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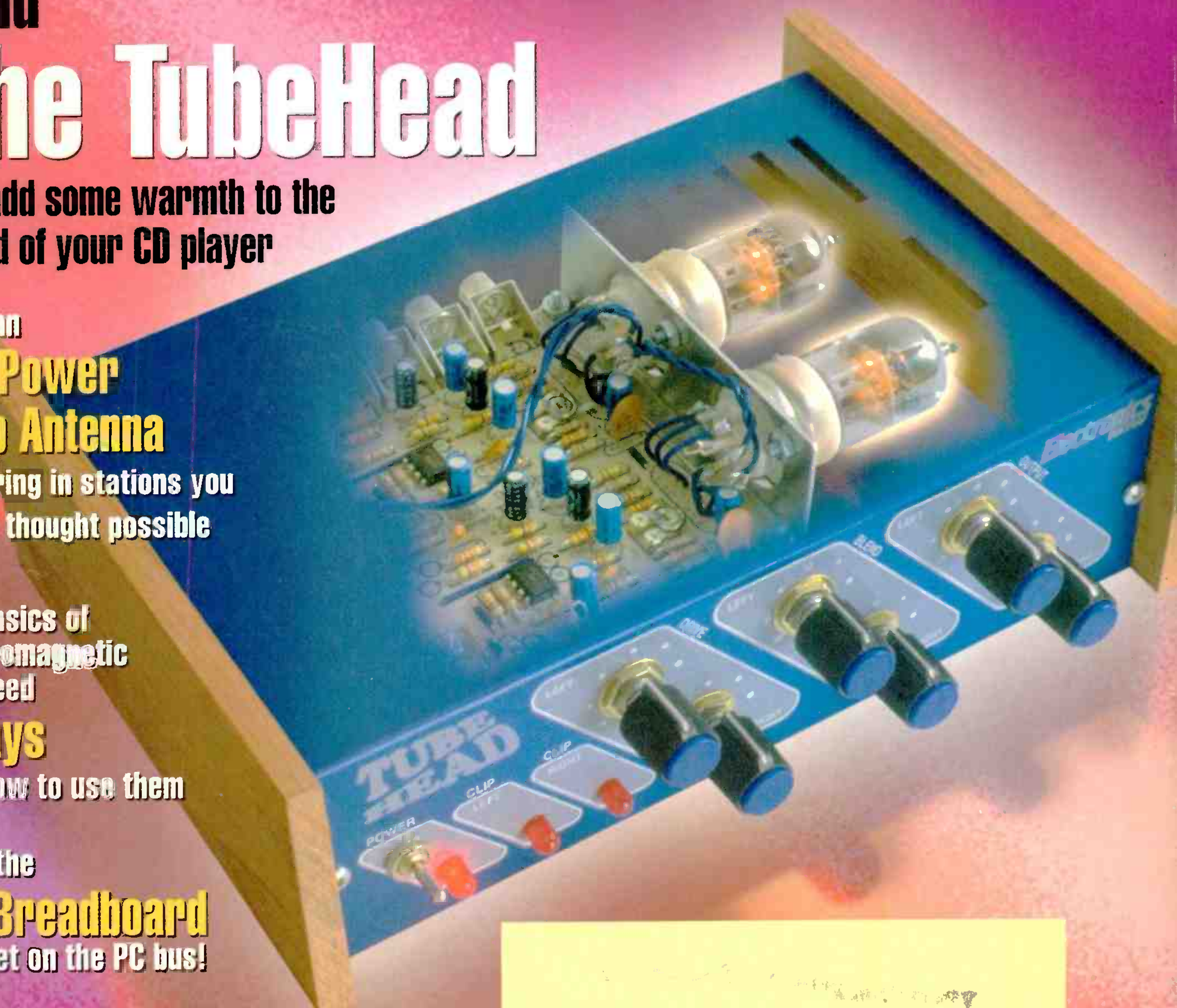

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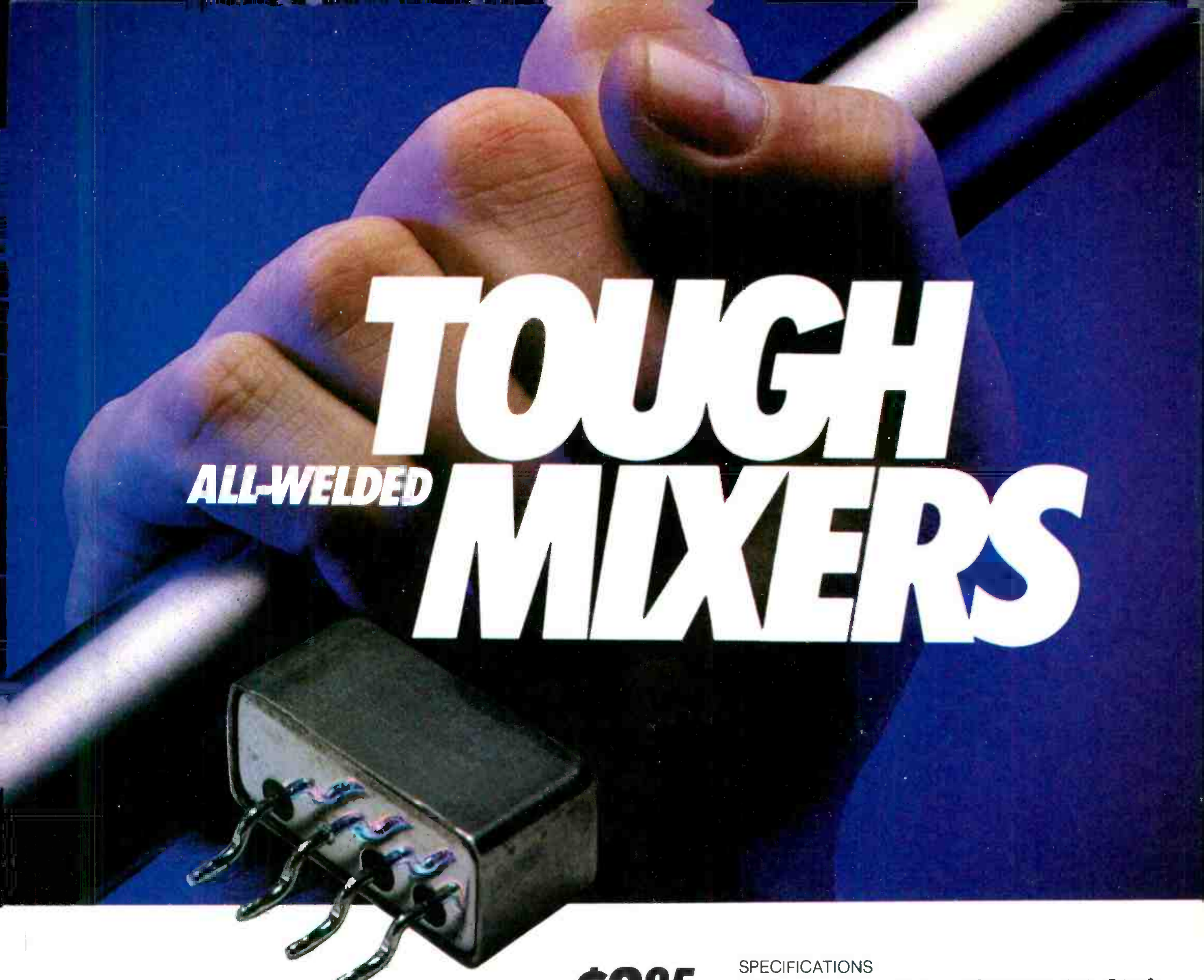

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SPECIFICATIONS

Model	LO Power (dBm)	Freq. LO/RF (MHz)	■ Conv. Loss (dB) $\bar{X}$	δ	Isol. L-R (dB)	Price,$ Ea. 10 qty
TUF-3	7	0.15-400	4.98	0.34	46	5.95
TUF-3LH	10		4.8	0.37	51	7.95
TUF-3MH	13		5.0	0.33	46	8.95
TUF-3H	17		5.0	0.33	50	10.95
TUF-1	7	2-600	5.82	0.19	42	3.95
TUF-1LH	10		6.0	0.17	50	5.95
TUF-1MH	13		6.3	0.12	50	6.95
TUF-1H	17		5.9	0.18	50	8.95
TUF-2	7	50-1000	5.73	0.30	47	4.95
TUF-2LH	10		5.2	0.3	44	6.95
TUF-2MH	13		6.0	0.25	47	7.95
TUF-2H	17		6.2	0.22	47	9.95
TUF-5	7	20-1500	6.58	0.40	42	8.95
TUF-5LH	10		6.9	0.27	42	10.95
TUF-5MH	13		7.0	0.25	41	11.95
TUF-5H	17		7.5	0.17	50	13.95
TUF-860	7	860-1050	6.2	0.37	35	8.95
TUF-860LH	10		6.3	0.27	35	10.95
TUF-860MH	13		6.8	0.32	35	11.95
TUF-860H	17		6.8	0.31	38	13.95
TUF-11A	7	1400-1900	6.83	0.30	33	14.95
TUF-11ALH	10		7.0	0.20	36	16.95
TUF-11AMH	13		7.4	0.20	33	17.95
TUF-11AH	17		7.3	0.28	35	19.95

*To specify surface-mount models, add SM after P/N shown.
■ $\bar{X}$ = Average conversion loss at upper end of midband ($f_U/2$)
δ = Sigma or standard deviation

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TECHNOLOGY

DEPARTMENTS

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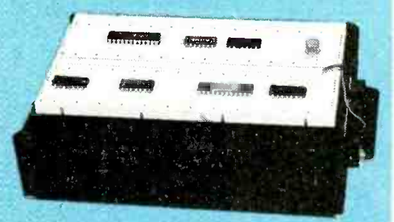

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AND MORE

ON THE COVER

Although most of us love CD's for their sound quality as well as their convenience, many audiophiles feel that compact discs lack the depth and warmth of albums, and that today's sophisticated digital components just don't measure up to the old-fashioned, tube-based gear. We won't take sides in that heated argument, but we will give you the opportunity to judge for yourself the difference that tubes can make. The TubeHead is a final stage amplifier for your CD player that can soften the sometimes harsh sound of compact discs. The hybrid circuit uses both tubes and low-noise solid-state op-amps, allowing you to adjust the amount of sonic coloring to suit your individual audio preferences: crisp solid-state transparency, tube-amp warmth, or anywhere in between. Turn to page 33 for all the details.

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WHAT'S NEWS

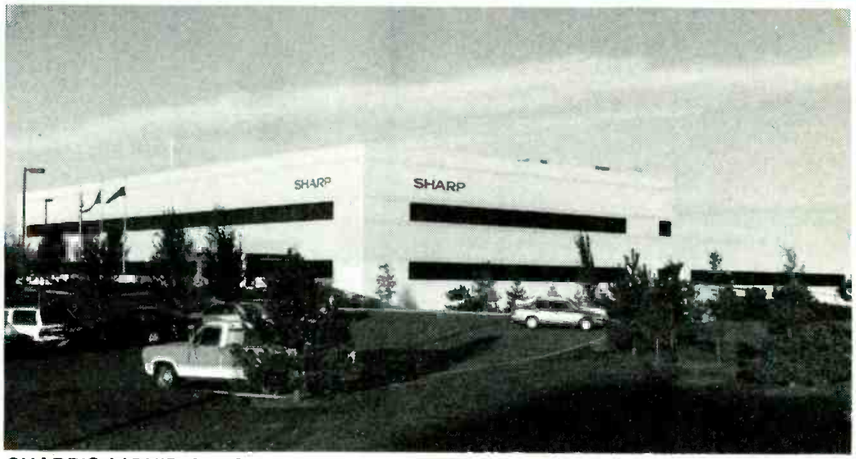
A review of the latest happenings in electronics.

Sharp to manufacture LCD's in U.S.

Sharp Electronics Technology, Inc. has announced plans to produce color active-matrix liquid-crystal display (AMLCD) panels for battery-portable computers at its present plant in Camas, WA.

A 53,000-square-foot expansion of an existing building will house Sharp's first AMLCD manufacturing facility outside of Japan. Company officials say the plant will have a start-up capacity of 10,000 AMLCD modules per month. The expansion will also allow Sharp to increase the production of large-format, passive-matrix color LCDs to 10,000 units per month.

The expansion will be big enough to include a new technology development center for research and testing of LCD technologies. Sharp reports that it will add about 160 new jobs when the production and research facility is fully operational in 1995.



SHARP'S LIQUID-CRYSTAL DISPLAY facilities in Camas, WA, will be expanded by 53,000 square feet for Sharp's first active-matrix LCD (AMLCD) manufacture outside of Japan.

1000-channel cable TV transmission system

In news related to HDTV, General Instrument Corporation (GI) and Zenith Electronics Corporation have signed a cross-licensing agreement under which GI will be the first company to license the 16-level vestigial sideband (16-VSB) digital transmission. This technology is expected to increase the digital information that can be transmitted on cable-TV systems significantly without additional video compression.

According to Zenith, 16-VSB will expand the capabilities of digital cable-TV systems from the reported 500 channels to 1000 channels. The system is expected to transmit and receive 43 megabits of digital information per second. That represents 33% more data than can be handled by the proposed 64-QAM (quadrature amplitude modulation).

Not only will costs be lower, Zenith says, but it will have twice the data capacity of 32-QAM technology. Depending on the amount of compression, the 16-VSB decoder will be able to receive as many as 23 movies or nine live televised events in each 6-MHz analog cable channel. The system will also send two digital HDTV signals on a single 6-MHz channel.

The integrated circuits for the 16-VSB TV settop decoder box are expected to be available in quantity late in fourth-quarter 1994. The key digital device is being developed jointly by Zenith and LSI Logic Corp., while a 16-VSB analog chip is being developed in conjunction with Raytheon Company.

Zenith, also under the cross-license agreements, is licensing DigiCipher access control, digital compression, and QAM transmission technologies from General Instrument. Those technologies will complement Zenith's work in MPEG-2 digital compression.

Fiber-optic "FISHNet"

Cablevison System Corporation of Woodbury, NY has opened a stretch of the "information superhighway." It has announced FISHNet for Fiber-optic, Island-wide, Super High-speed Network. The network will be an interactive link between researchers and physicians at three Long Island-based institutions: the Brookhaven National Laboratory, the State University of New York at Stony Brook, and Grumman Data Systems, the system's integrator and software developer.

FISHNet is one of the first systems based on asynchronous transfer mode (ATM) technology. With ATM technology, information is processed into 53-byte cells that permit it to be moved in bursts. As a result, system users can send more data at higher rates and obtain better image quality than is now possible with coaxial cable.

At FISHNet's announcement held at the Brookhaven Laboratories in Upton, NY, three applications were demonstrated. During an X-ray scan of a heart, the high-speed ATM link allowed Stony Brook physicians to study and manipulate the images taken at Brookhaven s National Synchrotron Light Source.

Doctors at Brookhaven and Stony Brook jointly conducted a radiology/oncology examination with medical image manipulation and real-time teleconferencing. Finally, a groundwater prediction model helped researchers track the movement of pollutants in groundwater supplies. Ω

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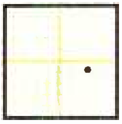
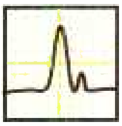


One Point Captured. Single event capture using Equivalent Time Sampling. 20 MS/s 100 MHz DSO.



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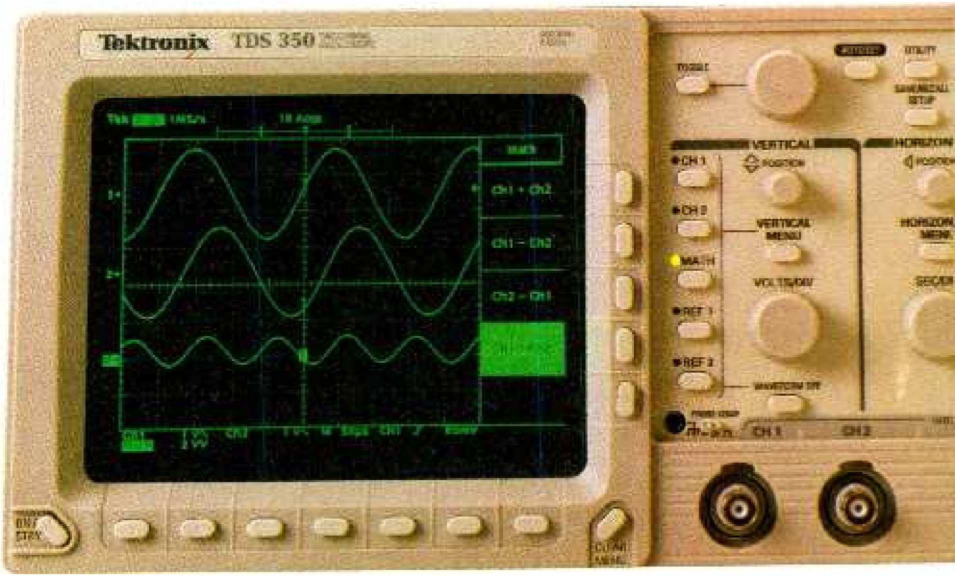

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Channels	2	2	2
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Vertical Resolution	8 bits	8 bits	8 bits
Record Length	1K/channel	1K/channel	1K/channel
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VIDEO NEWS

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

DAVID LACHENBRUCH

• **More brands die.** Sylvania is the latest old-line TV brand to disappear from the scene. That brand name is being discontinued by Philips Consumer Electronics, whose Netherlands-based parent bought the brand name at the same time it bought the Philco and Magnavox names. Magnavox has proven to be the major attraction among the plethora of Philips brand names (including its own Philips brand), so Philips has decided to concentrate its marketing efforts on the Magnavox name. It bought the famous Philco name from General Telephone and Electronics, which in turn bought it from Ford.

Philco was a major innovator in the early days of television, holding many patents in color and monochrome, but it is now virtually a private brand for K-mart stores. The Sylvania brand will be dropped this year, but it could be revived later for special products. Interestingly, the Philips brand line is being reserved for high-tech innovations. In Europe, the Philips brand line is a mainstream bread-and-butter brand.

• **Japanese HDTV flops.** The trade and technical press has been extremely polite in its assessment of the success of the Japanese Hi-Vision HDTV system to date. But when an official of Japan's Posts and Telegraph Administration admitted that the analog satellite-delivered system was a loser, everybody jumped on the bandwagon—except the Japanese TV manufacturers, of course. When the chief of the Broadcasting Bureau of the Post Office Department said that Japan might discontinue its 20-year experiment in analog HDTV and join with other countries in developing a digital system, the nation's TV-set manufacturers—which had been trying to sell Hi-Vision TV sets—reacted violently. Backtracking, the chief said that he really meant that a new system would be tried some time in the 21st century—excuse me. But the lid was off, and despite some apologies and face-saving, the subject has now been brought into the open. Consequently, there is now more talk in Japan of adopting a digital system.

In Europe, where plans for an analog system collapsed, work is now in progress toward developing a digital system. And there is now hope for a unified world system, or at least compatibility among the world's TV systems at some point in the future.

• **Widescreen vs. HDTV** Widescreen TV sets with a 16:9 aspect ratio (as opposed to the standard 4:3) have been selling well in Japan—so well that it was forecast that widescreen will take over the large-screen market completely this year. Even before the officially expressed doubts about the analog HDTV system, a real fear was expressed that widescreen would cut into the market for HDTV sets. Widescreen sets are now outselling the HDTV sets by about 10-to-1 in Japan. And widescreen presents the most obvious visual appeal of HDTV: a movie-screen proportioned picture. While some manufacturers see widescreen as a stepping stone to HDTV, most think that any purchases now represent HDTV purchases lost or deferred. The lesson hasn't been lost on American manufacturers, who are beginning to push widescreen sets now. They are worrying about what the impact will be on their efforts to push more expensive HDTV sets when they become available.

