the processors and memory through the Sun-developed "S bus," which pushes data through at 100-megabytes per second at 25 MHz.

The L64852 Mbus-to-Sbus controller is used to control the two buses. That IC has five primary functions: 1. to act as an Mbus arbiter, 2. to act as an Sbus controller, 3. it is an Mbus and an Sbus master/slave controller and data buffer, 4. it provides Mbus-to-Sbus protocol conversion, and 5. it is used for I/O memory management.

The set is rounded off by a main-memory controller, the L64850, a Standard I/O controller, the L64851 and a DMA controller, the L64853, which connects to a small-computer systems interface (SCSI) and local-area network (LAN) controller. Two versions of the system are the SparKIT-25 and the SparKIT-40, which provide 18 and 29 MIPS of performance, respectively. Both chip sets are used in LSI Logic's proprietary 0.7-micron HCMOS process. The SparKIT-25 is $1,327.00 per kit, in 1000-unit quantities.

Memory in a flash

As new types of microprocessors hit the scene, so too must new types of microcomputer memory to support them. One such new type of memory is the flash memory from Intel. Touted as non-volatile RAM, these devices are more similar to a higher-speed, lower-cost EEPROM's.

The chips are non-volatile in nature and data can be read randomly, but that's where the RAM similarity ends. Writing and erasing has to be done to the whole chip at once. Erasing an entire 1-megabit chip takes one second, while writing data to that whole chip takes four seconds.

A possible application of flash memory is shown in Fig. 2. Flash memory can be used to store entire programs from disk, which the CPU runs as if it were from RAM. RAM is still needed to store program heaps, stacks and variables and other data that must change randomly while the program is running.

Since they can't be written to randomly, flash memories will not likely replace a l of the RAM in any systems. They can be of great use, however, in reducing PC-board real estate in workstations that need a lot of memory to store running applications. Such applications will, of course, have to be rewritten to map temporary memory contents into RAM and keep executable and overlay files in flash. Of course, their first application will likely be as nonvolatile backup memory that will come into play in the event of a power failure or as storage in laptop computer systems.

The typical cost of Intel's flash memory chips varies according to the memory density. The price for a 1-megabit 28F010 is $18.70, and is sold in a DIP package. A 2-megabit 28F020 costs $34.80 in a DIP package, and $45.20 in a thin small-outline package (TSOP) used in surface-mount technology (SMT) designs. All prices are for 10,000 unit quantities. We'll see you next month for a look at the all but forgotten world of analog multiplier IC's and the role they play in phase-locked loops. **R-E**

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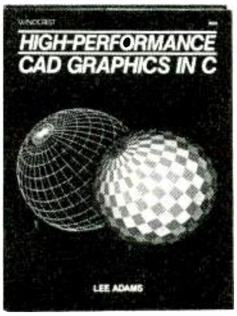

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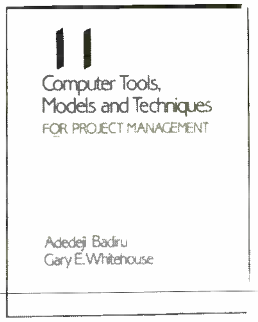

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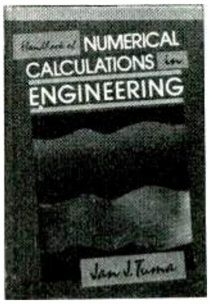

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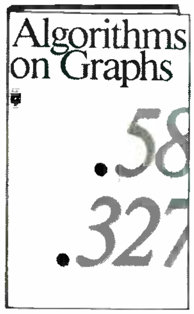

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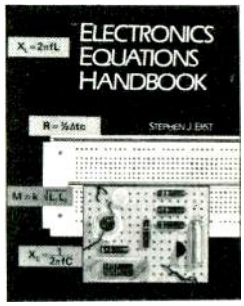

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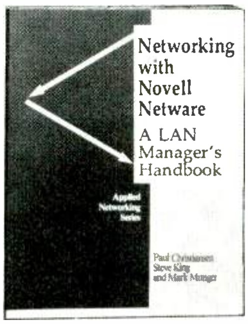

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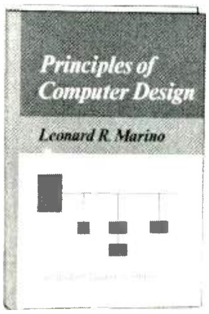

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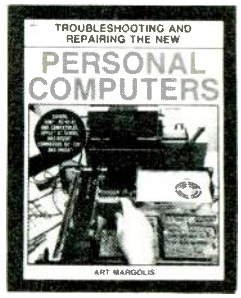

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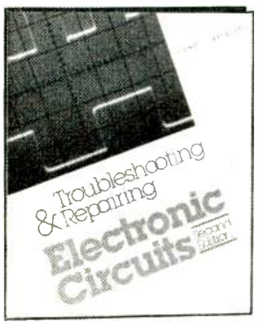

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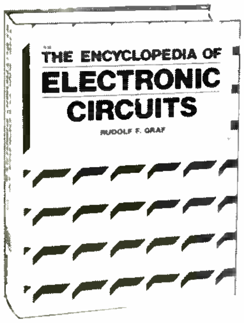

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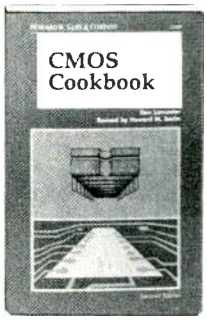

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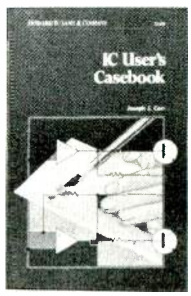

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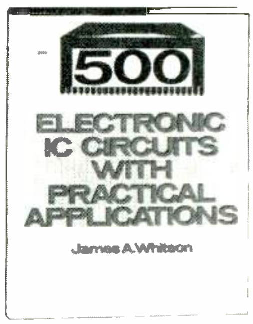

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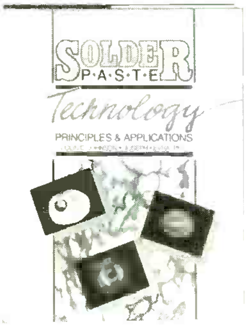

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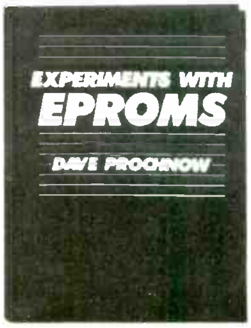

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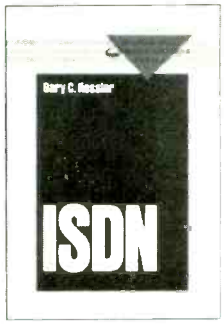

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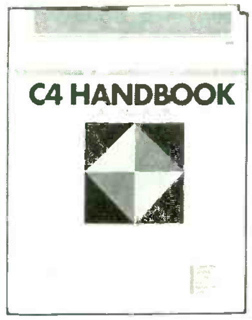

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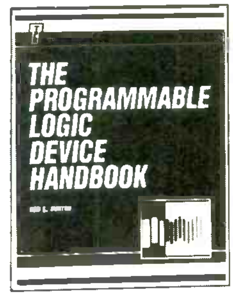

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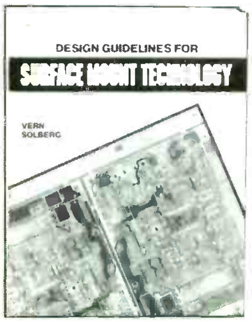
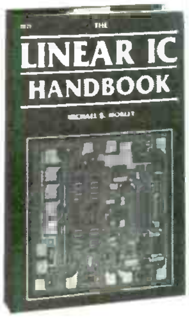
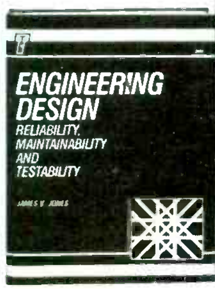
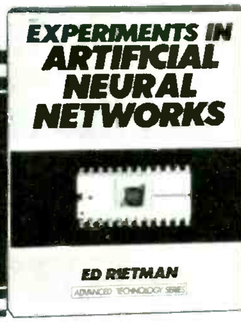
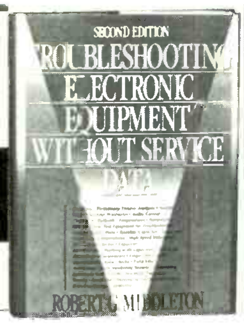
ELECTRONIC COMPONENTS