Thomson Consumer Electronics has been the major proponent of widescreen TV's in the United States. The 34-inch (diagonal) RCA G34170, with built-in storage for a laserdisc player, VCR, discs and tapes, has a suggested retail price of $4,499.

So far, widescreen sets haven't sold that well in the United States. Although several manufacturers are offering them, sales have been low—numbering in the low thousands in 1993. However, in Japan, 210,000 widescreen sets were sold last year, and some manufacturers are forecasting sales as high as 1,200,000 this year, despite a serious recession in Japan. Even in Europe, where economic conditions have been depressed for the last two years, widescreen TV sales have been reasonably good compared to the United States.

The main difference between those two regions and the U.S. is the amount of widescreen programming available. Broadcasting of letterbox product is common in Europe and Japan, and there is none in the U.S. Here, widescreen fans depend on laserdiscs, but laserdisc players are few and far between in the general populace. Some manufacturers—notably Thomson Consumer Electronics, now the owner of the RCA brand name—are promoting widescreen programming on cable, tape, and disc.

Those same manufacturers are sponsoring, or at least looking forward to, HDTV. But there are those who say that every widescreen TV set sold today represents an HDTV set that won't be sold to anyone tomorrow.

• **Videogame battles continue.** The hottest fight ticket in town is the battle between Sega and Nintendo. The upstart Sega has thrown the erstwhile champ Nintendo off balance with a big year in 1993. Now the two game giants are engaged in infighting. Standing on the sidelines is Philips with its CD-i system, which isn't billed as a game at all, but as an educational-entertainment multimedia wonder. Now CD-i's principal competitor, 3DO, has suddenly gotten more competitive. It had been counted out of the race because of its high price, but suddenly Panasonic—the only 3DO hardware producer as of this writing—reduced the price of its console from $699 to $499, and The 3DO Company promised to prime the pump by producing its own software.

At the same time, the two major Korean electronics manufacturers, Samsung and Goldstar—both known for their aggressive pricing—have signed 3DO licenses and promise to offer hardware in the United States shortly. Ω

Q & A

Write to Q & A, Electronics Now, 500-B Bi-County Blvd., Farmingdale, NY 11735

CMOS PARANOIA

I'm starting to work with CMOS ICs, and I've found that all the specification sheets warn about the potential for damage caused by electrostatic discharge (ESD). I know that there are wonderful advantages to the CMOS family such as noise immunity and low power dissipation, but I'm concerned about the issue of ESD damage. Is it true that do I really have to worry about this?—P. Fleming, Greenwich, CT

Do not disregard the warnings because there is a real possibility of electrostatic discharge damage. On the other hand, I have to say that I've been pretty cavalier in working with with CMOS ICs over the years, and I have never had any damage to parts caused by ESD.

One advantage of a CMOS IC is that it draws appreciable power only when it changes state. Unfortunately, that's also the reason for its susceptibility to ESD. As shown in Fig. 1, each of the transistors in a typical CMOS inverter has a small gate capacitor at its input. (That's also why current draw is so low—during the time that the gate is in a steady state, current in the microampere range is all that's needed to maintain the charges on the two capacitors.) The input capacitors are extremely fragile, and it doesn't take much electrostatic discharge to damage their thin dielectric insulators permanently.

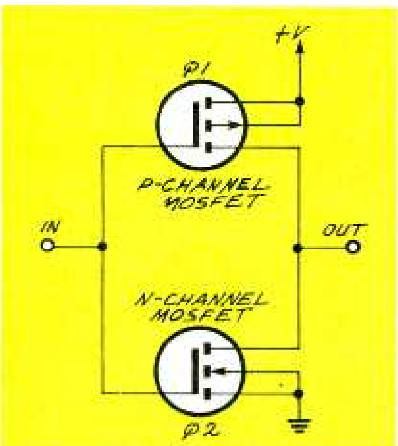


FIG. 1—A TYPICAL CMOS INVERTER. Each transistor has a small gate capacitor at its input. The input capacitors are extremely fragile, and it doesn't take much ESD to damage them permanently.

Reasonable precautions can keep the possibility of ESD damage down to a bare minimum. There are no absolute standards I can give you, but you can take some comfort from the fact that CMOS input protection has been improved over the years. Some time ago I built a CMOS-based device and, for reasons that are unimportant, I soldered the connecting wires directly to the IC pins. The ICs were glued together, one on top of the other, and when I had to change the circuit it was necessary to drill out the IC, glue another one in, and again resolder right on the pins.

I did that several times and never once did an IC "blow up." I know that test isn't scientifically significant, but it does indicate that CMOS isn't quite as fragile as you might imagine from reading data sheets.

OS/2 OR DOS?

There seems to be a lot of competition between the operating systems for IBM-compatible PCs. It seems that DOS is coming to an end soon, and the two main choices will be either some version of IBM's OS/2 or a variation on Microsoft's Windows. I'm familiar with DOS, but I have almost no experience with the others. I'd like to start learning about them, but I don't want to learn both. Do you have any thoughts about which system I should choose?—G. Fishdel, Bogota, NJ

Unfortunately I just sent my crystal ball out to be recharged, and my cable company doesn't carry the Psychic Friend's Network, but because you're looking for an opinion, I'm sure I have one of those around here somewhere.

To start off, I don't think you should write off DOS at this time. The high rate of progress in the computer industry is often at odds with the high level of conservatism among computer users. It's a safe bet that DOS will be around for quite a while yet because most users (particularly businesses) are less interested in operating systems and more interested in applications. Their principal reason for having a computer is to run particular software, and as long as they can run the applications they need to, the underlying operating system is really a non-issue.

I do agree that as time goes by, more and more computers are going to be using a graphics-based operating system, but there's no way to tell whether Microsoft, IBM, or some other company is going to capture the majority of the market. All we can do is look at the market now and make an intelligent guess about what's going to happen in the next five to ten years.

I don't have current numbers, but there's no argument that the most popular PC graphic operating system at the moment is Windows. Although it's only a 16-bit system, I suspect that the 32-bit version will be available in the next few months. When that shows up, you can bet that there will be no end of comparative reviews in the computer press.

OS/2 is supposed to be able to run both Windows and DOS programs in their native modes with no problems, and maybe that's true. I suspect that claim is made because there's not a whole lot of native OS/2 software available now—just take a trip to your local software store and you'll see what I mean. OS/2's hardware requirements are significantly greater than Windows', so I'd guess that the installed OS/2

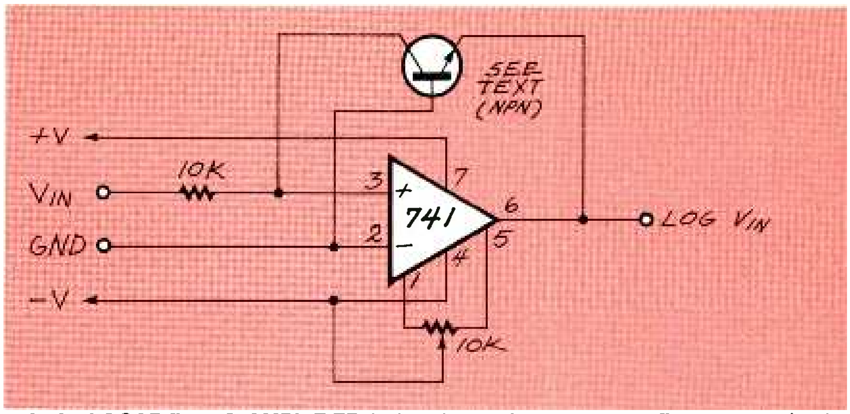


FIG. 2—LOGARITHMIC AMPLIFIER built with a single op-amp. The current in the feedback loop of the op-amp is equal to the current flow at the input of the op-amp.

base will always lag behind the installed Windows base.

The last consideration is the "hassle quotient" of doing the installation. I've installed Windows more times than I can remember, and in well over 95% of those cases there weren't any problems. In my experience, the success rate for OS/2 is much lower. As a matter of fact, I don't know of any installation that worked the first time around. The bottom line is that Windows is apparently a much more mature product than OS/2, and its bug count is much lower.

A lot of letters will probably show up on this subject but, given the way things are at the moment, I think your best choice is to spend your time studying Windows.

LINEAR TO LOG

I'm building a circuit that has to give me a logarithmic output for a linear input. I've found several circuits that can do this, but they all seem extremely complicated. Do you have any simple circuit that can help me?—A. Blumenthal, Lexington, KY

Those used to be really common circuits, especially in meter drivers and audio compressors, but I don't see them very often these days. I guess this is another consequence of the digital revolution.

The schematic in Fig. 2 is a basic logarithmic amplifier built with a single op-amp. This setup is often referred to as a "transdiode" circuit because the op-amp output is equal to the base-emitter voltage of the transistor. The current in the feedback loop of the op-amp is equal to the current flow at its input.

Since the input current is proportional to the voltage across the input resistor, it's also proportional to the collector current in the transistor. The base-emitter voltage of the transistor is related logarithmically to the collector current, so the output of the op-amp will vary logarithmically with its input voltage.

Although the circuit is built with a 741 op-amp, you can use any op-amp you have handy. The transistor, however, should give high-gain and be capable of handling the power at that part of the circuit. Since you're using it only to drive a meter, you can probably get by with a transistor like a 2N3391. The potentiometer lets you trim the circuit to take into account the offset introduced by the op-amp.

Because the log of one is zero, you should feed the amplifier with one unit of positive signal and tweak the potentiometer to get zero out of the op-amp. The accuracy you're going to get depends on the gain of the transistor, the temperature, and the value of the input signal.

FOLLOW THAT NOISE

I'd like to be able to trace live circuits back to their source panel without having to find the wires in the walls and follow the conduit runs. Commercial instruments that do this are fairly expensive. Do you know of a simple circuit that will do the job?—M. Reisen, Irving, TX

Yours is one of those questions that shows up here every few years. I know what a pain in the neck it is to follow wires in walls, and I agree that it's a bit tedious to sneak around

Continued on page 31

LETTERS

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

CORRECTIONS

Some errors in "The Lost Art of Regeneration" (*Electronics Now*, March 1994) should be corrected.

In Fig. 1, Diode D1 should be reversed. In Fig. 8, pin 7 of ICl should be connected to the positive side of battery B1, and the missing value of capacitor C6 is 0.1µF. In Figure 11, the schematic should show that the collector of Q1, capacitor C1 and L2 are all connected because the crossed wires are connected. I hope that no readers have been inconvenienced by these errors.

CHARLES KITCHEN
Wilmington, MA

REGENERATION REEXAMINED

The title of the article, "The Lost Art of Regeneration" (*Electronics Now*, March 1994), is misleading. Regeneration was not "lost," it was legislated out of existence because receivers based on that principle became transmitters that annoyed radio listeners for blocks around.

When the regenerative control was advanced to the oscillation threshold on sets that were coupled to the long antennas used in those days, the whistles generated could be picked up miles away. Moreover, superheterodyne receivers were becoming more popular at that time.

The article omitted some other items of interest: For instance, many different materials worked as detectors in crystal sets; among them are coal, razor blades, copper oxide and some iron ores.

The most popular way to cause regeneration in my part of the country was with about a 250-kilohm potentiometer shunting the tickler coil, and a B+ voltage applied to the slider. You might warn listeners of regenerative sets (old or new) to prevent them from oscillating or they might get a visit from the FCC in the United States—or the DOC in Canada.

Incidentally, super-regenerative circuits were developed into superhets by amplifying the difference frequency produced in an IF circuit. Those were usually called *autodyne* circuits.

S. BIALKOWSKI
Lethbridge, Alberta, Canada

RESTORING VINTAGE RADIOS

I read with pleasure Marty Knight's article, "Vintage Radio," in the January issue of *Electronics Now*. I was disappointed, however, when I found no mention of some of the "old-timers" still out there repairing and advising on the repair of those radios. One of them is my 94-year-old uncle, Leslie Restine, of Fort Smith, Arkansas, who has been involved with radios since the early 1920's.

I am sure there are many more senior experts out there, and that many collectors and wannabe collectors would like to know who they are. Their experience would be invaluable in helping the collectors get through the problem areas (and there are so many) of restoring vintage radios. A follow-up article on this would be great.

Nevertheless, while Mr. Knight might be a whiz at the electronic end of radios, his advice on restoring wooden cabinets is off the mark, and could lead to damaging the wood and finishes. Some of those cabinets were and are real works of art, and cleaning them with today's "mild detergents" could destroy them.

The advice that Knight should have given to persons unfamiliar with restoring antique radios is to start by getting a good book on restoring antique furniture before attempting antique radio restoration. Then after reading and learning from it, they would be less likely to destroy the cabinet inadvertently.

The so-called "mild detergent" you might use to clean fine china could easily soften the glue between the laminations, mottle the finish, or worse. Modern detergents and woodworking chemicals are much harsher than those in use up to the 1940's.

CHARLES A. NAPIER
Uijongbu, Korea

ANSWERING THE AUDIO-SCRAMBLER CHALLENGE

I am responding to Michael Harwick's critical letter (*Electronics Now*, April 1994) about what he alleges is a "design flaw" in my Audio Scrambling System circuit. He seems to think that the addition of resistor R4 and capacitor C12 is a "patch" to get rid of a troublesome glitch, and he suggests that the circuit either will not work or it will have nasty faults.

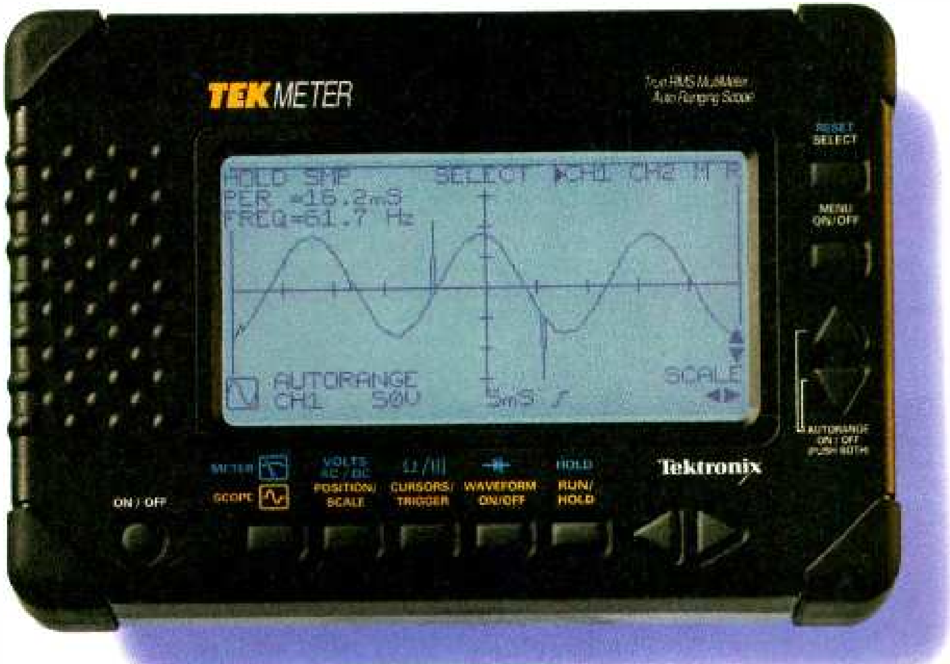
When working on the initial breadboard for that project, it was evident that the addition of R4 and C12 solved a potential problem. When we prepare a construction article for publication, we typically build from five to ten prototypes. All of those for this and other projects have worked the first time.

I'll admit that the addition of R4 and C12 is an inexpensive quick fix—but it works! We stand behind the reliability and the simplicity of this circuit. In my opinion, it is one of the simplest approaches to speech inversion so far published. It appeared several years ago in an engineering journal. Admittedly the counter chain has a flaw, but it is easily overcome.

We expect every one of our prototypes to work satisfactorily the first time they are powered up without the builder having to resort to any tricky tweaking or special component selection. Unless that goal is achieved, we continue to work on the project to iron out all the difficulties before we submit the manuscript for publication or offer part kits for it.

We also design complex circuits so that the reader has no need for specialized, expensive test instruments to complete the projects. We

The newest tool of the trades.

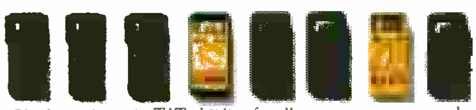


Introducing TekMeter.™ The easy-to-use combination DMM and autoranging scope.

If you're like most people in the electrical and electronic service business, when you've got a job to do, you need to get it done fast, with a minimum of hassle. And preferably without juggling a bunch of tools on site.

To answer these concerns, Tektronix created TekMeter. Designed with input from customers, TekMeter is the only test and measurement tool that integrates true RMS multimeter and autoranging oscilloscope capabilities in one powerful yet lightweight package.

Best of all, you don't have to learn scope skills. TekMeter has a familiar DMM-like interface for every function. You just hook up the probes and toggle between DMM and waveform.



Check out the entire TekTools™ line for all your measurement needs.

At the push of a button, you'll see exactly what you're measuring.

Easy to afford, too.

At only 2.2 pounds, TekMeter won't weigh heavily on your belt, and it won't do much damage to your wallet, either. Starting at $859,* the TekMeter packages a remarkable set of capabilities that will enhance your productivity and will be easy to justify.

Put one in your hands today.

Of course, the best way to take full measure of TekMeter is to try it for yourself. For the name of your nearest authorized Tektronix distributor, call 1-800-426-2200, ext. 800 and put one to the test.

Come test drive the TekMeter at your local distributor and judge for yourself.

Once you've seen everything TekMeter can do—and how easily it does it—we think you'll agree it's the one tool you won't want to trade for anything else.

Tektronix

*Suggested retail price

CIRCLE 92 ON FREE INFORMATION CARD

know that most hobbyists and experimenters do not have access to well-equipped electronics test labs.

Moreover, we strive to achieve that goal even with radio frequency projects that operate well up into the UHF region where more problems relating to parts layout are likely to appear. If Mr. Hardwick was aware of all the engineering and testing man hours that go into the development of projects such as those we submit to *Electronics Now*, he would have known that we were aware of the problem he mentioned.

We do not want to discourage any reader interested in building the Audio Scrambling System. We had no problems with the prototype, and it seems that no one else has had any. We have not been asked about any difficulties with the circuit so far.

Based on orders for parts that we we have received, we estimate that well over 100 systems have been built—and repeat orders have been coming in. Thus, we must conclude that the probability of any problem showing up at this time is very low. We are confident that any we hear about can be easily resolved.

We do not design experimenter projects for critical safety or life-support applications, so we do not perform the kinds of exhaustive environmental tests that would be required to qualify projects for those applications. We have made it a matter of pride and good business to help out those readers who have, through inexperience or error, been unable to get our projects to work successfully at first turn-on. If any components in our kits are faulty, we replace them free of charge.

Many circuits published in magazines, technical papers and operator's manuals have inadvertent "glitches." Component specification sheets might not give enough design data or support information to permit them to be applied successfully in all situations. (The manufacturer might not have tested his product extensively enough to provide this information to cover all "gray."areas.)

Economic factors might force component manufacturers to cut corners in characterizing their products for all possible extremes of operation to save money. Capable component engineers know how to get around these "blank spots." The company can still offer a component that satisfies the vast majority of customers for general middle-of-the road applications.

The products are, for the most part, cost-effective, suitable for high-volume production, and reliable, despite some technical limitations. Overcoming those limitations in certain applications requires engineering ingenuity—perhaps the use of "patches," as Mr. Hardwick calls them. This calls for experience and judgment not given by computer-aided design programs.

Perhaps a better way for Mr. Hardwicke to demonstrate the viability of his alternative design would be to write a complete article describing it, rather than trying to "sell" it through negative comments in the "Letters" column.

WILLIAM SHEETS, MEE.
Hartford, NY

VINTAGE-RADIO LINE CORDS

I got into the radio hobby/repair field in the 1930's, so I enjoyed Marty Knight's article, "Vintage Radio," in the January issue of *Electronics Now*. I remember many enjoyable hours spent reading Hugo Gernsback's *Radio Craft* magazine.

One thing that Marty didn't mention is the use of power resistors inside some line cords. Finding a replacement for them is a special challenge. (However, if your set has a transformer, you don't have to worry about that.)

Resistor line cords were installed on some AC/DC (transformerless)

Continued on page 26

EQUIPMENT REPORTS

L-Com DXB65 Ethernet Cable Tester.

CIRCLE 15 ON FREE INFORMATION CARD

It's easy to track down defective Ethernet cables when you use the right equipment.

Network downtime has become a real economic threat for nearly every business in the country. Downtime means money lost when it prevents employees from getting their work done, and downtime is always a burden on the guy who is responsible for getting the network up and running again.

When a computer network is down, conditions soon become just plain ugly—we waited for four hours in line one afternoon at a Department of Motor Vehicles office only to have its network go down just before it was ready to close. Needless to say, by the time all the people were told they would have to come back another day, the network technician must have been halfway home.

More often than not, it's just a simple cabling problem that's troubling a computer network. But simply finding the faulty cable can be frustrating and time-consuming.

While general-purpose test equipment is certainly better than none when trying to locate a troublesome Ethernet cable, specialized equipment will always speed up the job. However, the main complaint with specialized equipment, especially where computer networks are concerned, is its usual high cost. Well, prices for specialized Ethernet cabling testers have taken a downward spiral with L-com's new line of testers (L-com, Inc., 1755 Osgood Street, North Andover, MA 08145, 508-682-6936).

The L-com DXB65

We took a look at the L-com model DXB65 Dual Cable Tester which has a low price of $79.95. The DXB65 basically just tests two kinds of Ethernet cables—10Base-2 thin coaxial ("cheapernet") and 10Base-T UTP (unshielded twisted pair)—for proper continuity and short circuits between conductors. But although it's functions are limited, the DXB65 makes certain jobs very easy because of its clever design.

The difficulty with checking an already installed network cable for short circuits or breaks is that the two ends of the cable are usually in different rooms. That makes it very difficult for one person to do the checking, even with a multimeter and long test leads. The slide-lock design of the DXB65 splits the unit into two sections, a master and a remote, which can then be connected to both ends of a suspected cable and make quick work of evaluating its condition. When the two halves of the DXB65 are connected together, the unit is better suited for the bench testing of cables or for carrying around in your pocket.

Each half of the unit has a BNC and RJ45 jack on one end, and an array of indicator LEDs on its front panel. The remote half houses a 9-volt battery, and it can be used by itself to test coaxial cables for short circuits because they will show up at either end of a coaxial cable. The remote half has two LEDs on its front panel which indicate the type of cable connected—coaxial or 10Base-T. Normally one of these LEDs will indicate the type of cable connected only when both halves of the unit are connected. However, if a short-circuited coaxial cable is connected to the BNC connector on the remote half, the coaxial LED will light. A push of a button will illuminate a red LED, confirming that a short-circuited coaxial cable is connected to the BNC jack.

The master half of the unit has LEDs that indicate continuity for coaxial and 10Base-T cable. After the remote half is connected to one end of a cable under test, the master half is connected to the other end. A green LED will light on the master when both halves are connected to a fault-free coaxial cable. 10Base-T cable contains four-conductor wires that carry two pairs between two RJ45 jacks, on pins 1 and 2 and 3 and 6. Two separate LEDs on the front panel of the master half indicate whether both pairs at the RJ45 jack have continuity.

To test a cable effectively, the network should be shut down, and both ends of the suspected cable should be disconnected from the computer equipment to eliminate the possibility that the equipment—possibly defective—could interfere with cable testing.

The DXB65 measures only about 2¼ by 5½ inches, so it is small enough to fit in your pocket. While the instructions in the included manual are rather sparse, nobody should have difficulty in figuring out how it works.

The DXB65 Ethernet Cable Tester will pay for itself the first time it helps bring a network back up. If Ethernet cables have you down, get your hands on an L-com DXB65—it will help to bring you back up in no time. Ω

NEW PRODUCTS

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

CIRCLE 16 ON FREE INFORMATION CARD

PC ENERGY SAVER. *B&B Electronics* introduced its new *Green Keeper* that automatically turns off computer monitors and reduces electric bills during periods of inactivity, without affecting the computer itself.

The *Green Keeper* is connected in series with the keyboard of any IBM-compatible PC. The computer monitor is plugged into the circuit's AC outlet. Windows and DOS versions of the included software communicate turnoff signals to the monitor after a user-specified period of inactivity. Power is restored to the monitor when the mouse or keyboard is touched.

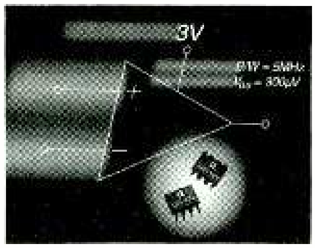
Turnoff time can be programmed to differ depending on the time of day or the day of the week. Up to nine different timeouts can be preset, allowing different intervals during working hours for breaks, lunch, and the like.

The *Green Keeper* sells for $69.95.

B&B Electronics Manufacturing Company
4000 Baker Road
P. O. Box 1040
Ottawa, IL 61350
Phone: 815-434-0846
Fax: 815-434-7094

5-MHz OP-AMPS. Two new 5-MHz operational amplifiers, the single-channel *OP-183* and the dual-channel *OP-283* from *Analog Devices*, will work satisfactorily from +3-volt, +5-volt, or ±15-volt supplies. The manufacturer guarantees maximum DC specifications such as 1-millivolt input offset voltage, ±50 nanoampere offset current, and 600 nanoampere bias current.

Powered from a +3-volt supply, the op-amps will tolerate input voltage swings from 0 to +1.5 volts and will give 260 volt per millivolt large-signal voltage gain with 104-dB common mode-rejection. Powered from +5-volt or ±15-volt supplies, the op-amps offer wider input voltage spans with improved large-signal voltage gain (1000 volt per millivolt at ±15 volts).

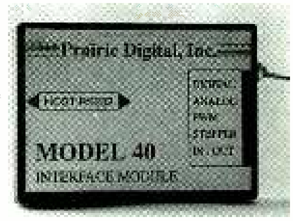


CIRCLE 17 ON FREE INFORMATION CARD

The *OP-183* and *OP-283* 5-MHz op-amps are available in 8-lead plastic DIPs and SO-8 packages. Prices start at $1.58 and $2.39, respectively.

Analog Devices, Inc.
181 Ballardvale Street
Wilmington, MA 01887
Phone: 617-937-1428
Fax: 617-821-4273

DATA-ACQUISITION AND CONTROL MODULE. *Prairie Digital's Model 40* data-acquisition and control system module can plug into the serial port of a personal computer (presently IBM-PC/AT and compatible). Battery-powered, it will also work with laptop and palmtop computers.



CIRCLE 18 ON FREE INFORMATION CARD

It has eight channels of 8-bit analog input, 28 digital input/output (I/O) lines (individually programmable as either input or output), RS-232C serial interface, built-in stepper-commands, four channels for reading relative resistance or capacitance, and a pulse-width modulation output. An optional AC adaptor is available.

The *Model 40* data-acquisition and control module is priced at $99.

Prairie Digital, Inc.
846 17th Street
Prairie du Sac, WI 53578
Phone: 608-643-8599
Fax: 608-643-6754

POWER-QUALITY ANALYSIS METERS. The *CPM2000* (for AC voltage) and the *CPM2100* (for AC and DC voltage) clamp-on, hand-held power meters from *Wavetek* include harmonic filters and can measure power factor, true RMS, and complete digital-multimeter functions.

The meters can perform diode checks and measure true power to 2000 kilowatts and apparent power to 2000 kVA. They can measure current to 2000 amperes, AC voltage to 750 volts and DC voltage to 1000 volts. Resistance can be measured to 400 kilohms and frequency can be measured to 1000 Hz with 0.1 % resolution. Both instruments measure power factor to analyze the power requirements for inductive and capacitive loads. Both also have a low-pass 100-Hz filter for detecting the presence of potentially destructive harmonics.

CIRCLE 19 ON FREE INFORMATION CARD

True RMS values are measured on all waveforms. Hall-effect sensors and the built-in, clamp-on jaw allow the measurements to be taken without interrupting the circuit. The peak-mode setting measures the instantaneous waveform maximum, and the surge-mode setting can detect and hold the maximum RMS current measurement.

The average-sensing mode measures in non-true RMS. A data-hold button permits measurements to be stored on the display. Both instruments can function as data loggers when they are connected to a computer through an RS-232 interface.

Wavetek's data logging software permits the recording of measurements. The *CPM2100* also features an analog output for viewing waveforms on an oscilloscope or a standard chart recorder.

The *CPM2000* is priced at $795 and the *CPM2100* is priced at $995 with a set of locking test probes, 9-volt battery, and carrying case.

Wavetek Corporation
9145 Balboa Avenue
San Diego, CA 92123
Phone: 619-279-2200

COMMUNICATIONS DECODER. *Optoelectronics' Model DC440* communications decoder makes two-way communications tests, monitors repeaters, enhances recreational monitors, and can perform security and surveillance monitoring. It can simultaneously read 50 sub-audible (CTCSS) tones, 106 digital codes (DCS), and 16 Touch Tone (DTMF) characters.

The decoder monitors the demodulated audio output from a communications receiver, service monitor, scanner, or interceptor. CTCSS tones and DCS codes are automatically detected along with any DTMF characters and displayed on a two-line, alphanumeric liquid-crystal display.

Six operating modes are available. On power up, the

CIRCLE 20 ON FREE INFORMATION CARD

all-mode decode mode permits automatic detection and display of CTCSS tones and DCS codes along with CTCSS characters. When connected to the discriminator circuit of a communications receiver and a logical output from the squelch circuit, the *DC440* can monitor tone, code, and non-coded transmissions. Other modes include CTCSS/DTMF, DCS/DTMF, period measurement, DTMF only, and DTMF recall.

A serial data jack permits the *DC440* to be connected to a a personal computer for remote operation. The decoder is compatible with ToneLog data-logging software for surveying busy communications channels, and with Scan Star software, for monitoring multiple communications channels.

The *DC440* is priced at $359, The NiCad 44 battery pack is $39, the interface is $89, and the data-logging software is $49.

Optoelectronics Inc.
5821 NE 14th Avenue
Fort Lauderdale, FL 33334
Phone: 305-771-2050
Fax: 305-771-2052

OSCILLOSCOPE SIMULATOR. *Meyers Associates' Scope* simulates oscilloscope waveforms on a computer. The program helps students understand and experiment with ten different electrical waveforms on an IBM PC or compatible computer. Summing, multiplying, phase shifting, changing rise times, choosing waveform duty cycles, and other operations can be performed at the computer keyboard.

Students can alter waveform input values and try various "what-if" scenarios. A menu provides single-key selection of waveforms, or they can be drawn by entering two or three values. Error messages signal any incorrect entries.

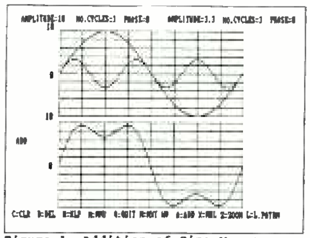


Figure 1. Addition of Sine Waves

CIRCLE 21 ON FREE INFORMATION CARD

A 27-page instruction manual is included with the *Scope* disk. The program displays typical transistor curve-tracer plots, an interactive resistor-capacitor/inductor time-constant calculator, and an resistor-capacitor curve plotter. All programs contain help screens.

Scope is priced at $20 plus $1.50 S & H.

Meyers Associates
12 Hamilton Terrace
Montclair, NJ 07043-1606
Phone: 201-746-5473

HANDHELD DIGITAL MULTIMETERS. Six new digital multimeters from *Protek* feature 4000-count liquid-crystal displays and auto-selection of AC and DC operation. Two styles are available. *Models 121, 122*, and *123* have rotary function selector switches on their front panels, and *Models 221, 222*, and *223* have thumbwheel selector switches for one-hand operation. All six are in high-impact plastic cases.

Models 121 and *221* each test AC and DC voltage, current, resistance, and LEDs. They include data hold and overload display functions. *Models 122* and *222* have an AC/DC select function that automatically selects and displays the dominant AC or DC component of the input. Other functions include autoranging with bargraph, frequency and resistance measurement, continuity testing, data hold, and diode testing.

CIRCLE 22 ON FREE INFORMATION CARD

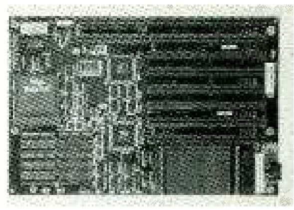
Models 123 and *223* each have additional features that will appeal to the professional. These include autoranging with bargraph, high current warning, relative set, mode select, continuity, data hold, auto power off, and diode testing.

Model 121 is priced under $40, 221 under $60, and 222 under $80.

Protek, Inc.
154 Veterans Drive
Northvale, NJ 07647
Phone: 201-767-7242
Fax: 201-767-7343

EISA/VESA-BUS MOTHERBOARD. *JDR Microdevices' MCT-M486EV-66* motherboard is intended for high-performance, data- and graphics-intensive workstations where large amounts of complex data must be displayed in real time. It has both VESA local bus and EISA bus interfaces.

The motherboard contains an Intel 66-MHz 486 DX2 MPU with an AMI BIOS and a VIA chip set. It also includes eight standard 9-bit SIMM sockets for up to 128 megabytes of DRAM and 128 kilobytes of external cache that is expandable to 1 megabyte. Each of the eight 32-bit EISA slots is compatible with standard 8- and 16-bit ISA cards. Two of the slots also have VESA local bus connectors.



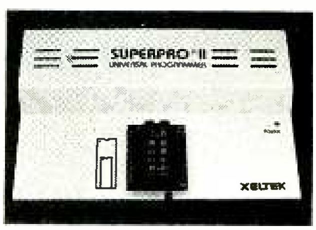
CIRCLE 23 ON FREE INFORMATION CARD

A VESA local bus VGA card can be plugged in for the fastest video response. Then an EISA SCSI-2 controller can be added for rapid disk transfers.

The *MCT-M486EV-66* motherboard is priced at $899.

JDR Microdevices
2233 Samaritan Drive
San Jose, CA 95124
Phone: 408-559-1200
Fax: 408-559-0250

UNIVERSAL IC PROGRAMMER. *Xeltek's Superproll* personal computer-based universal programmer can program more than 2000 memory devices from such suppliers as Intel, Motorola, Signetics, Hitachi, AMC, and Zilog. These include 8 megabyte EPROMs and EEPROMs as well as flash EPROMs. It interfaces with an IBM PC or compatible.



CIRCLE 24 ON FREE INFORMATION CARD

The programmer can also program programmable logic devices (PLDs) including PALs, GALs, and FPGAs. In addition, it can perform functional tests on integrated circuits, TTL and CMOS logic, as well as DRAMs and SRAMs.

Software provides a user-friendly interface and comprehensive control of the various functions of the device-under-test (DUT). Macro and batch functions automate programming procedures with single-keystroke control. Device updates are available at no cost to Xeltek customers over a 24-hour BBS.

The *Superproll* IC programmer costs $699.

Xeltek
757 North Pastoria Avenue
Sunnyvale, CA 94086
Phone: 408-524-1932
Fax: 408-245-7084

ELECTROMAGNETIC RADIATION DETECTOR. The *Digi-Field* field-strength meter from *IC Engineering* can measure electromagnetic radiation, television coaxial cable distribution loss, antenna performance, and electromagnetic or radio-frequency interference (EMI/RFI). It has a frequency response rating of DC up to 12 GHz.

CIRCLE 25 ON FREE INFORMATION CARD

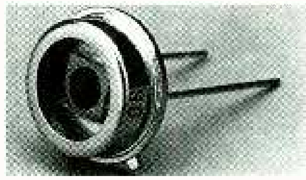
The handheld instrument can check antenna gain or loss and be useful in plotting polarization patterns. Measurements are displayed on the 3½-digit liquid-crystal display. They can be converted to dBm units with the included calibration curves.

The instrument can also measure RF leakage from TV receivers, computer monitors, cellular and portable radios as well as microwave energy leakage from microwave ovens. It can also detect hidden transmitters.

The *Digi-Field* field-strength meter is priced at $139.95 plus $6.50 S & H.

I.C. Engineering
16350 Ventura Blvd.
Suite 125
Encino, CA 91436
Phone: 818-345-1692
Fax: 818-345-0517

EYE-RESPONSE PHOTODETECTOR. *Centronic's Series E* photodiodes are packaged with a color-correcting filter that responds like the human eye.



CIRCLE 26 ON FREE INFORMATION CARD

The photodiodes are intended for measuring visible ambient light for use in a variety of applications, from light meters to instrument-panel controls.

Pricing starts at $10.

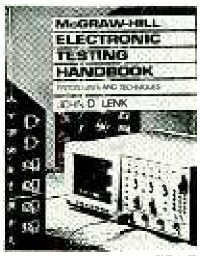
Centronic Inc.
2088 Anchor Court
Anchor Business Park
Newbury Park, CA 91320
Phone: 805-499-5902
Fax: 805-499-7770 Ω

NEW LITERATURE

Use The Free Information Card for more information on these books and literature.

McGraw-Hill Electronic Testing Handbook: Procedures and Techniques; by John D. Lenk. McGraw-Hill Book Company, 11 West 19th Street, New York, NY 10011; Phone: 1-800-2-MCGRAW; $39.50 (hardcover).

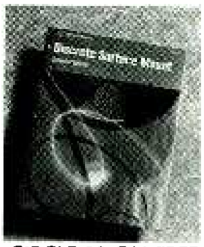
This handbook explains the tools and methods necessary to evaluate and select test equipment. It explains how to perform reliable tests on electronic components and circuits. Included is a review of the characteristics of the latest multimeters, oscilloscopes, signal generators, frequency counters, probes, transducers, and various special-purpose test equipment



CIRCLE 40 ON FREE INFORMATION CARD

Lenk's book gives clear explanations of the operation and applications of each instrument. Subsequent chapters describe a wide variety of test procedures from the performance of a simple test with a single instrument to evaluation of a system with a set of specialized instruments. The handbook offers expert advice on circuit and component diagnosis, how to interpret test results, troubleshoot products and systems, and analyze experimental or prototype circuits.

Discrete Surface Mount Selector Guide (SG370/D). Motorola Inc., Literature Distribution Center, P. O. Box 20924, Phoenix, AZ 85063; Phone: 1-800-441-2447; Fax: 602-994-6430; free.

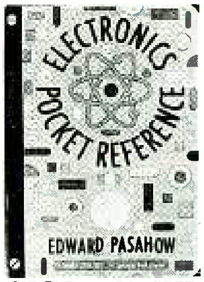


CIRCLE 39 ON FREE INFORMATION CARD

Motorola's guide to its discrete surface mount technology (SMT) components has been updated to include its latest products and related technical data. These products have been specially packaged for placement on SMT boards, and they can withstand the rigors of the vapor-phase and infrared solder reflow processes as well as wave soldering.

Electronics Pocket Reference; Second Edition; by Edward Pasahow. McGraw-Hill Inc., 1221 Avenue of the Americas, New York, NY 10020; Phone: 1-800-2-MCGRAW; $24.95.

The compact size of this handy pocket-size reference book can be misleading. It is packed with the essential information needed for practical work in electronics, but it does not include the voluminous tables (rarely used) that occupy so many pages in larger handbooks.



CIRCLE 38 ON FREE INFORMATION CARD

Pasahow has included the useful formulas and diagrams that will permit the user to derive all of the needed values quickly with readily available scientific calculators and personal computers.