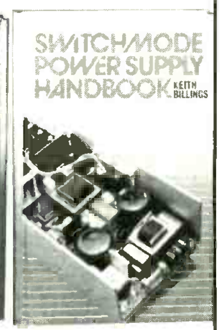












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Electronics Workbench, an electronic's lab simulation program

JEFF HOLTZMAN

You can throw away your solderless breadboard and spare parts junk box. Electronics Workbench (EWB) provides a full graphical simulation of an electronics lab, complete with breadboard, parts bin, and test instruments. The program allows you to build a schematic diagram of a circuit, simulate its operation, and display its output on a variety of test instruments, including a digital-volt meter (DVM), scope, eight-channel logic analyzer, Bode plotter, and so on. Building a circuit is simple and intuitive. Documenting your results is simple as well because the program provides nicely formatted printouts of everything, including the schematic, instrument readings, and parts list.

EWB comes on four floppy disks and requires about 1 megabyte of disk space, but it can run on a dual-floppy machine. You need at least 512K of RAM, a graphics monitor (Hercules, CGA, EGA, MCGA, or VGA), and a mouse. No extra memory or math coprocessor is required or used. Unfortunately, the current version of EWB costs $650, but the company, Interactive Image Technologies of Ontario, Canada, is working on a new "personal" version that should be priced for student and hobbyist use.

EWB actually consists of separate analog and digital modules; you cannot build "mixed" circuits. The digital screen is shown in Fig. 1. When you first start the program, the central area is blank; the figure shows a simple divide-by-two circuit. The screen is divided into three major areas. Across the top is a row of test instruments on the left, and program-control menus and icons on the right. Down the right side is the parts bin. To add a part to a circuit, you move it from the parts bin, place it where you want it, and connect it to other components. Unlike a real parts bin, there is an unlimited number of each component. The default parts bin includes items such as AND, NAND, OR, NOR, XOR, and NOT gates, as well as D, RS, and JK flip-flops. In addition, there is a half-adder, seven-segment LED display, discrete LED's, a ground, and +5-volt sources.

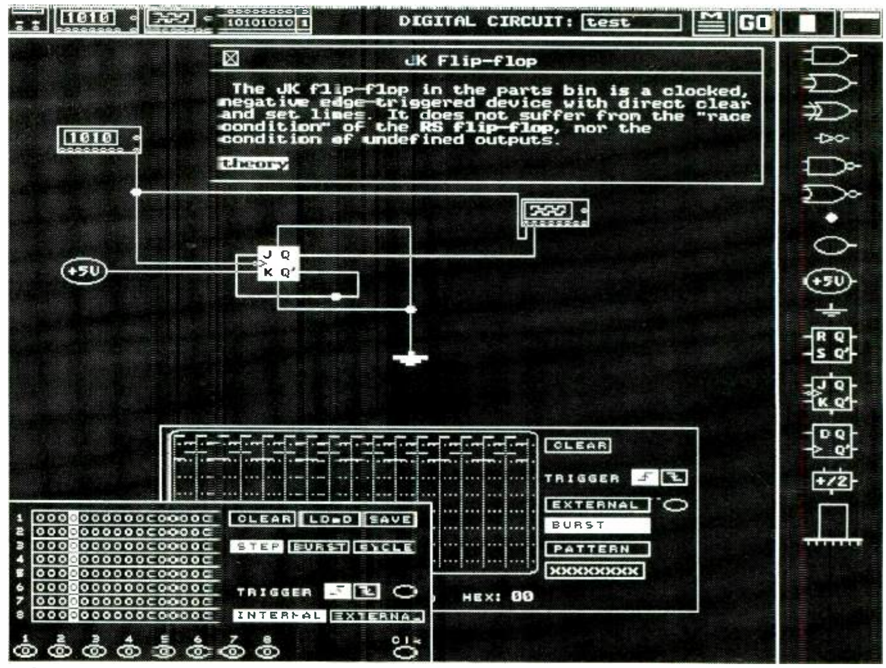

FIG. 1—THE ELECTRONICS WORKBENCH GRAPHICALLY simulates an electronics lab. In the digital module, you choose the components from a parts bin, build a schematic diagram on a breadboard, simulate its operation and display the output on a variety of test instruments.

You can even create your own parts using EWB's macro feature. For example, you might combine six hex-inverters and call the result a 7404. You can load and save parts bins independently of your circuits. You can give each part a label, and in the analog module, a value. Display of labels and values is normally disabled, but you can turn either or both on. The designations, however, often obscure the parts.

In Fig. 1, note that the K input is connected to +5 volts, the $\overline{Q}$ output is connected to the J input, and the CLR and PR inputs are grounded. Driving the $\overline{CLK}$ input is a pulse generator, with a zoomed-out view appearing in the lower left corner of the screen. The CLK output of the pulse generator drives the test circuit. Note, however, that the generator actually has eight outputs, and you can define 16-bit patterns to drive those outputs. Defining the bit patterns is somewhat awkward because you have to type in 1's and 0's; it would be easier and more logical simply to toggle a bit each time you clicked on it with the mouse. However, you can load and save bit patterns to disk files. The pulse generator has three different

ITEMS DISCUSSED

- Electronics Workbench ($650), Interactive Image Technologies, Ltd., 49 Bathurst Street, Suite 401, Toronto, Ontario, Canada M5V 2P2. (416) 361-0333.

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- *PC System Programming* ($59.95), *Turbo Pascal Internals* ($49.95), Abacus, 5370 52nd Street S E., Grand Rapids, MI 49512. (616) 698-0330.

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modes: 1) single step, in which one bit is delivered each time you click on the step button; 2) burst, in which all 16 bits are delivered sequentially; and 3) cycle, in which all the bits are output repetitively.

The output of the flip-flop is connected to a logic analyzer, a zoomed-out view appears *behind* and the pulse generator. The pulse generator drives channel one (shown in the upper trace) of the logic analyzer, the output of the flip-flop drives channel two (lower trace). Logic-analyzer options include positive, negative, and external triggering, and a display of the waveform, either as received or after receiving a pattern.

On-line help

EWB includes a top-notch on-line hypertext-based help system. Note that the text box of Fig. 1 describes the "JK Flip-flop". To get that type of description, you simply highlight a component and press F1. In that text box, the word *theory* is highlighted. You can click on it to receive a more-detailed description. It's hard to see in the figure, but "RS flip-flop" is highlighted as well. You can also click on it for comparative information. The help texts are brief summaries, so they are not really substitutes for full textbook explanations. However, the manual includes complete instructions for modifying and adding to the built-in help texts.

Moving from right to left, the icons in the upper right corner of the screen allow you to scroll through the parts bin, scroll the screen, start simulation, and drop down a command menu. The command menu allows you to get help; cut, copy, move, and rotate components; set preferences; and load, save, and print files. All common laser and dot-matrix printers are supported.

Moving from left to right, the icons in the upper left corner represent test instruments. First is a DVM, then the pulse generator, then the logic analyzer, then the "truth table." The latter converts digital circuits among three different representations; a circuit diagram, a truth table, and a

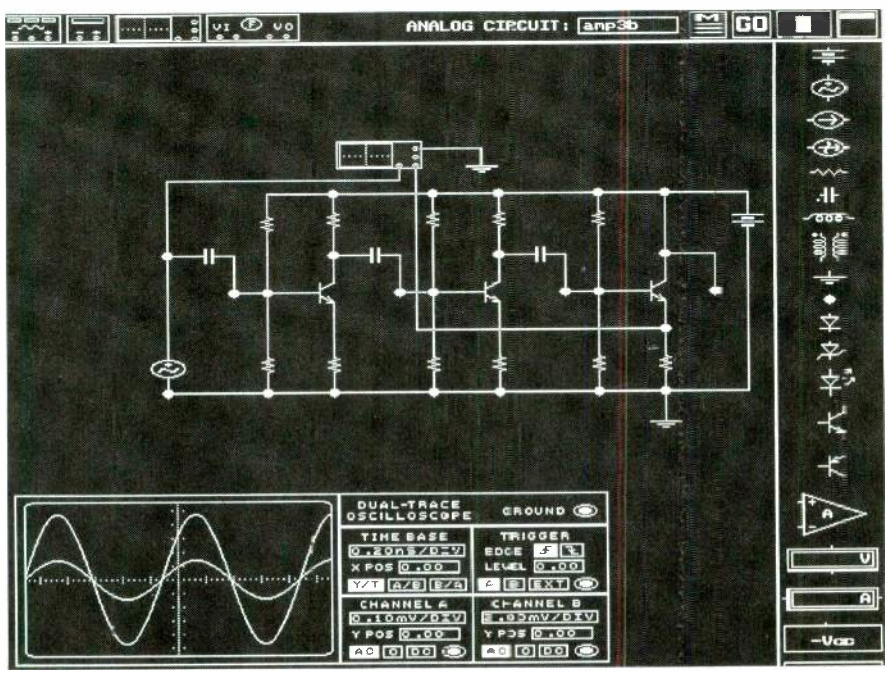

FIG. 2—EWB's ANALOG MODULE IS SIMILAR to the digital module except there are more components and different test instruments. Meter characteristics are ideal, but you can change their impedances to simulate real-world operation.