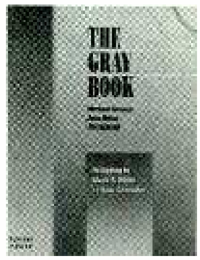
Pocket reference coverage ranges from the general laws of electricity to the basics of electronics, a discussion of the principles of analog and digital circuitry, and digital logic as it applies to digital computers.

This second edition has been updated to include entries on HDTV, information theory, error detection and correction, 32-bit microprocessors, digital buses, and computer interfaces. The information on each topic is compiled in a single section, simplifying the search for the wanted information.

Easily carried in a briefcase or toolbox, it is a handy reference for the office or in the field. It will appeal to the experienced professional as well as the entry-level technician, student, or hobbyist.

The Gray Book: Designing in Black & White on Your Computer, Second Edition; by Michael Gosney, John Odam, and Jim Benson. Ventana Press, P. O. Box 2468, Chapel Hill, NC 27515; Phone: 919-942-0220; Fax: 919-942-1140; $24.95.

Even if you do not have color printer for your computer, you can obtain vivid textures and contrasts for your computer graphics with various shades of the gray scale. You can take advantage of your computer's abilities to show the effects of light, shadows, and distance.



CIRCLE 37 ON FREE INFORMATION CARD

This book reveals simple, professional techniques that make graphics stand out with reversals, shadows, patterns, backgrounds, bleeds, and multiple shades of gray. This revised edition includes 25 new illustrations. Step-by-step explanations tell you how to recreate the effects shown.

1994 Equipment, Tools & Supplies Catalog; Print Products International, 8931 Brookville Road, Silver Spring, MD 90910; Phone: 800-638-2020; Fax: 800-545-0058; free.

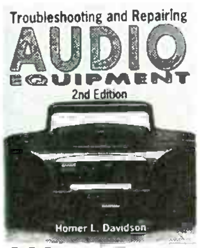
This 84-page catalog includes descriptions and illustrations of test and


CIRCLE 36 ON FREE INFORMATION CARD

measurement equipment offered by Print Products International. Among the new products are spectrum analyzers, signal-strength meters, logic analyzers, protocol analyzers, digital and analog oscilloscopes, semiconductors, and surface-mount soldering and desoldering tools.

Troubleshooting and Repairing Audio Equipment, Second Edition; by Homer L. Davidson. Tab Books Inc., Blue Ridge Summit, PA 17294-0850; Phone: 1-800-233-1128; $19.95.

This guide book explains how to diagnose and fix household and automotive audio equipment including cassette decks, CD players, turntables, "boom" box receivers, speakers, tuners, amplifiers, and answering machines.



CIRCLE 35 ON FREE INFORMATION CARD

This second edition has been revised to include mention of the latest circuits, components, and test instruments. More than 500 practical how-to photos, circuit schematics, and illustrations supplement the text. The book also includes time-saving troubleshooting charts.

Flyback Transformers Cross-Reference Guide; Philips ECG, Riviera Beach, FL; Phone: 1-800-526-9354; free.

This is a handy guide for anyone who services or rebuilds television sets and computer monitors with flyback transformers. An expanded cross-reference indexes flyback transformer replacements by manufacturer's part number and brand name.

CIRCLE 34 ON FREE INFORMATION CARD

The Philips ECG flyback transformer replacement line now includes 142 models to replace 350 OEM part numbers for TV and computer monitors from different companies. Ω

LETTERS

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line-powered sets. At that time, some local power companies were supplying 110-volt DC, and transformer sets would not work on that power. But the real reason AC/DC sets were introduced was to eliminate the expensive, heavy power transformers.

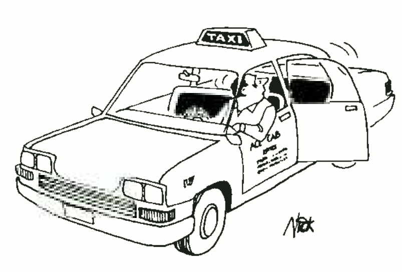
In those days, power resistors dropped the voltage to the filaments. That practice began with the introduction of "ballast tubes," which were just power resistors inside plug-in envelopes that resembled metal vacuum tubes. The dropping resistor was later placed inside the line cord to save space.

To replace a line cord with an internal resistor, you must first determine the resistance and power rating of the resistor by Ohms law. Then substitute a discrete power resistor with the same ratings and position it on the top of the metal chassis. You can then install a conventional line cord.

The introduction of the dynamic speaker is worth mentioning. Early speakers were little more than an assembly of a horseshoe-shaped electromagnet with a metal diaphragm coupled to the cone. Then the dynamic speaker with a voice coil was developed.

The first models had electromagnetic field coils. The electromagnetic version was likely to be energized by using its coil as the "L" part in the LC filter on the rectified high-voltage supply for the plates. Later those speakers were replaced by speakers with permanent magnets.

HOMER B. TILTON
Tuscon, AZ



"Patent Office, please."

COMPUTER CONNECTIONS

David and Goliath (or) Bill's Bad, Awful Day

JEFF HOLTZMAN

Grover's Bad, Awful Day is a Sesame Street story about a character named Grover. In the story, everything that can go wrong does go wrong. On the way home from school, Grover's ice cream falls off the cone and it starts to rain. He steps on a piece of bubblegum and his boot gets stuck, so he runs home through the rain in his socks. Soaking wet, he arrives home where his mommy kisses and hugs him, and takes him to retrieve the lost boot. Then together they visit the ice cream parlor and Grover's world is set aright.

Grover is not the only one who has bad days. Bill Gates, for example, admits that he too had a bad day recently. Bill didn't lose his ice cream; rather, his company lost $120 million in a suit filed by Stac Electronics against Microsoft for patent infringement. Asked to comment on the situation, Gates said, "I had a pretty bad day yesterday."

In case you haven't followed the saga, here's a quick recap; Fig. 1 summarizes the timeline of events. Stac Electronics develops and sells data-compression hardware and software. Stac introduced its flagship software product, Stacker, in November 1990. Stacker integrates itself tightly with DOS, and just about doubles available disk space (typical results are more like 1.8×).

Growing acceptance of Stacker, as well the emergence of a horde of clones, convinced Microsoft that disk compression should be built-in as part of the MS-DOS operating system. Microsoft negotiated with Stac and several other companies for the rights to their technologies. At one point, it seemed as if Stac would cut deals with both Microsoft and IBM (for inclusion with both OS/2 and PC-DOS).

However, negotiations with Microsoft broke down, apparently because Microsoft wanted to pay Stac a flat fee for the technology, whereas Stac wanted royalties on every copy of DOS sold. Microsoft refused, and instead it cut a deal with a company called Verisoft. It is Verisoft's technology that forms the basis of DoubleSpace, the disk-compression technology introduced in DOS 6.0.

In late 1992 and early 1993, Microsoft released several preliminary versions (betas) of DOS 6.0 containing DoubleSpace and a background compression product called MaxCompress. In January of 1993, Stac filed suit against Microsoft, charging that DoubleSpace violated

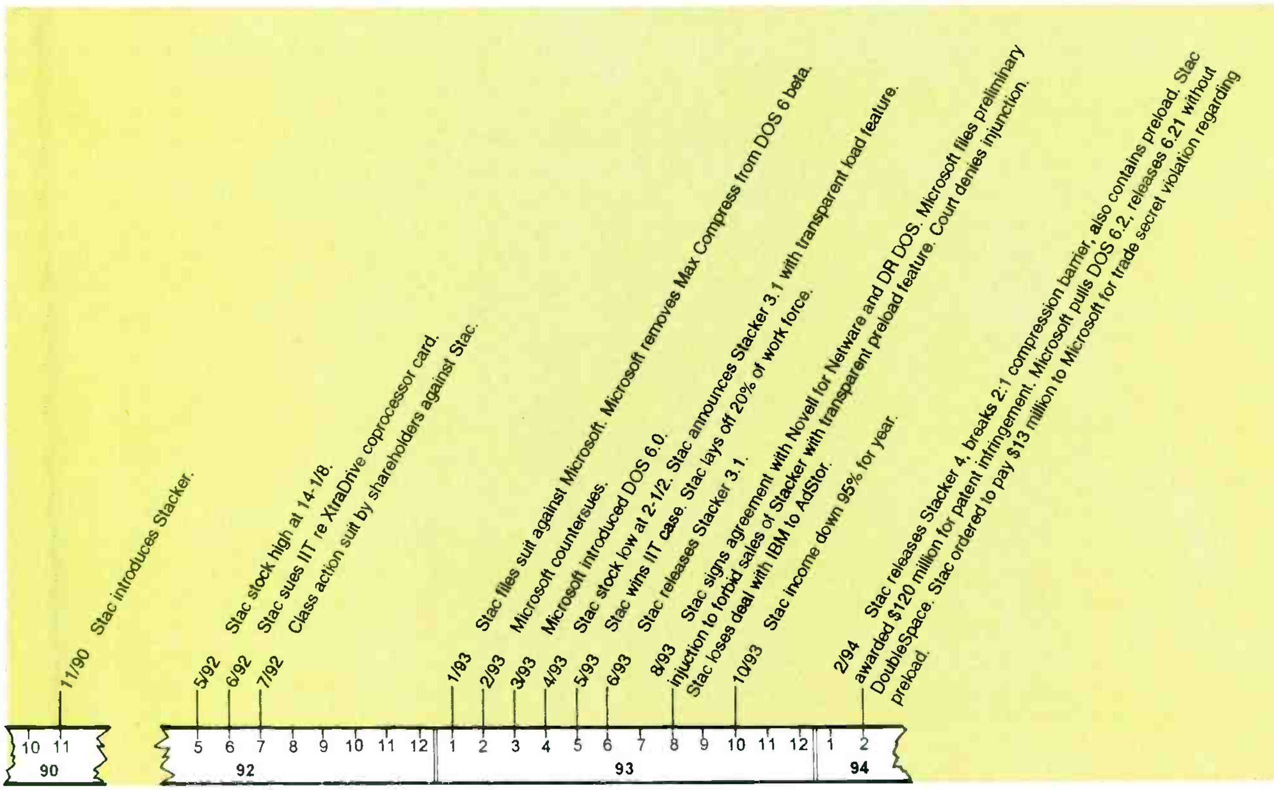


FIG. 1—HISTORY OF STACKER, the technical and market leader in disk-compression software. Microsoft was recently ordered to pay Stac $120 million in compensatory damages for patent infringement.

U.S. Patents 5,016,009, "Data Compression Apparatus and Method," and 4,701,745, "Data Compression System," both of which were owned by Stac.

A month later, Microsoft countersued, charging Stac with infringing on a Microsoft patent (that Microsoft had reportedly purchased in the interim), for breach of contract, and for civil conspiracy to commit fraud. Microsoft also removed MaxCompress from subsequent beta releases, as well as on the release version of DOS 6.0, which came out in March.

Although they have their differences, Stacker and DoubleSpace are more alike than different. The cleverest trait about DoubleSpace is its ability to load itself transparently, as part of the operating system. Prior disk-compression products—including Stacker—had to be loaded as device drivers in the CONFIG.SYS file. They also required duplicate copies of key system files. Moreover, they were complex to manage, although Stacker had built-in "intelligence" for automating the process.

So Stac promptly went to work and figured out how to get Stacker to load transparently, just like DoubleSpace. In June, the company released Stacker 3.1, which incorporated that feature.

A few months later, in August, Microsoft filed a preliminary injunction to stop sales of Stacker 3.1, alleging misappropriation of trade secrets—presumably for figuring out how to use DOS's "hooks" for loading the product transparently. The court wouldn't hear of it, however, and it continued to allow Stacker to be sold.

Revving up

Throughout 1993 several interesting things—unrelated to its David and Goliath battle against Microsoft—happened to Stac. In May, the company won a different but related technology-infringement case against Integrated Information Technology. On the other hand, that same month, Stac laid off 20% of its work force. Around that same time, the company's stock also sank to a low of $2½ from its former high of about $14⅛.

Later that summer, in August, Stac's prospects took one step forward and one step back. The company failed to reach an agreement with IBM, which ended up licensing compression technology for PC-DOS from a company called AdStor. However, Stac did sign an agreement with Novell that gave Novell use of Stac's compression technology in both NetWare and DR-DOS, and that gave Stac rights to Novell's DOS Protected Mode Service (DPMS). Using DPMS, the newly released Stacker version 4, now requires about 17 kilobytes of conventional memory, about one third the "footprint" of the previous version. Most Stacker 4 code runs from extended memory under 386/486 protected mode. This makes Stacker code much less susceptible to inadvertent or malicious corruption.

Later that fall, Stac released more bad news. Income for the 1993 fiscal year had fallen 95% over the preceding year. In other words, if you took all of Stac's fiscal year 1993 income and subtracted all of its fiscal year 1993 expenses, the difference amounted to only 5% of the preceding year's value. In short, by the end of 1993, Stac's prospects looked pretty bleak.

A luge team on an ice track

Early in 1994, the gods appear to have smiled down on Stac Electronics: The company won the first round in its suit against Microsoft. A U.S. District Court in Los Angeles found that Microsoft was guilty of patent infringement, and it awarded Stac $120 million in compensatory damages. This worked out to be about $5 per copy of DOS 6 sold. Although Microsoft has vowed to appeal the ruling, it promptly removed DoubleSpace from DOS 6 and released a new version, 6.21, without it. However, most vendors were planning to continue selling their existing supplies of DOS with DoubleSpace.

The court also awarded Microsoft $13.7 million in compensatory and punitive damages on its counterclaim that Stac had misappropriated and used Microsoft's trade secret pre-loading feature.

As I see it, Microsoft will certainly appeal the ruling, which will likely drag the case out for years. Meanwhile, the fates of current DoubleSpace users, disk compression in general, and Stac Electronics are all up in the air.

With regard to present users, Microsoft has vowed to support them, although the company can no longer sell DOS with DoubleSpace. How long will Microsoft continue to support a product that can, in principle, generate no revenue? This will be a very painful decision. On the other hand, Microsoft might be able to license another wholly independent disk-compression product, or even develop its own. It could then provide a migration strategy for current DoubleSpace users to this new product. It might even be possible that after all that has transpired, Microsoft will still license Stacker technology from Stac.

Disk compression is a controversial technology. Critics claim that it greatly increases the risk of catastrophic disk corruption. Others claim that it actually reduces risk, because a given amount of data can be written to disk in less time in compressed than uncompressed form.

I believe that compression can be useful in inherently low-risk application, such as when a computer is run from a reliable uninterruptible power supply (UPS), when a computer is backed up regularly, and when the user knows enough not to accidentally delete a compressed volume (which is nothing more than a big DOS file) or other critical system files. I would not even consider using current-generation disk-compression products on a network file server.

As for Stac Electronics, the company is still in a precarious position. You can't help but admire Stac for standing up to Microsoft. If Stac can sign enough cross-licensing deals with companies like Novell and IBM, it might be able to survive what could be years of legal battles. For the sake of competition, I certainly hope so.

Many people resent Microsoft as they once did IBM. Those with the most negative and the most vocal sentiments work for small firms that

Continued on page 31

Two possible designs for our tachometer's counting circuit.

ROBERT GROSSBLATT

We're finally ready for the nuts and bolts of the tachometer design. So far we have a conditioned version of the ignition pulse and a power supply. The next step is to design the circuit that does the counting. Counting circuits are a dime a dozen but, as you will see, tachometers belong to a special group of counters that require some unique considerations.

Several IC manufacturers have produced ASICs (application-specific integrated circuits) for the tachometer market that take care of the input-signal conditioning and counting. Some of the devices even have their own display drivers so they can "talk" directly to any number of seven-segment LEDs. There are two major problems with tachometer ASICs: The first is that they teach you no more about tachometer design than TV dinners teach you about cooking. The second is that very few, if any, of these ASICs handle either count averaging or display updating in a satisfactory manner.

One of the most interesting design criteria for a tachometer is derived from the difference between what the circuit is measuring and how it displays its result. Significant problems will arise if the raw data from the counter directly drives the display on the dashboard. Remember that the rate of pulses from the engine is useful information only if it is put in a framework of time. This means that you have to look not so much at the number of pulses as at the number of pulses per time period—and it's the time period that's at the root of the design problem.

Suppose that a one-minute time base is used for counting the pulses from the ignition. By doing that one would be able to drive the display directly from the counter, but the undesirable effect would be that the display would update only once a minute. That would make the tachometer immune to "bobble," but the information it provided would be, to put it mildly, less than useful. Not only that, but the reading we would get on the tachometer would be the average engine speed for the last minute—not too terrific, even if you have the world's most perfect cruise control in your car.

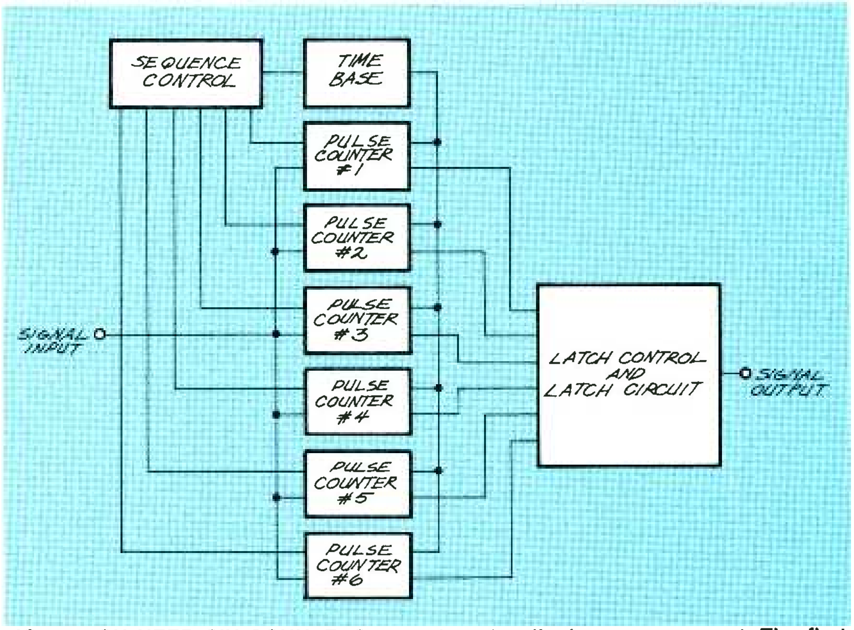


FIG. 1—YOU NEED SIX COUNTERS to update the display every second. The first counter counts pulses 1to 6, the second counts pulses 2 to 7, the third 3 to 8, and so on.

Lowering the sampling rate from a minute to, say, one second would make the tachometer more responsive, but the price paid would be a display so overloaded with bobble that the information it provided would be just as useless as it would be with a time base of one minute. While the information collected by the tachometer is the number of revolutions per second, you must multiply that number by 60 to get the number you really want—which is revolutions per minute. And when you multiply the pulse count, you also multiply the difference between one second's worth of pulses and the next.

An engine is far from a perfectly steady-state machine. Even if you hold your foot perfectly still on the accelerator, there will always be a small variation in the speed of the engine from one second to the next. These small variations can cause significant differences in the rpm readings produced by the tachometer because they're multiplied by 60 when you convert revolutions per second to revolutions per minute.

The solution to this problem can't be found by finding a timebase compromise. While it's true that the longer the sampling rate, the steadier the display, any rate greater than one second will cause an unacceptable delay in updating the display. What technique will combine the best of both extremes with a minimum of cost and complexity? The tachometer must update the display frequently enough for the numbers to have some real meaning while at the same time keeping the display from being so jittery that the numbers are useless.

There are two basic ways to solve

the problem: The first is a kind of linear approach in which you decide the sampling period that will eliminate the inherent engine bobble (usually at least six seconds), and design circuitry that will do the necessary arithmetic to calculate the number to revolutions per minute. If you want to update the display at a rate faster than the sampling rate, you'll have to add enough counters to count successive six-second periods. To update the display every second, for instance, you'll need six separate counters.