Boolean expression. You can create a circuit by filling in a truth table. On the other hand, you could attach it to a working circuit, get a truth table, and verify your design. EWB uses the Quine-McCluskey synthesis algorithm when going from a truth table to a Boolean expression.

You can place only one copy of each test instrument into a circuit, but after running a simulation, you can measure signals at various points as long as you don't change the circuit itself.

Analog module

The analog module works similarly, but there are more components and different test instruments. Components include resistor, capacitor, inductor, transformer, NPN and PNP transistors (but no FET's or MOS devices), diode, Zener diode, op-amp, battery, AC and DC sources. Test instruments include a function generator, DVM, dual-channel scope, and Bode plotter.

There are volt meters and ammeters in the parts bin; multiple copies of each may be inserted into a circuit. The function generator provides sine, square, and triangular waves; the frequency can range from 1 Hz to 999 MHz; you can also adjust the duty cycle, symmetry, amplitude, and DC offset. The DVM measures current, voltage, resistance, and dB. By default, meter characteristics are ideal (infinite impedance for voltage measurement, zero for current), but you can vary characteristics to simulate real-world conditions, and that's a nice touch. Similarly, you can alter the operating parameters of the active components, and load and save different models of the same component.

Conclusion

EWB is a wonderful program. It is limited in that you can't model very large circuits, nor (in the digital module) can you account for propagation delays, so you would never be able to model a high-speed 32-bit wide 486 bus.

But that's not what EWB is intended for. It's really intended for first-year college or university students coming to grips with the fundamentals, and in that sense, works admirably. At $650, EWB is much too expensive for individual purchase. I have discussed that with Interactive Images, and they are working on a lower-cost version.

I'd strongly urge you to write to the company as well. If the company sees a great deal of interest in the product, they would be more inclined to believe that they can make up through volume what they lose in the per-piece price.

Books from Abacus Press

I have just had the pleasure of perusing a couple of thick, dense books written by Michael Tischer and published by Abacus press: *PC System Programming* and *Turbo Pascal Internals*. Tischer's stated goal in *PC System Programming* is to provide a complete system overview, including detailed information on hardware, BIOS, and DOS.

Although that is an ambitious goal, Tischer for the most part manages to achieve it. The book consists of more than 900 pages of lucidly presented information with lots of example programs in assembler, C, Basic, and Pascal. All programs listed in the book (about 1 MB total) are included on a pair of floppy disks, which eliminates tedious and error-prone typing.

For example, the book contains an excellent discussion of device drivers (with examples), a set of routines for determining video-card type, using extended and expanded memory, determining CPU type, hard-disk partitioning, and a whole lot more. All in all, these books put to shame certain well-known volumes by certain well-known industry personalities. The Pascal book provides equal meat. For example, Tischer shows disassembled versions of standard Turbo functions and procedures, illustrating why DEC and INC are more efficient than PRED and SUCC, as well as X := X + 1.

Major topics include a complete window manager, a swap unit that allows your Turbo program to shell to DOS with a maximum amount of memory by leaving only a 1K stub behind, and another unit that allows you to build a multi-tasking system under Turbo. *Turbo Pascal Internals* has about 750 pages, and also comes with about 1 MB of source code. Neither book is for the beginner. However, if you've already mastered the basics of PC hardware and software, these books can provide a one-stop source for moving up to Guru status. **R-E**

MEMORY QUIZ

Find out how much you know about random access memory.