The basic idea is shown in Fig. 1. While that might seem overly complicated, remember that it's the same circuit duplicated six times. The first counter counts pulses one through six, the second counts pulses two through seven, the third counts three through eight, and so on. The complex parts of this design are the controls necessary to make each of the six counters successively dump its count to the arithmetic circuit and then be immediately cleared to start a fresh count. After the first six engine pulses, the first counter sends its count to the arithmetic unit and is reset to zero. When the seventh pulse shows up, the same thing happens to the second counter, after the eighth pulse the third counter is accessed, and so on.

With this method, the display will show the average of the last six pulses and will be updated once every second. There's a lot of silicon overhead in the form of support circuitry that has to be added in order for this design to work. In addition to the basic counters, you need a selector to keep track of the counter which is the next to be accessed, and some kind of rate multiplier-based circuit to multiply the number of pulses and arrive at the rpm value you want for the display.

The second, and more common approach to the problem is shown in Fig. 2. The first thing to notice here is that the circuit is a lot less complex in terms of the parts count. While this might often be a desirable thing, nothing comes without a price. At the heart of this technique is a phase-locked loop (PLL) with a divider circuit inserted between the voltage-controlled oscillator (VCO) output and the PLL's comparator input. The circuit will produce pulses at a rate equal to the input rate multiplied by the divide-by factor. At first glance this seems like a terrific way to get the job done.

The problem of engine speed bobbling exists no matter what kind of circuit you put together, and it has to be taken into account with the PLL design as well. Because the PLL is responding to each pulse

WINSCHEME

I must pass along a piece of news I received from the Great SoftWestern Company. These are the people who wrote The Auto-Board System, an extremely powerful and (because it works inside AutoCAD) extremely expensive program for the layout, design, and routing of schematics and printed-circuit boards.

The company is about ready to release a product called WinScheme that does schematic capture, and either manual or automatic signal line drawing. The latter means that you indicate the two pins you want to connect, and the software will figure out how the signal line should be drawn and then draw it for you. Although it's not an autorouter, Winscheme will also produce a netlist in several popular formats so that you can export the schematic to a routing program and then generate a printed-circuit board layout.

WinScheme is aggressive and it will work very hard to draw the signal lines you indicate. It will follow the ground rules you set such as those for avoiding components that you tell it are off limits, as well as the standard schematic rules about the placement of signal lines. The schematics are saved in WinScheme's own file format, but you can export them as a DXF (AutoCAD) file, or send them to the Windows clipboard and put them anywhere you want.

The program is sold with extensive parts libraries and designing any custom components (usually an awkward procedure in programs like this) is a simple and straightforward operation. Basically, you lay out the schematic much as you would on paper by selecting components from the libraries and then start connecting the pins. WinScheme works inside Windows, so any system that can run Windows can run WinScheme. Just about the only handicap is that you need about 10 megabytes of free disk space for the program. This isn't as much as that required for a lot of other Windows-based software. A lot of that space is taken up by the parts libraries, so you can cut down on the program's size by eliminating the libraries you don't need.

The reason I'm telling you about this software is that, while the list price of WinScheme is $179, Dennis Jump, the president of The Great SoftWestern Company will let readers of *Electronics Now* buy WinScheme for $149. For more information, you can contact the company at:
The Great SoftWestern Company
919 South Carroll Boulevard,
Suite No. 103
Denton, TX 76201-6869
Phone (800) 231-6880

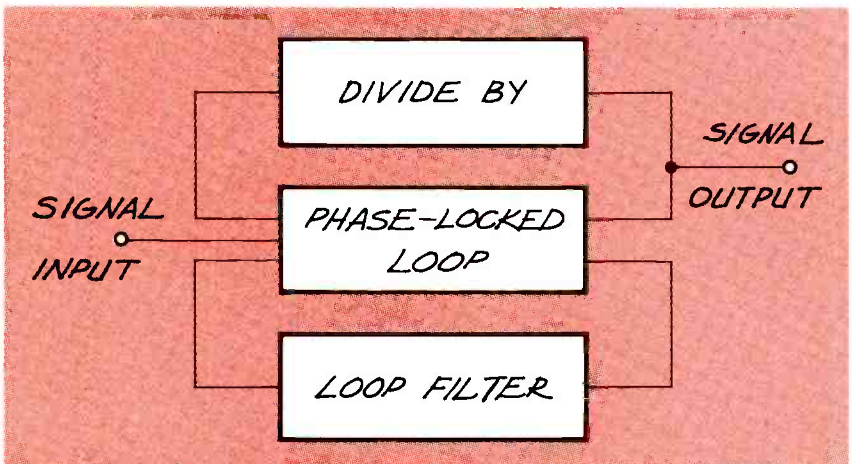


FIG. 2—THE HEART OF THIS DESIGN is a PLL with a divider circuit inserted between the VCO output and the PLL's comparator input.

from the engine, the inherent engine speed variation must be compensated for in the design of the loop filter. The settling time and the damping factor require special attention. These variables are set by the selection of resistors and capacitors for the loop. If you use a 4046 CMOS PLL, you're talking about the choice of basically just three components: two resistors and a capacitor.

Any time you have a situation in which the success or failure of a circuit hinges on three component values, you know the possibility of flaky operation is a very real one. If you make the loop settling time too long, the PLL will be too sluggish, and it won't be able to respond to rapidly changing input pulse rates. If the settling time is too short, the PLL will either become too jittery or the VCO will become completely unstable. There's a set of component values that will work for the expected range of input rates. But, the wider the expected input range, the more compromise you must make between a fast response and a jitter-free display.

In the case of a tachometer, the expected input rates will vary by at least ten-to-one (say 500-to-5000 rpm), and the lower the engine speed, the more erratic the input rate will be. Anyone who has ever fooled around with cars knows that a 10% variation in engine rpm during idle is perfectly normal. However, if you add a couple of misses from a less than healthy engine, the variation in input pulses will be a lot worse than that. For that reason, a PLL design comes up a bit short since the loop characteristics needed during idle are just about the opposite of those needed at higher engine speeds.

There's no hard and fast rule as to which of those two methods is best because both can work well. One of the criteria I use for deciding between several design choices is the amount of knowledge that I can learn from going through them.

Next month I'll run through the PLL design and then start on the other approach. The success of the PLL design depends on how well you understand PLLs so start reading up on the subject! Ω

Q & A

continued from page 12

behind the walls and in the crawlspace trying to find wires.

The easiest way to do the job is to use equipment you already have around the house. Once you realize that commercial units are nothing more than transmitters and receivers, it should be easy to invent something similar. First you have to see what kind of receivers you have in your house, and then generate a signal that they can receive. The most common receiver in use today is a radio, and the easiest signal to pick up with any radio is the RF generated by a noisy appliance. These might have DC motors with a set of old brushes in them. You can spot this by looking for lots of sparks created where the brushes ride on the armature. When you find that kind of appliance, plug it into the line you want to trace. Then just tune the radio between stations (you might find the AM band to be better), turn up the volume, and follow the static to its source. Ω

COMPUTER CONNECTIONS

continued from page 28

ended up in direct competition with Microsoft—and lost. That attitude is understandable, perhaps even justified. But you can't fault Microsoft's technology. Throughout its history, it has continually improved its end-user products. By contrast, competitors like WordPerfect, Lotus, and WordStar, to name a few, let their products and strategies languish, only to wake up several years later wondering what happened to al their customers.

For example, WordStar buried its head in the sand a decade ago and lost big. Lotus released version 2.01 of 1-2-3 for DOS, and for years it ignored the emerging importance of graphic user interface (GUI) environments. The same is true of WordPerfect with its namesake word processor. Meanwhile, Microsoft was releasing version after version of Excel, Word for DOS, Word for Windows, and other products, incrementally improving them with each release. Then one day Lotus and WordPerfect woke up and realized that Windows 3.0 was *big*, and that they had no products for that environment. Two years later they were finally catching up. Meanwhile, Microsoft recognized and rode the market trends with more and more GUI-based products. Ergo, the behemoth we see today.

Across the finish line

On the other hand, Microsoft has made mistakes. Its early commitment to and subsequent abandonment of OS/2 burned lots of developers, many of whom still hold it against the company. And there are other issues, such as the ongoing question of whether Microsoft applications programmers had unfair access to undocumented features of Microsoft system software (DOS and Windows). But that point is ultimately moot. If Excel is a better spreadsheet than 1-2-3, it is because Microsoft made a commitment to rediscover continually what users want and provide it. It is not because of some questionable knowledge of obscure system calls that are far removed from business success. Besides, plenty of companies other than Microsoft have developed excellent Windows-based products with no knowledge of those system calls.

All in all, the computer industry, and we users, are better off with Microsoft than we would have been without it. If evolution had been left up to Lotus and WordPerfect, we'd still be pushing numbers and text around on DOS-mode text screens. Microsoft developed its vision early, stuck to it through extremely rough times, and is now enjoying the fruits of it.

On the other hand, the company owes it to Adobe and Stac for PostScript and Stacker. Without the concept and subsequent success of those products, there would not even be a question about TrueType and DoubleSpace. If Microsoft continues swallowing up market segments, then bright, innovative minds will leave the industry for greener pastures. And without innovation, the industry will become comatose, as Detroit once was. Ω

BUILD THE TUBEHEAD

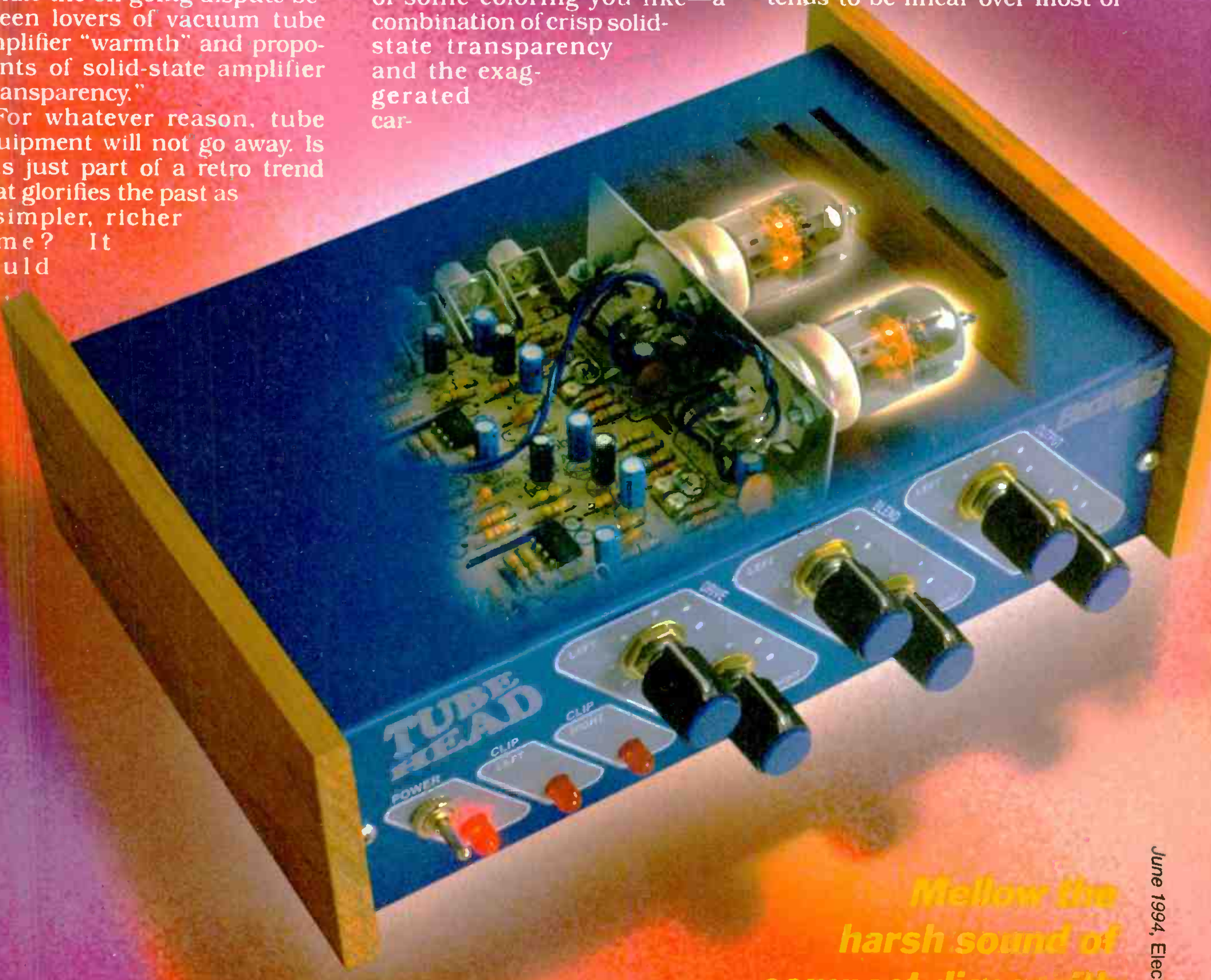
THE OPTICAL PITS ON COMPACT discs that store sound digitally are a remarkable technical accomplishment as far removed from the spiral grooves in vinyl records as ICs are from vacuum tubes. However, many audiophiles believe that compact discs are just the pits—nothing more than over-sampled, error-corrected digital records.

Opinions run so deep on this subject that the arguments rekindle the on-going dispute between lovers of vacuum tube amplifier "warmth" and proponents of solid-state amplifier "transparency."

For whatever reason, tube equipment will not go away. Is this just part of a retro trend that glorifies the past as a simpler, richer time? It could be, but the differences between solid-state and vacuum-tube amplifiers are more than myth—they are real. To see (hear actually) how tube technology might improve the sound of your CDs, read on and take a close look at the TubeHead, a preamplifier with a twist. This hybrid circuit uses both low-noise solid-state op-amps and tubes together, so you can dial in the precise amount of sonic coloring you like—a combination of crisp solid-state transparency and the exaggerated caricature of tube-amp warmth.

Tube sound?

Many people believe that vacuum tube amplifiers sound "warmer," "fuller," or just plain louder than their solid-state cousins. There's wide, but not universal, agreement that those differences originate in the ways that solid-state and vacuum-tube amplifiers overload. Where solid-state circuitry tends to be linear over most of



Mellow the harsh sound of compact discs with the TubeHead preamp.

JOHN SIMONTON

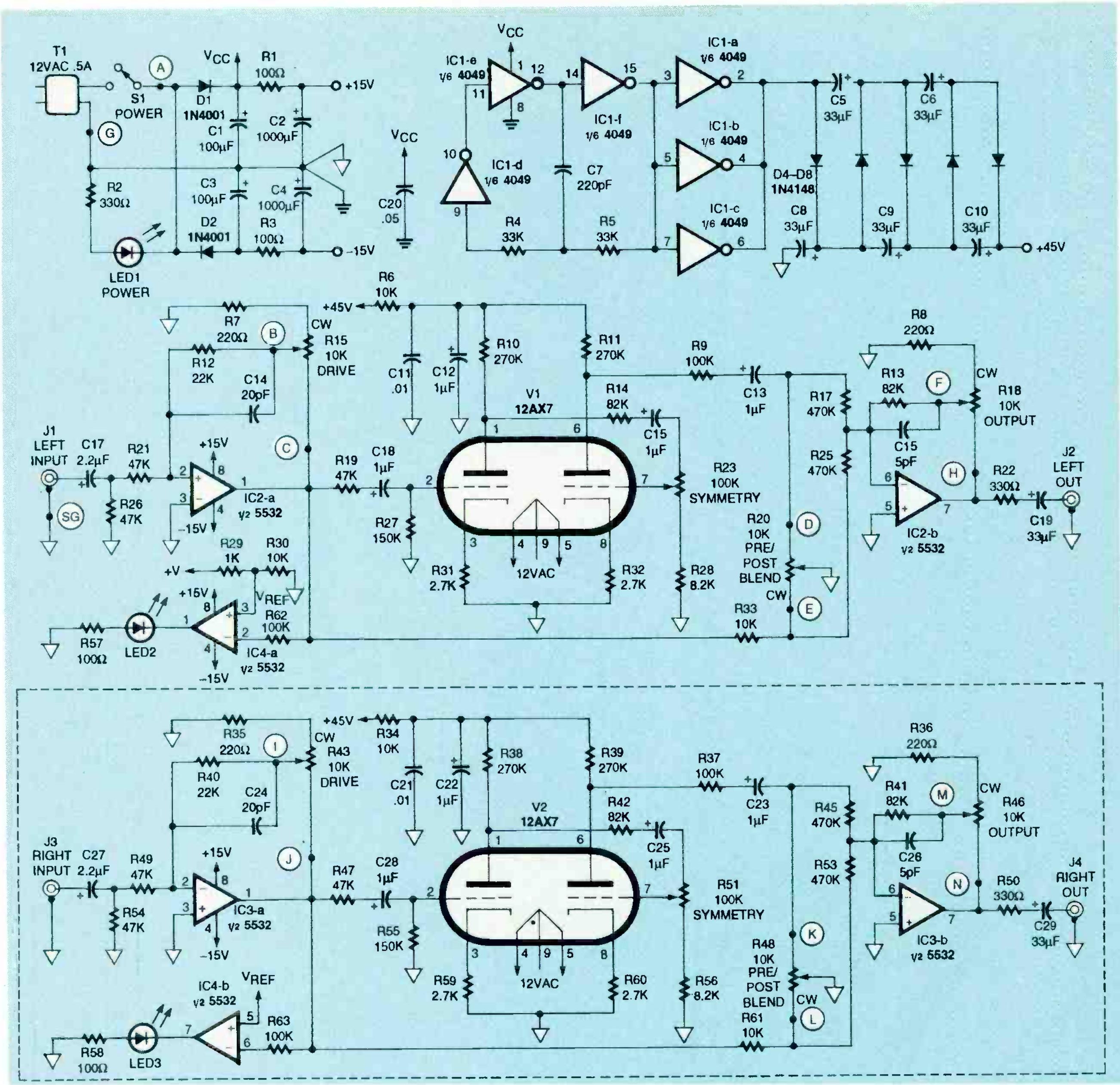


FIG. 1—TUBEHEAD SCHEMATIC. Output from transformer T1 is positive half-wave AC rectified by D1 and filtered by C1, C2, and R1 for a +15-volt supply. A −15-volt supply is available from D2, C3, C4, and R3. The plate supply for the 12AX7 tubes is produced by a voltage multiplier.

its operating range before it suddenly clips, tube amplifiers usually start "squashing" the signal well before they run out of headroom (see the "Clipping and Squashing" sidebar).

Both of those responses produce harmonic distortion, adding frequency components that were not in the original signal, but "squashing" generates much lower order harmonics. The result doesn't have the "buzzy fuzziness" that comes from the high-frequency components produced by clipping. If the "squashing" is asymmetrical (more on the top than the bottom or vice-versa) the result can be strong second- and fourth-order overtones. These are musically benign in terms of producing dissonance, and more pleasing (though not necessarily more interesting) than the odd harmonics of clipping.

Consider this: All natural instruments generate an increasingly complex harmonic structure when they're played louder. They don't just produce higher sound pressure levels—in a very real way they get "fuller." In fact, the increase in harmonic complexity gives the strongest indication to your ears (actually the brain attached to them) that one sound is louder than another. The squashing distortion of vacuum tubes extends this same principle to amplifiers. This might be the reason why tube amplifiers are so often subjectively judged to be "louder" than solid-state units.

Any preference for the warmer, fuller sound of tubes might be nothing more than habit. After all, even with vacuum tubes out of the picture, analog

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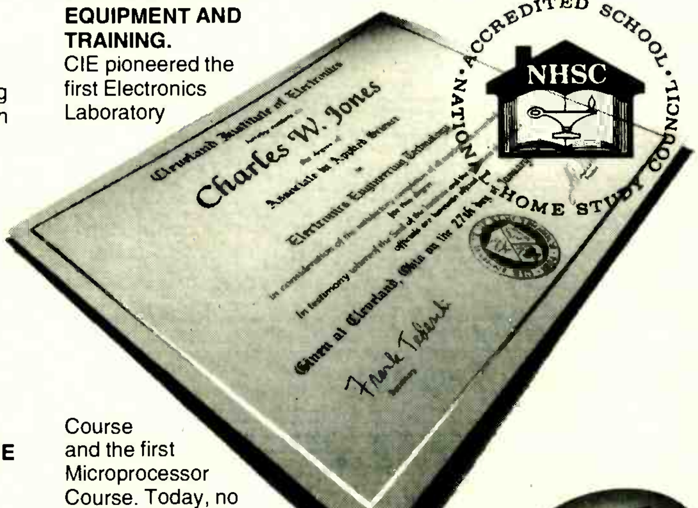

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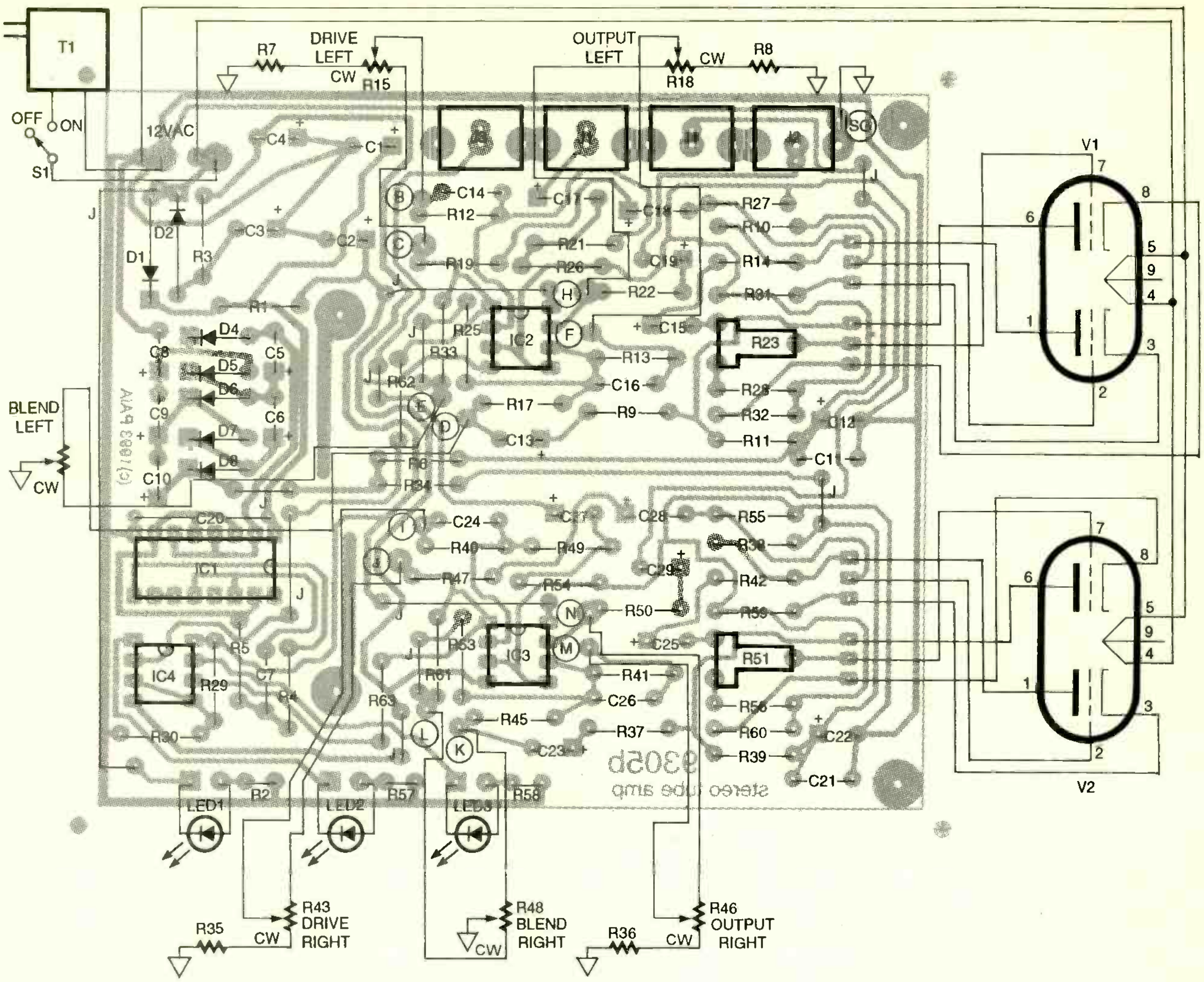


FIG. 2—**PARTS-PLACEMENT DIAGRAM. Any accepted assembly technique can be used for the TubeHead, but a PC board is recommended.**

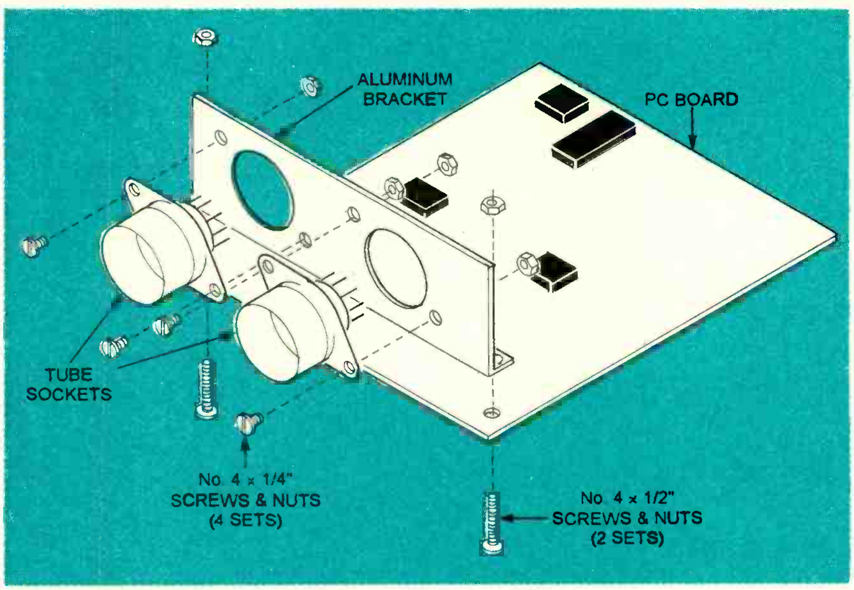


FIG. 3—THE TUBES ARE MOUNTED HORIZONTALLY to fit in a low-profile case. Four No. 4 × ¼ inch machine screws and nuts fasten the tube sockets to their mounting bracket. The right-angled aluminum bracket is fastened to the circuit board with four No. 4 × ½-inch screws and nuts that also hold the assembly in the case.

tape and vinyl records still had the same compressing non-linearities. It's not unusual to find a listener expressing a preference for a taped copy of a CD over the CD itself. It was the general acceptance of CDs and digital sound recording that finally removed the last vestiges of natural "imperfection."

If tube preference is only habit, it is deeply ingrained. Even with the overwhelming editing and duplicating advantages of digital audio tape, many artists and engineers prefer to record on analog tape before transferring the sound to digital audio tape. Also, some of the most expensive condenser microphones used in professional recording have a vacuum-tube preamplifier built into the microphone. And if you don't know that tube amplifiers are *de-rigueur* in rock 'n' roll, it can only be because you don't care.

CLIPPING AND SQUASHING

All amplifiers become non-linear when they're driven hard enough, but tubes and transistors distort in distinctly different ways. An easy way to see these differences is with transfer curves such as those shown here. The input at the bottom responds to the curves to produce the outputs shown at right.

The transfer curve shown in Fig. 1-*a* is typical of a solid-state amplifier. Response is linear and wonderful until you run out of headroom, and then the signal is suddenly clipped. The curve in Fig. 1-*b* shows what happens in the typical vacuum-tube amplifier. Because the ends of the curve roll over gradually rather than suddenly reaching a plateau, an increasing output is gracefully "squashed" rather than suddenly "clipped."

When you refer to the work of Fourier related to this clipping and squashing business, he tells us that a "discontinuity," such as the point where the output of the solid-state amplifier suddenly stops changing, splatters a spectrum of harmonics. These frequency overtones in the original waveform, both odd and even, easily extend into and beyond audible range. Even a guitarist's "fuzz box" doesn't generally produce harmonic structures like this because, in a musical context, the strong odd-order harmonics can lead to unplanned, unpleasant dissonances.

"Squashing," on the other hand, has no discontinuities and, because of this, the harmonics cluster within a few octaves of the fundamental. A particularly interesting observation is that while linear response leaves harmonics unchanged and clipping can only add harmonics, this squashing distortion can actually decrease total harmonic content. In Fig. 2, a triangular waveform is passed through a squashing function to produce a nearly sinusoidal output; the odd-order harmonics that made the input a triangle have been suppressed. Unlike a filter, this harmonic suppression is not frequency sensitive. Ω

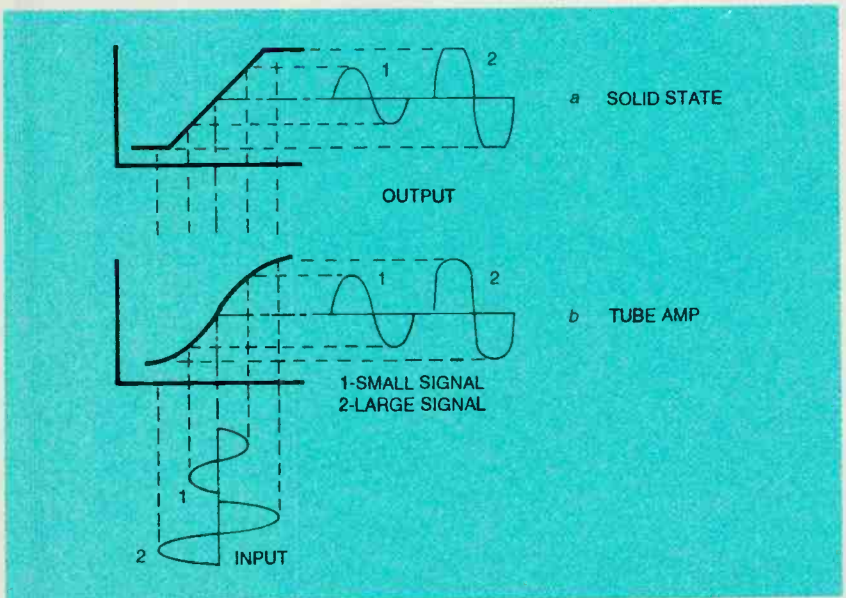


FIG. 1—TRANSFER CURVES show how an input is transformed into an output. The solid-state amplifier (*a*) is linear over most of its useful range before it suddenly plateaus. A tube amplifier (*b*) is never completely linear and goes into saturation gradually.

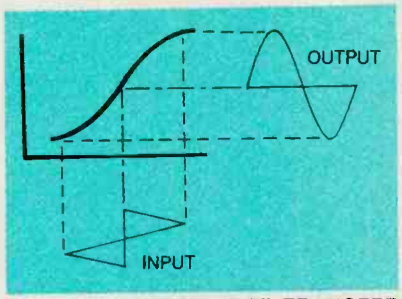


FIG. 2—A "SQUASHING" TRANSFER function can decrease total harmonic content of a signal, such as the triangular wave shown here.

The TubeHead circuitry exaggerates the natural non-linearities of the tubes by operating them at fairly low voltages and plate currents (see the Vacuum Tube Fundamentals sidebar). In addition to controlling how hard the tubes are driven, and consequently how much the signal is squashed initially, the circuit also features a blend control that sets the relative amounts of pre-tube or post-tube signal in the output.

How it works

The TubeHead schematic is shown in Fig. 1. The output from 12-volt AC transformer T1 is positive half-wave AC rectified by D1 and filtered by C1, C2, and R1 for a +15-volt supply. A −15-volt supply is obtained from D2, C3, C4, and R3.

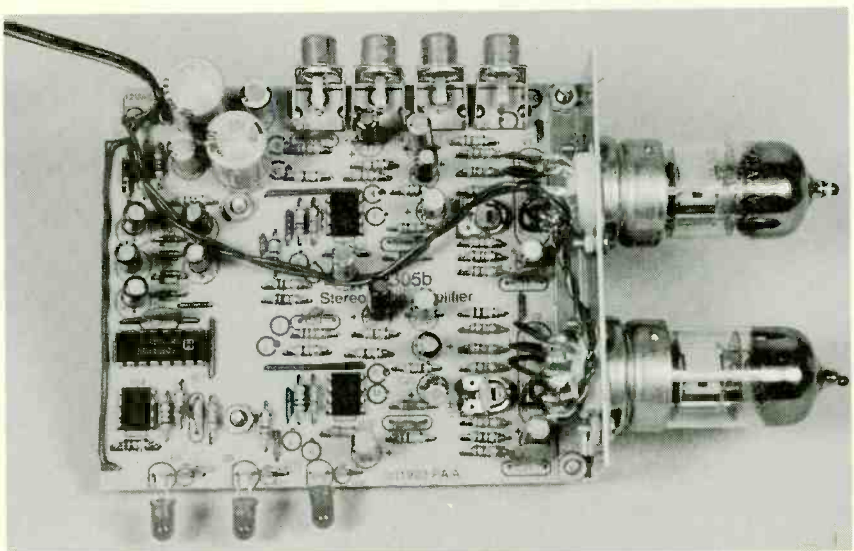


FIG. 4—COMPLETED PC BOARD and tube assembly.

Most tube circuits operate at high plate voltages, often hundreds of volts, and components needed to obtain those voltages

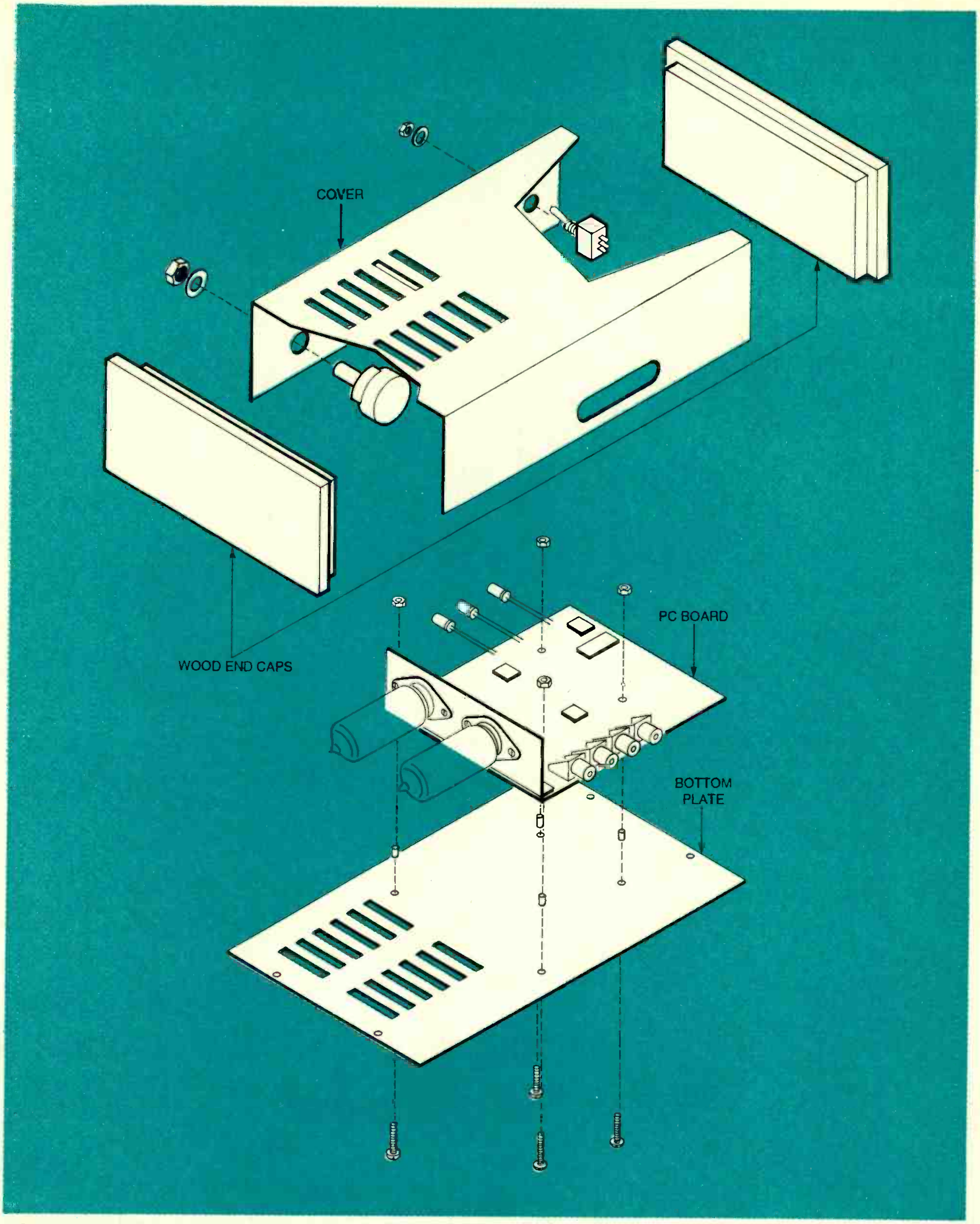


FIG. 5—THE CASE IS FORMED from 0.040-inch sheet aluminum with the top and bottom held together by screws driven into the wooden end caps. You can purchase this case from the source given in the Parts List.

can be expensive and difficult to find as well.

However, the method used to make a tube *really* sound like a tube is to "starve" it with low plate voltage.

The 45 volts required for the TubeHead is higher than would typically be found in solid-state circuitry. In place of an exotic multiwinding power transformer, the tube's plate supply is produced by a voltage multiplier. Capacitor C7 and resistors R4 and R5, together

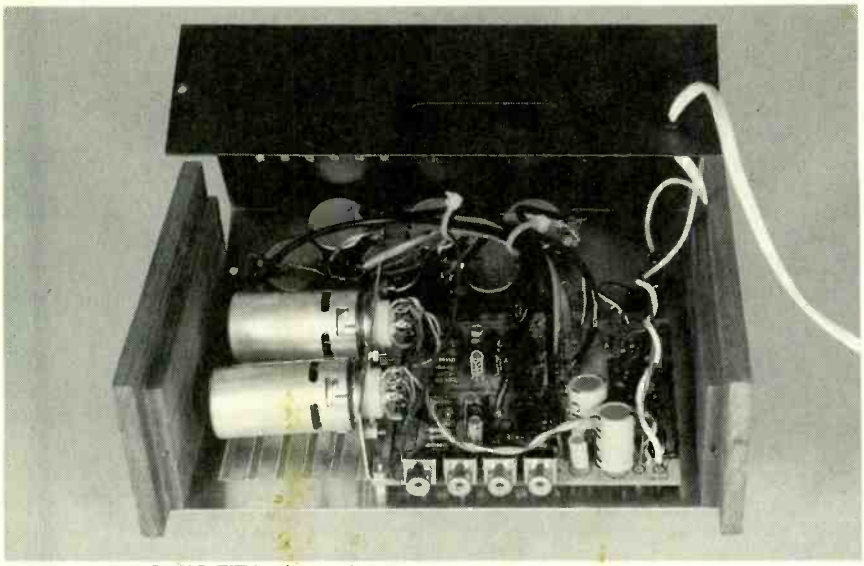
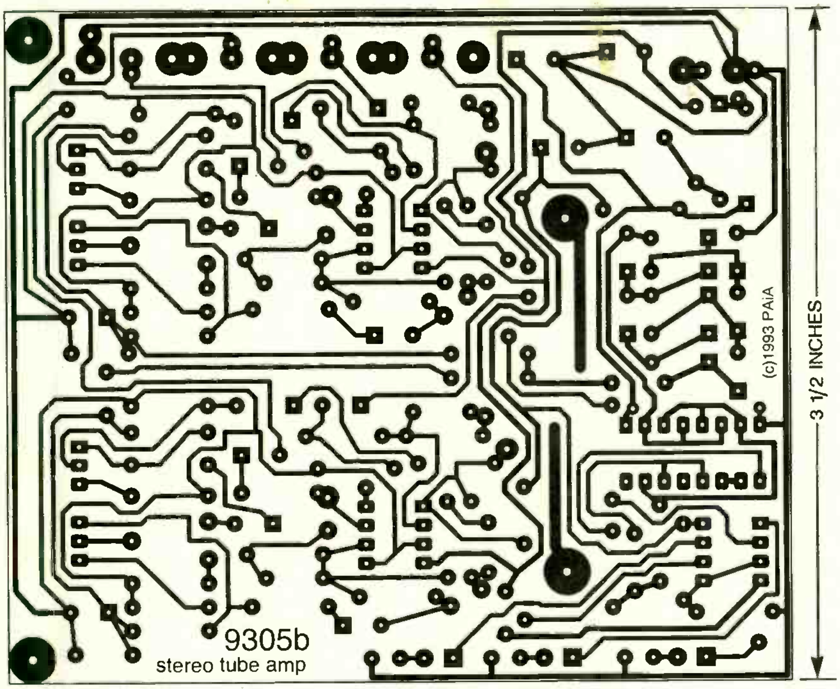


FIG. 6—IT'S A SNUG FIT in the prototype case.