ALVIN G. SYDNOR

1—Most popular RAM devices are available in two types, which are:
(a) metal-oxide semiconductor (MOS)
(b) 64K bytes
(c) bipolar
(d) high-power

2—In dynamic memories, each storage cell is composed of:
(a) PNP IC's
(b) a single MOS
(c) a MOS-processed capacitor
(d) silicon chips

3—The term "performance" relates to how fast the RAM can operate in a given environment. That parameter is usually rated in terms of:
(a) bits per second
(b) transfer time
(c) time-temperature
(d) access time

4—Bipolar memories offer very high performance but have the disadvantage of:
(a) being very bulky
(b) operating at high voltage levels
(c) high power dissipation
(d) limited storage

5—The great advantage of dynamic RAM's (DRAM) lies in:
(a) long-term memory storage capabilities
(b) the small size of their storage cells
(c) low-voltage operation
(d) a long "refresh" time

6—The term "RAM organization" refers to the:
(a) physical size of the chip
(b) method of manufacturing
(c) grouping of the cells
(d) width of the memory word

Answers

1—(a and c) The two current popular RAM devices use bipolar and MOS technologies.

2—(b and c) In dynamic memories, each storage cell is composed of a single metal-oxide semiconductor field-effect transistor (MOSFET) and a tiny MOS-processed capacitor.

3—(d) Generally, the term performance relates to how fast the RAM can operate in a given system environment. This parameter is usually rated in terms of access time; that is, how long it takes the RAM to respond to a read or write command from the CPU.

4—(a and c) Bipolar memories offer very-high-performance capabilities, but are fairly bulky and dissipate significantly more power than the average MOS memory device.

5—(b) The great advantage of dynamic RAM lies in the small size of their storage cells, which makes it possible to achieve high densities. This also significantly reduces the cost compared to that of static RAM.

6—(d) Depending upon the organization of the device, the required number of active RAM's can vary. RAM organization refers to the width of the memory word. During their early inception, RAM's were organized as nK × 1 bits. **R-E**

CHRISTMAS CARD

continued from page 47

the microphone causes a voltage to appear. Do not increase the setting until R17 through R20 are adjusted so as to give a complete range through each bargraph. The best bet for making these adjustments is to play a stereo audio source (actually, any source will do) at a normal listening level. Simply adjust the potentiometers for what you consider to be a pleasing or most Christmas-like interpretation of the sound.

If you have any problems with the device, the first thing to do is decrease the setting (counterclockwise) of all the potentiometers. A filter that still oscillates after decreasing the potentiometers most likely has an incorrect component or one that does not meet its tolerance.

For high-Q versions of the circuit, sometimes the component tolerance is such that the filter will begin to oscillate when presented with a large input. If that's the case, all you must do is interchange the two filter capacitors; this old technician's trick usually works, assuming that there aren't any problems with the other components.

If you still have problems, check that the analog ground is stable. A variation on that line will cause serious problems with the operation of the unit. If you cannot find the problem, the best thing to do is to shut off the display by lifting one lead of both R1 and D5. With the load of the display removed, it's easier to locate problems.

The finished, working board can be installed in any kind of housing you like, although the custom black metal frame adds a nice touch, as does the mat that keeps the circuitry from view. After installing the unit in the frame you may want to readjust the potentiometers, since the frame and front glass seem to couple the microphone to the surrounding air. Vibrations picked up by the device will also produce a display; a fan operating nearby is almost always displayed. Have fun, and don't forget to have a merry Christmas, as well! **R-E**

DRAWING BOARD

continued from page 79

lower four bits of the data port associated with the parallel port you're using (LPT1 in this example).

Since the four most significant bits at the data port aren't being used (at the moment), it doesn't matter what value we give them. I'm mentioning this only because the OUT instruction will send a full byte out to the port. An instruction such as OUT 956,1 will send the same four least-significant bits to the port as an OUT 956,177. Those two numbers may look very different but the similarity between the two shows up when you think of the numbers in hex instead of decimal.

Since you want the lower half of the byte to be a 1h, any number can be stuffed in the upper half of the byte. A 177 decimal is B1h, so it will be the same (as far as our circuit is concerned) as a 01h, 21h, 31h, and so on.

The output of the 5088 can be fed into the line input of a standard amplifier or, if you're a DTMF freak, you can probably connect it to a set of high-impedance headphones. There's no guarantee of the initial state of the lower four bits so there's no telling what tone you're going to hear when you first connect the circuit to the port.

If you've wired up everything properly, you'll hear the tones change as you send different data out the port but, as you may have noticed, all the possible values you can put on the lower four bits are legal input codes for the 5088. That means there's nothing you can send to the port to shut the circuit off. While that won't cause any electronic problems, it can still cause a bit of brain damage. There's an easy way around that however, since the TONE ENABLE input (pin 2) is specifically designed to take care of the problem.