TUBEHEAD FOIL PATTERN.

with three of the six inverters in IC1 form a 60-kHz, 15-volt, peak-to-peak, square-wave oscillator. The remaining three buffers in IC1 are wired in parallel to provide the greater output current necessary for driving a network of diodes (D4 to D8) and capacitors (C5, C6, C8 to C10) that multiply the 15-volt square wave to a DC voltage as high as 45-volts.

The stereo TubeHead consists of two identical preamplifier/tube/final amplifier sections. The left channel is built around a 12AX7 tube (V1) and a 5532 op-amp (IC2). The right channel is identical to this section.

The signal path begins with an adjustable gain stage built around op-amp IC2-a. Input signals are coupled by C17 and appear across R26. When the DRIVE control R15 is fully counter-clockwise, the voltage gain is set to a minimum of ½. At the clockwise end, the voltage gain is set to a maximum of 25. Capacitor C14 rolls off the high frequency response at a corner frequency of about 30 kHz. An op-amp wired as a comparator (IC4-a) turns on LED2 when the output of the gain stage starts to clip.

Two tube stages provide maximum control of the output waveform's asymmetry. Both tube stages are within the envelope of V1, a 12AX7 dual triode. The output of IC2-a is coupled by R19 and C18 to R27, the grid resistor of the first tube stage. The output of the first tube stage appears across plate-load resistor R10, and is coupled by R14 and C15 to SYMMETRY trimmer R23. Trimmer output sets the amount of signal applied to the grid of the second stage. The output of the second stage appears across plate-load resistor R11.

A final output buffer stage built around op-amp IC2-b converts the relatively high impedance output of the tubes to a lower impedance consistent with contemporary audio equipment. Its operation is very similar to that of the circuitry around IC2-a.

Op-amp IC2-b also mixes the dry signal (pre-tube) with the post-tube processed signal using the BLEND potentiometer R20. At the clockwise end of R20's rotation, the final amplifier is fed exclusively with the output of the tube. At the counter-clockwise end, it's fed by the buffered input signal from the first gain stage. At intermediate settings of R20, a mix of the dry signal and the tube output drive the final buffer. The relative values of R37 and R61 compensate for the additional gain of the tubes so that the overall level is fairly constant as BLEND is varied from "pre" to "post."

Building the TubeHead

Any accepted conventional technique can be used for the assembly of the TubeHead electronics. The foil pattern for the PC board in the TubeHead is provided in this article if you want to make your own. However, ready-to-use PC boards and other components are available from the source given in the Parts List. Figure 2 is the parts-placement diagram for the PC board.

If you build the TubeHead from scratch, there are some

PARTS LIST

All resistors are ¼-watt, 5%, unless otherwise noted.
R1, R3, R57, R58—100 ohms
R2, R22, R50—330 ohms
R4, R5—33,000 ohms
R6, R30, R33, R34, R61—10,000 ohms
R7, R8, R35, R36—220 ohms
R9, R37, R62, R63—100,000 ohms
R10, R11, R38, R39—270,000 ohms
R12, R40—22,000 ohms
R13, R14, R41, R42—82,000 ohms
R15, R18, R20, R43, R46, R48—10,000 ohms, panel-mount potentiometer
R17, R25, R45, R53—470,000 ohms
R19, R21, R26, R47, R49, R54—47,000 ohms
R23, R51—100,000 ohms, horizontal-mount trimmer potentiometer
R27, R55—150,000 ohms
R28, R56—8200 ohms
R29—1000 ohms
R31, R32, R59, R60—2700 ohms
Capacitors
C1, C3—100 µF, 25 volts, electrolytic
C2, C4—1000 µF, 16 volts, electrolytic
C5, C6, C8–C10, C19, C29—33 µF, 25 volts, electrolytic
C7—220 pF, ceramic disk
C11, C21—0.01 µF, ceramic disk
C12, C13, C15, C18, C22, C23, C25, C28—1 µF, 50 volts, electrolytic
C14, C24—20 pF, ceramic disk
C16, C26—5 pF, ceramic disk
C17, C27—2.2 µF, 25 volts, electrolytic
C20—0.05 µF, ceramic disk
Semiconductors
D1, D2—1N4001 diode
D3—not used
D4–D8—1N4148 diode
LED1–LED3—Red light-emitting diode
IC1—CD4049 CMOS hex inverting buffer, Harris or equivalent
IC2–IC4—NE5532 dual low-noise op-amp, Signetics or equivalent
Other components
J1–J4—RCA phono jack (PC mount)
S1—SPST switch
T1—12.5-volt AC, 500 milliampere wall-mount transformer
V1, V2—12AX7 dual triode tube

Miscellaneous: tube sockets and mounting brackets, wire, solder, hardware, PC board, case, etc.

Note: The following items are available from PAiA Electronics, Inc., 3200 Teakwood Lane, Edmond, OK 73013, phone (405) 340-6300, fax (405) 340-6378:
- **TubeHead PC board with tube-mounting bracket (9305pc)—$22.50**
- **Complete kit of parts and PC board, less case, for 2-channel TubeHead (9305k)—$78.25**
- **Punched, formed, and anodized case with 2-color legending and wooden end caps (9305cen)—$19.50**

Please add $5 P&H to each order.

precautions to observe: Every ground in the system should return to a single point, but this is not always practical. Nevertheless, it is *very important* that there be separate wires for the ground of the audio circuitry and the power ground to IC1. The frequency of the 60-kHz square wave that drives the voltage multiplier is above the audio range, but if it leaks into the audio path it can cause unpleasant distortion. It is also recommended that you separate the voltage multiplier from the audio components (particularly the tubes and related components) by placing them at opposite ends of the board.

Connect the tube filaments directly to the points where the transformer wires meet the PC board with separate wires. Be sure that no filament power passes through any part of the signal ground. Twist the filament wires together and route them away from all of the audio components.

When installing components, observe the polarity of electrolytic capacitors and diodes. Note that a single-channel version of the TubeHead can be built by eliminating all of the components drawn within the dashed lines on the schematic.

The TubeHead circuitry will fit into a low-profile case if the tubes are mounted horizontally. A right-angle aluminum bracket holds the tube sockets to the component board as shown in Fig. 3, and individual wires connect the socket's solder lugs to the rest of the circuitry. Figure 4 shows the completed PC board and tube assembly.

The prototype case was formed from 0.040-inch sheet aluminum with the top and bottom held together by screws driven into the wooden end caps (see Fig. 5). However, any case with interior dimensions greater than 7 × 5 × 2 inches will work well. If you make your own case, don't forget that tubes radiate a lot of heat. In the prototype, twelve 1 × ⅛-inch ventillation slots were cut in the metal above and below each tube to allow for adequate air flow. Figure 6 shows how all the components fit in the prototype case.

When you have completed the assembly and thoroughly checked your work, it's time for the all important "smoke" test. If any fault shows up, it is most likely to occur at this time.

Plug the wall-mount transformer into an outlet and turn on the power switch. The POWER indicator (LED1) should light; if it doesn't, you should immediately unplug the unit and find out why. Improperly placed components or solder bridges on the circuit board might be the cause. Also check the orientation of the integrated circuits.

When LED1 lights, let the unit idle for a few minutes while you check for passive components that might be getting hot, smoke, or any unusual smell. Observe the tube filaments to be sure they're glowing—if not, check the soldered connections on the tube sockets and the twisted pair that connects the filament circuit to the power supply.

If everything works well after a few minutes of operation, connect a low-impedance, line-level source to the left input (J1), and connect the corresponding output (J2) to an amplifier. Set the left channel DRIVE, BLEND, and OUTPUT controls to midrange and confirm that the signals flow correctly through the unit. Change the settings of the controls and observe that each one affects the sound. Notice that at

VACUUM-TUBE FUNDAMENTALS

Figure 1 shows a typical triode vacuum tube. Because of the Edison Effect, heat from the filament drives free electrons from the oxide coating on the cathode. The positive voltage on the plate attracts the electrons, and the moving electrons produce a current flow. A negative bias voltage on the grid repels some of the electrons and prevents them from reaching the plate, resulting in lower current flow. In this way, a changing negative charge on the grid can modulate the plate current.

One source of non-linearity in vacuum tubes is "space charge;" electrons that are driven from the cathode but don't reach the plate simply accumulate. This cloud of negatively charged electrons has the same effect as a negative voltage applied to the grid—it decreases current flow. This is referred to as "self-biasing." This is a non-linear process because increasing negative grid voltage blocks electrons, which produces more space charge. This has the effect of making the grid even more negative.

Operating a vacuum tube at low plate voltages doesn't significantly affect the number of electrons that leave the cathode; that is primarily set by the filament temperature. So at low plate voltages and currents, space charge becomes a more important factor (just as many electrons are leaving the cathode, but fewer of them are reaching the plate). As a result, the non-linearity which is present in all tubes is exaggerated.

The TubeHead circuitry operates at such low voltage and current that it completely self-biases. To see this, measure the voltage between any of the grids and ground with a high-impedance scope or voltmeter. You will find that the grid is about 1 volt, negative. The negative voltage is the result of electrons boiling off the cathode and clustering around the grid. Ω

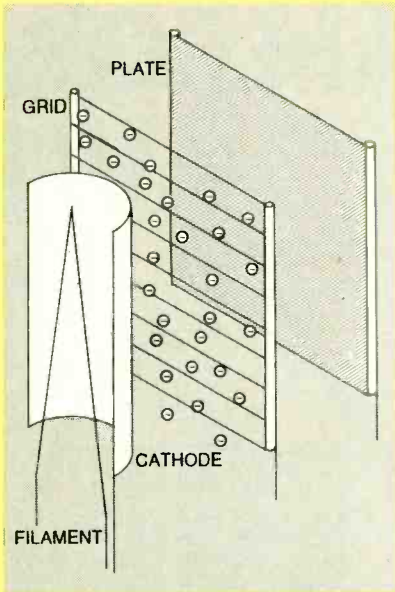


FIG. 1—TYPICAL TRIODE vacuum tube. Heat from the filament causes electrons to boil off the cathode. Any electrons not attracted to the positive plate voltage form a cloud that biases the tube.

some point in the rotation of the DRIVE control potentiometer, CLIP indicator LED2 turns on.

Disconnect the source and amplifier from the left channel and connect it to the right channel. Confirm that this channel behaves the same way as the left channel.

Using the TubeHead

The 50:1 gain range available from the TubeHead's input buffer stage allows a wide range of signal sources to be processed. Typically, the signal source, such as a CD or tape player, can be plugged into the TubeHead inputs, and the outputs can plug into the main amplifier. The tape monitor input and output jacks on your integrated amplifier will provide a handy "effects" loop.

Each channel has three front-panel controls and one internal trimmer. The DRIVE control determines how hard the tube is driven and, as a result, how much it "squeezes" the signal. The circuitry is designed so that with DRIVE set to minimum, the tube begins its non-linear response at about 0 dBV. With DRIVE at maximum, non-linearity onset occurs at about a 20-millivolt input.

The BLEND control sets the relative amounts of pre- and post-tube sound in the output. With the control fully counter-clockwise (the "pre" setting), only the clean signal appears in the output. Turning the control fully clockwise (the "post" setting) provides an exclusive output of tube sound.

The final panel control for each channel is the OUTPUT level. After setting the DRIVE and BLEND controls, set the OUTPUT level as needed for the best balance and lowest overall noise in the signal path.

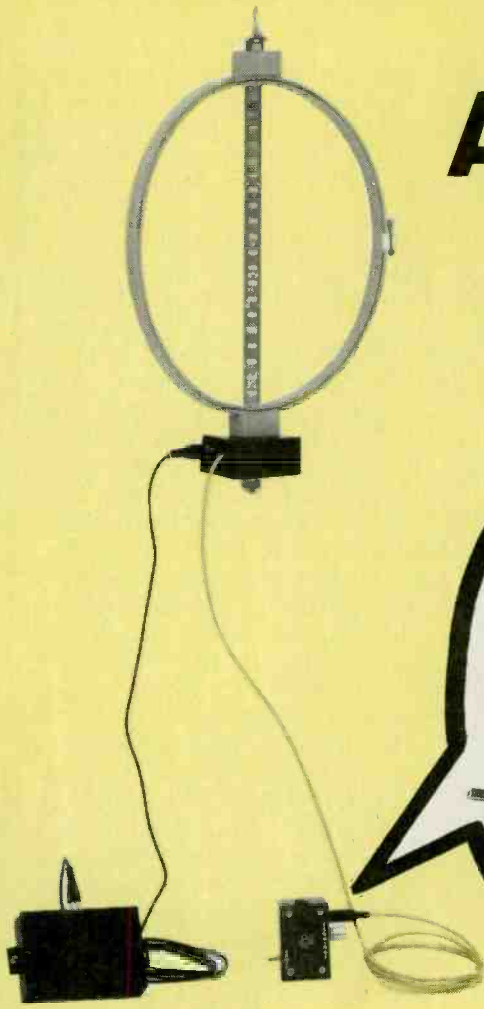
As with the front panel controls, the SYMMETRY trimmer for each channel should be set to taste. These trimmers (R23 for the left channel and R51 for the right) are arranged so that at the clockwise end of their rotation, the output of the TubeHead is approximately symmetrical. Counter-clockwise rotation of these trimmers increases the asymmetry.

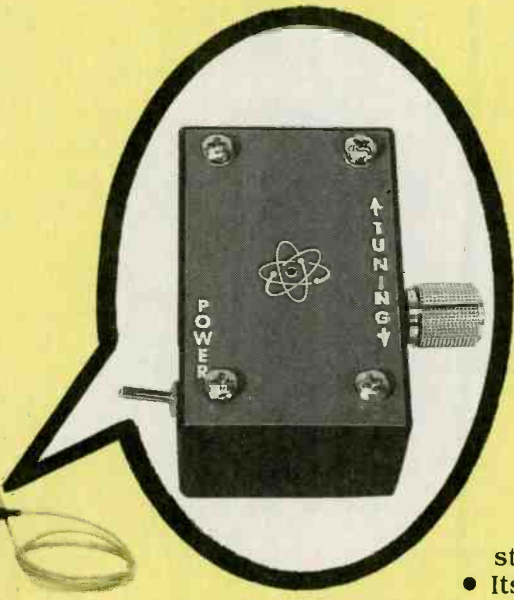
Notice that CLIP indicators LED2 and LED3 light when the first op-amp gain stage begins to clip; they are not intended to indicate distortion in the tube. If the CLIP indicator for a channel lights, reduce the DRIVE until the light goes off. Overloading the tube produces the desired effect, but overdriving the op-amps does not.

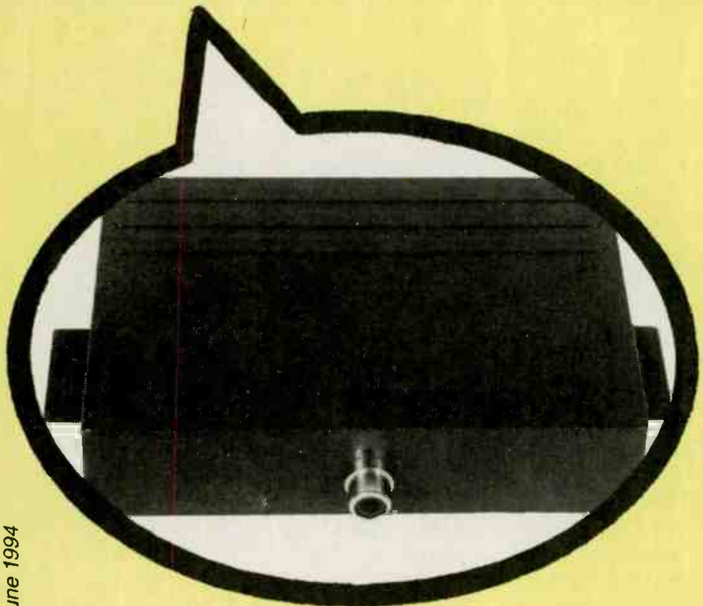
If you're involved in the production of music, either as musician or sound engineer, you'll find the TubeHead to be a useful addition to your bag of audio tricks. In addition to its warming ability, the TubeHead's "squashing" action makes it a useful substitute for an audio compressor or sustainer. The compression of an overloaded vacuum tube is not the same as a normal studio compressor. Compressors act on the average level of a signal over a relatively long time period. They affect the envelope of the signal without altering the harmonic structure. The tube's action is on a cycle-by-cycle basis, but with the exception of the subtle harmonic distortion that this produces, other effects are similar.

The nominal input impedance of the TubeHead is about 20 kilohms, consistent with most hi-fi equipment, synthesizers, and sound blasters. However, it is a little low for a proper match with high-impedance sources such as guitar pickups. A few minor changes will overcome this incompatibility; remove R26 and C14 and change the value of R21 to 680 kilohms and R12 to 100 kilohms. This increases the input impedance to 680 kilohms, making it compatible with such instrument transducers as piezoelectric microphones and guitar pickups. Ω

AM POWER LOOP ANTENNA







Build this AM radio antenna booster and receive distant stations that you never expected!

ALLEN A. GAULT

IF ANY OF YOUR FAVORITE AM RADIO stations is hard to receive because it is so far away, the Power Loop, an AM radio antenna booster, is the project for you. When coupled to your AM receiver, the improved signal-to-noise ratio it makes possible to boost the reception of any station in the 535 to 1705 kHz AM band. It will help out in poor reception areas, and you might even find yourself listening to AM stations that you never knew existed!

Here are some reasons you'll want to build this compact, easy to operate Power Loop:

- It eliminates the need to "jockey" your radio around to get the best signal from the AM station you want to hear.
- Its directivity reduces or eliminates most undesired interference, including radiated AC hum.
- It reduces or eliminates annoying heterodyne whistle.
- It compensates for AM receiver antenna circuit *tracking error*," assuring ideal RF tracking across the entire band.

The Power Loop is an easy to build, high-performance accessory for your AM radio. It contains no costly, hard-to-get components or critical wiring. Both circuit board construction and a modest amount of mechanical crafting are needed to build the project. Its power consumption is very low—a matter of milliwatts, and no special tools or test instruments are needed. However, a multimeter will be helpful for troubleshooting if the Power Loop does not work correctly when it is first turned on.