You can tie that pin to one of the other data lines—bit 7 is a good choice—and use that data line to turn the chip on and off. A high on the data line will enable tone generation and a low will disable it, no matter what data is being sent on the lower four bits.

When we get together next time we'll finish this thing off by adding some circuitry to control the phone line, a telephone, and a few other things. See you then. **R-E**

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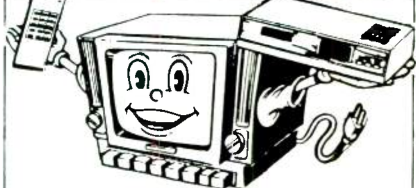

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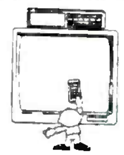

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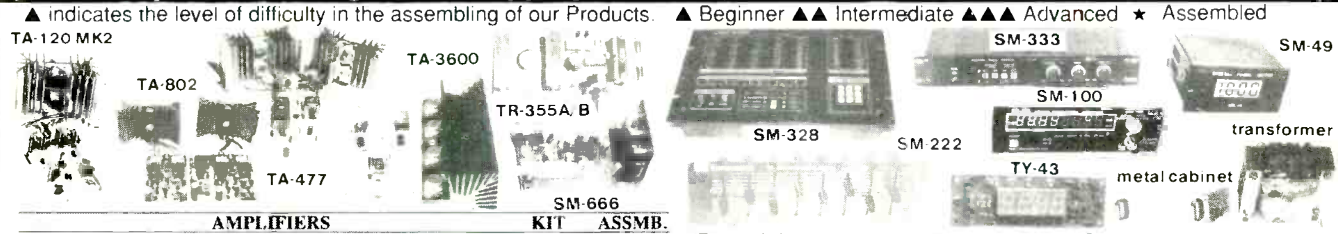

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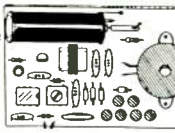

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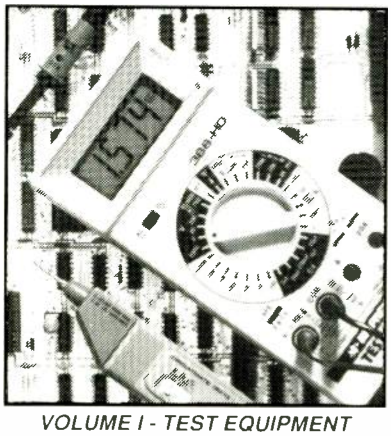

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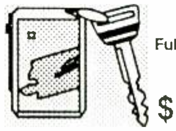

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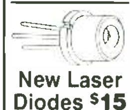

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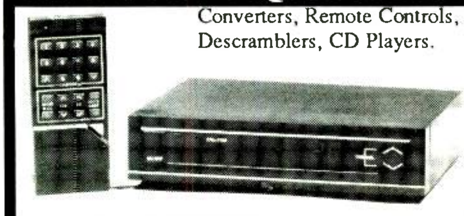

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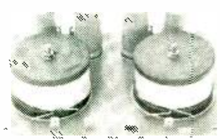

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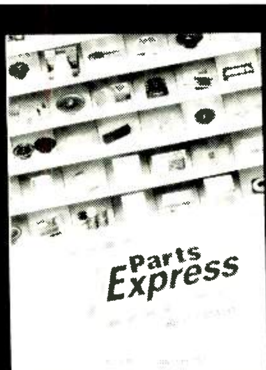

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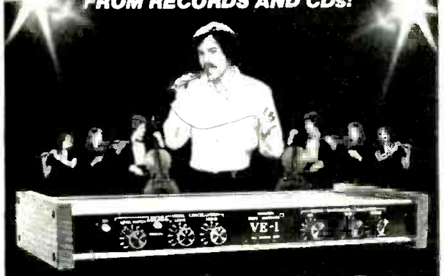

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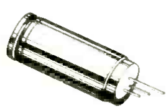

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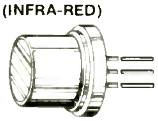

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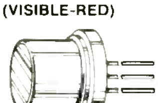

- Output: 5 mW (max.)
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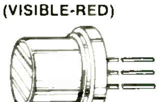

- Output: 4 mW (max.)
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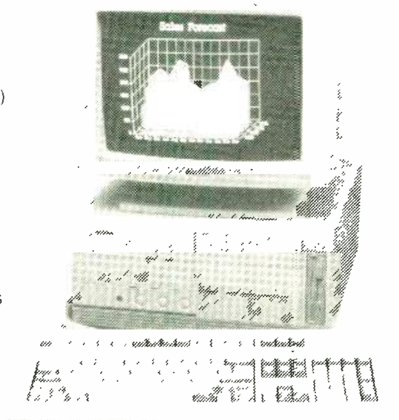

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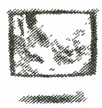

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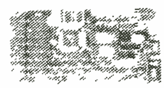

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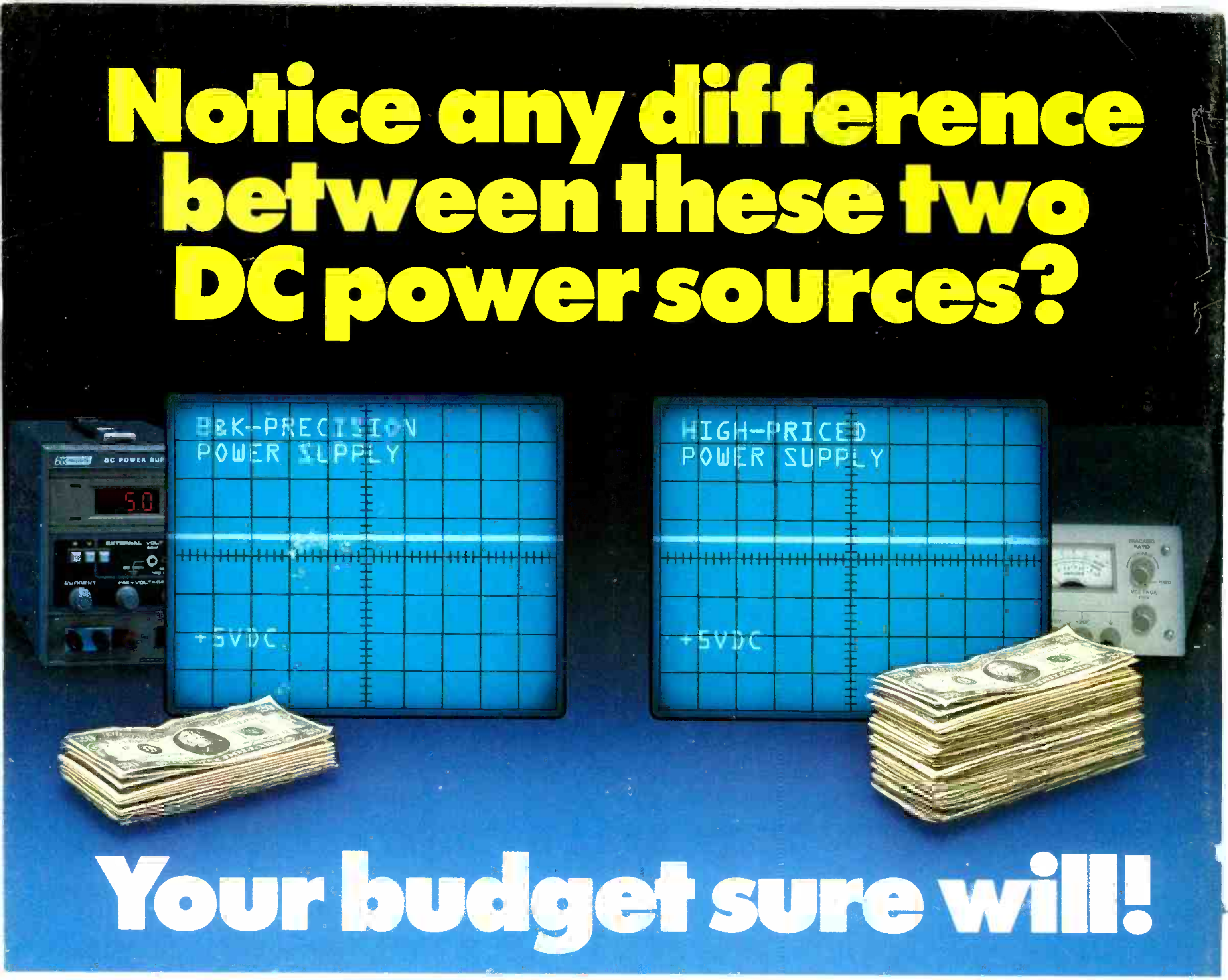

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