The high-Q loop can be remotely tuned with a rotary potentiometer control. The loop, the largest component in the system, can be attached to the wall above your AM radio. No electrical connections to your radio are needed because the loading coil, an important system component, is inductively coupled to the ferrite "stick" antenna in your radio. If the enclosure on your AM receiver is large enough, the loading coil can be placed inside.

Power Loop system

The Power Loop has four components and five functional sections, as shown in Fig. 1:

1. *Tuner amplifier*—includes the loop antenna and the tuner-amplifier. The varactor-tuned antenna is connected to the low-noise amplifier mounted at the base of the loop. The assembly consisting of the tuner amplifier and loop antenna can be attached to the wall near your AM receiver with a picture hook, suction cups or adhesive pads.
2. *Remote tuning control*—contains the power switch, tuning potentiometer and power indicator LED. Its rectifier-filter circuit converts the 24-volt AC input from the wall outlet-mounted transformer to filtered DC. The unit provides the variable voltage required to tune the loop to the desired frequency.
3. *Loading coil*—is placed near the AM receiver to couple the amplified RF signal to the host AM radio receiver inductively.
4. *Transformer*—a plug-in, wall-outlet-mounted transformer that supplies 24-volt AC to the remote tuning control from the 120-volt AC line.

Circuit operation

Figure 2 is the schematic for the tuner-amplifier. The loop antenna is connected to the gate input of transistor Q1, and it is tuned by varactor D1. Tuning voltage is available through R1, which is connected to the remote tuning control with a two-wire shielded cable and plug PL1. The drain output of Q1 is coupled to the gate of Q2 for additional amplification. The drain output of Q2 is coupled to the gate of Q3, which is connected as a source-follower.

The high input impedance of Q1 presents minimal loading on the tuned loop. The Q3 source-follower powers the loading coil

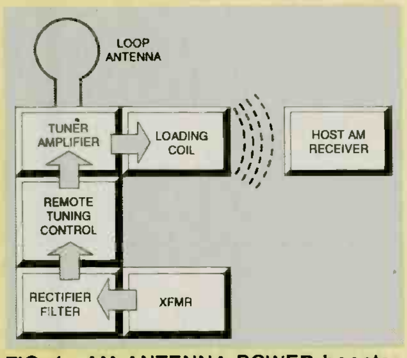


FIG. 1—AM ANTENNA POWER booster block diagram. The loop antenna can be mounted on or near the host AM radio. The loading coil field couples to the AM radio's antenna.

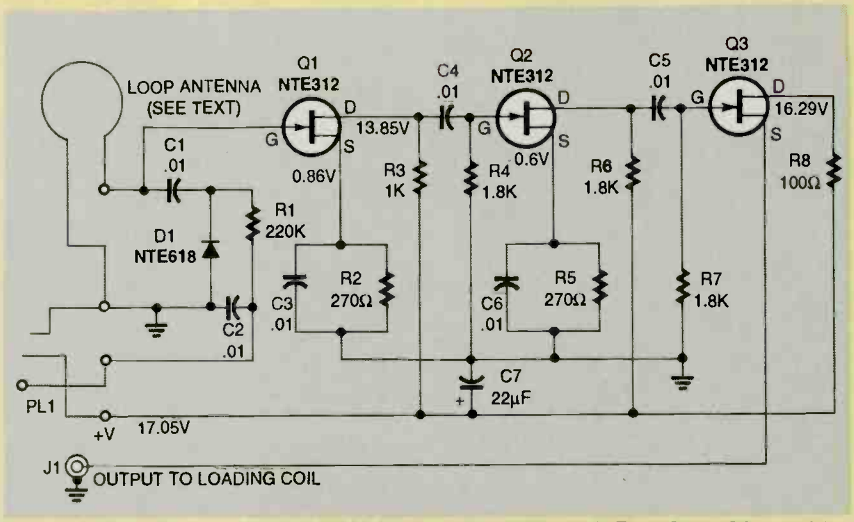


FIG. 2—TUNER-AMPLIFIER SCHEMATIC DIAGRAM: Three JFETs, Q1 to Q3, amplify the signal. Loop antenna tuning is performed by varactor diode D1.

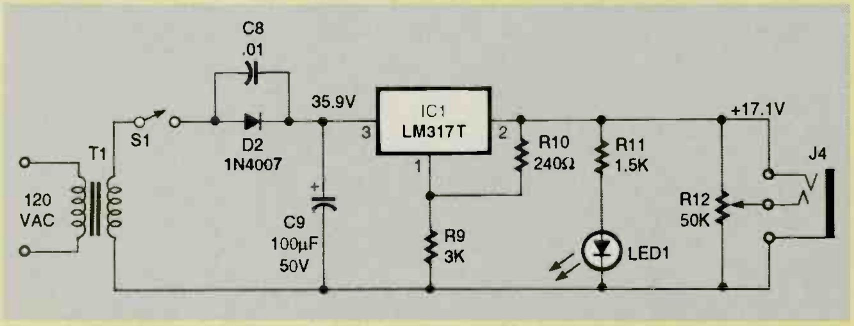


FIG. 3—REMOTE TUNING CONTROL UNIT SCHEMATIC DIAGRAM. Raw 24-volt AC input is rectified and regulated in this circuit designed for improved filtering. Potentiometer R12 permits fine tuning.

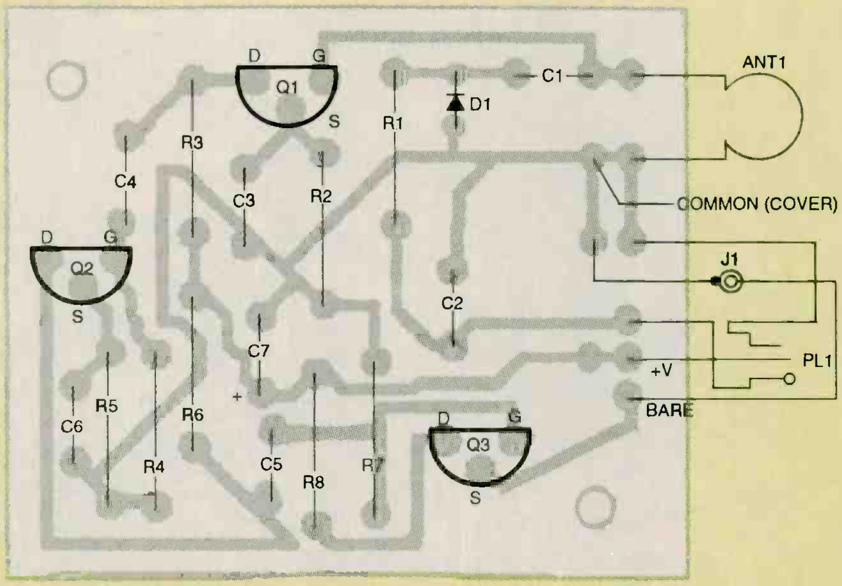


FIG. 4—PARTS PLACEMENT DIAGRAM FOR TUNER-AMPLIFIER. Jack J1 and plug PL1 are mounted on the case.

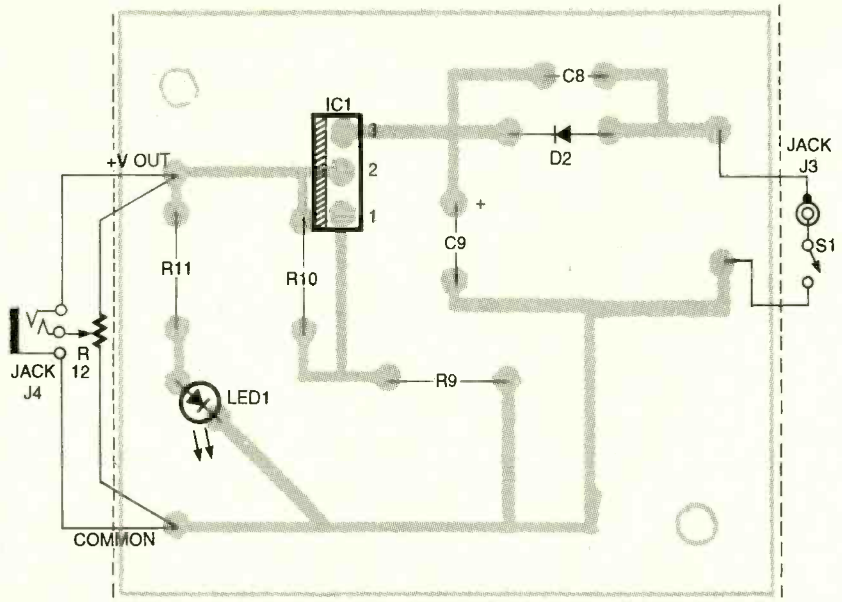


FIG. 5—PARTS PLACEMENT DIAGRAM FOR THE REMOTE TUNING CONTROL. Jacks J3 and J4, potentiometer R12, switch S1 and LED1 are mounted off the case.

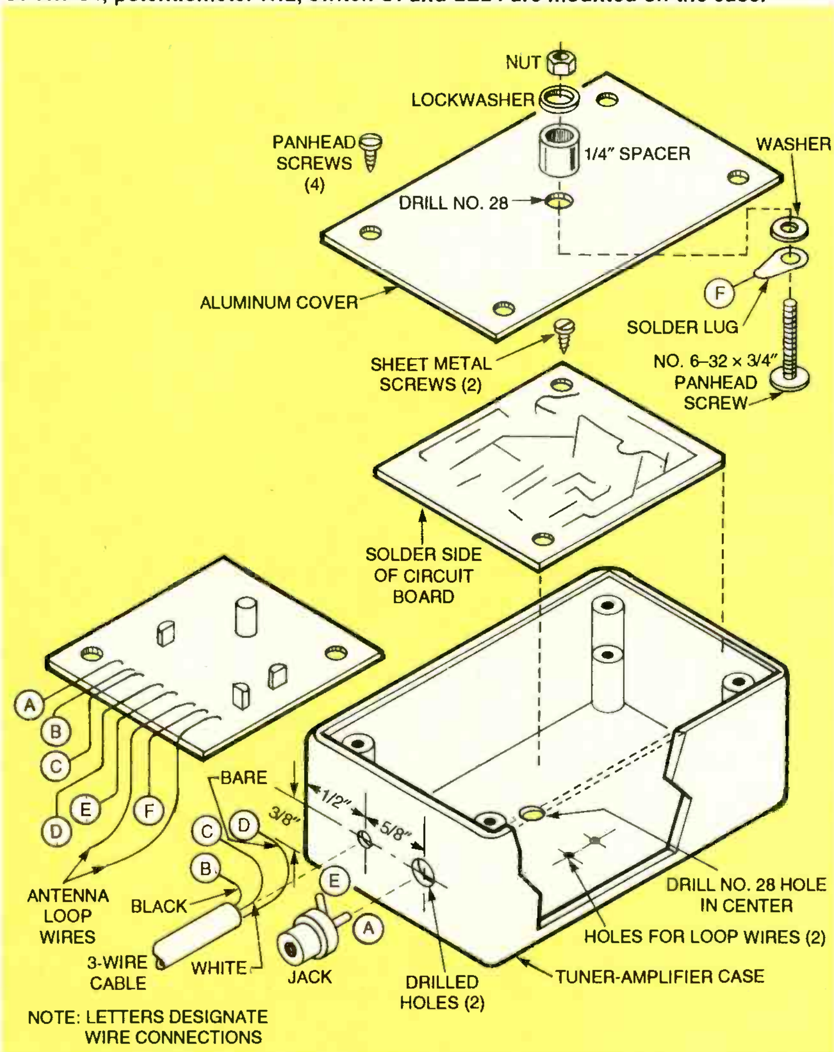


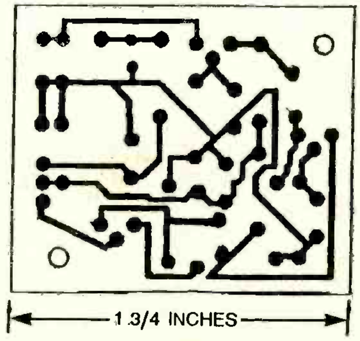
FIG. 6—ASSEMBLY DIAGRAM FOR THE TUNER AMPLIFIER. The circuit board is mounted in an inverted position, and the complete unit moves with the loop antenna.

through a shielded phono cable. The voltage values to be expected at various test points in the circuit are given.

Figure 3 is the schematic for the remote tuning control. The 24-volt AC from the wall-outlet transformer via cable can be turned on and off by switch S1. Diode D2 rectifies the input AC voltage, and C8 filters out AC line hum. Capacitor C9, part of the "L" input filter, filters the rectified voltage.

Three-terminal TO-220-packaged voltage regulator IC1 can be adjusted to provide about 17 volts DC by setting the ratio of the value of resistor R9 at pin 1 with respect to that of R10 shunting pins 1 and 2.

The rectification and filtering function are included in the remote tuning control to eliminate tunable hum likely to be present if a stock wall outlet-mounted AC-to-DC adapter were used. Capacitor C8, in parallel with diode D2, blocks tunable hum.



FOIL PATTERN FOR TUNER amplifier PC board.

At least a 17-volt output is needed to tune the loop over over the entire AM broadcast band, but the distributed capacitances of each system and the varactors like D1 (see Fig. 2) are likely to vary. A voltage slightly higher than the minimum requirement assures adequate capacitance change to cover the entire AM band. The voltage values to be expected at various test points in this circuit are also given to two decimal places on this schematic.

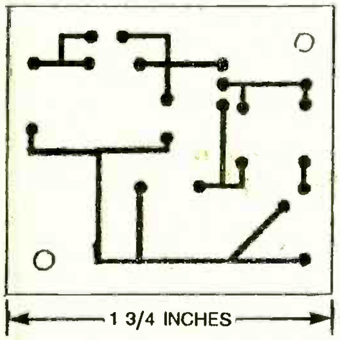
Loading coil

Loading coil L1 in the Power Loop is a ferrite-rod antenna, typical of those found in most AM radio receivers today. It can be salvaged from a discarded radio or purchased from the source given in the Parts List. Only the high impedance part of the winding is used.

Electronic construction

Tuner-amplifier—Refer to Fig. 2 and the tuner-amplifier parts-placement diagram Fig. 4. A foil pattern for the tuner-amplifier circuit board is included in this article if you want to make your own, but a finished board is available.

Insert and solder the components to the circuit board following conventional practice. Be sure the soldering iron is appropriate for the small size of this circuit board and that it is



FOIL PATTERN FOR REMOTE tuning control PC board.

at the at the right temperature for melting rosin-core solder. Observe the orientation of the packages and pins on JFETs Q1, Q2 and Q3, and observe the polarity of electrolytic capacitor C7 when inserting them in the board.

Remote tuning unit—Refer to the schematic Fig. 3 and the remote tuning unit parts placement diagram Fig. 5. A foil pattern for the tuner-amplifier circuit board is included in this article if you want to make your own, but a finished and drilled board is also available from the source given in the Parts List.

Insert and solder the components to the circuit board, again following conventional practice. Again, be sure the soldering iron is appropriate and at the right temperature for melting rosin-core solder. Observe the correct positioning of the package and pins of voltage regulator IC1 and the polarities of electrolytic capacitor C9 and diode D2 when inserting them.

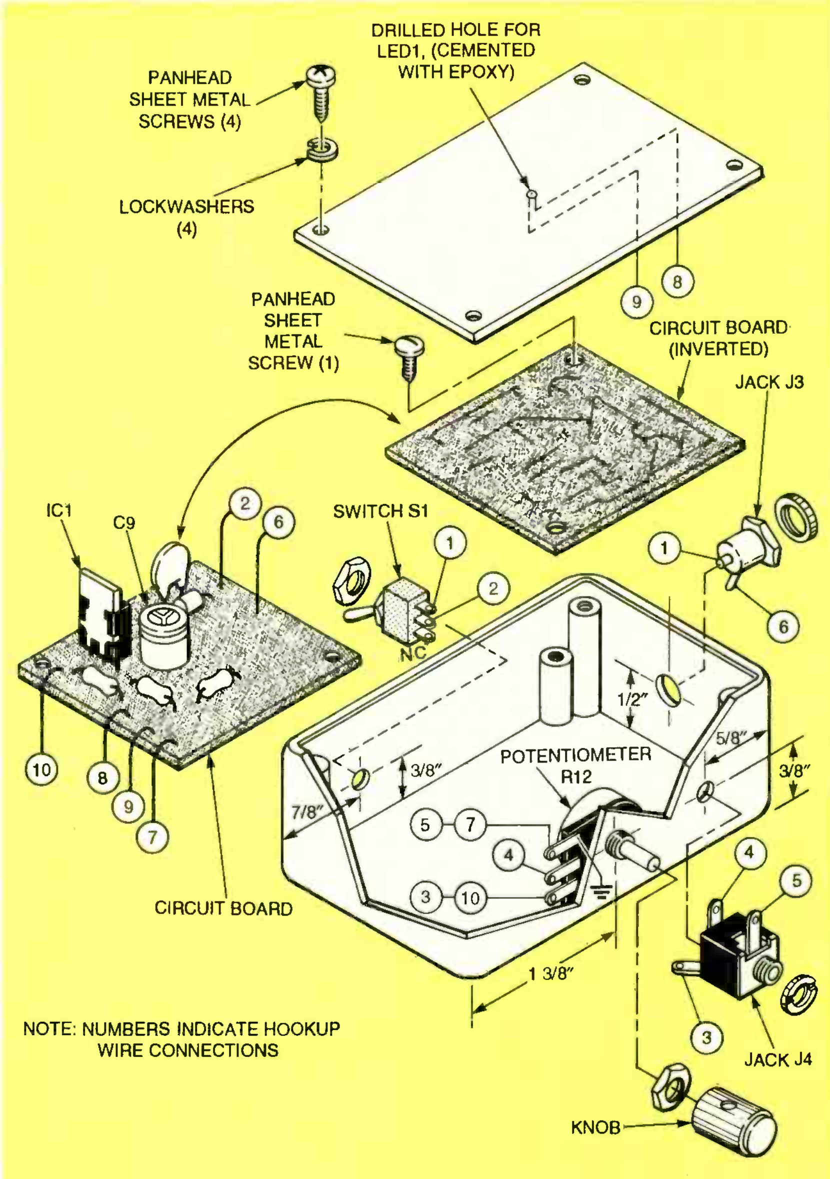
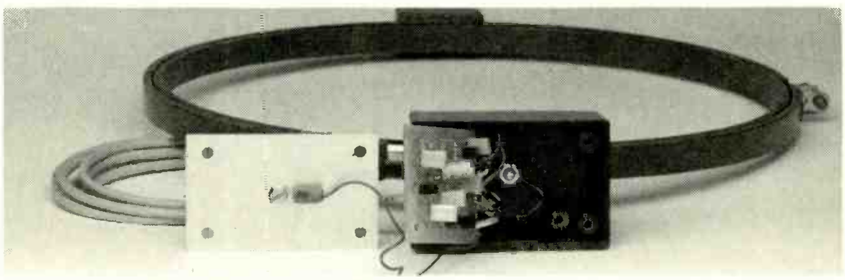


FIG. 7—ASSEMBLY DIAGRAM FOR THE REMOTE TUNING CONTROL. This unit includes the rectifier and filter for noise-free DC and the tuning potentiometer R12.



ANTENNA-TUNER AMPLIFIER ASSEMBLY.

Packaging the electronics

Tuner-amplifier. The tuner-amplifier case is a stock project case with an aluminum cover that measures $2^{11}/_{16} \times 1^{11}/_{16} \times 1^{3}/_{16}$ inches. Refer to the assembly diagram Fig. 6, and drill a hole in the center of the cover with a No. 28 drill.

Cut and strip both ends of a 4-inch length of insulated, No. 22 hookup wire and solder a lug to one end. Place the lug on a No. 6-32 $\times$ ¾-inch panhead machine screw as shown in Fig. 6, and assemble a washer before inserting it in the hole and fastening it with a ¼-inch spacer, lockwasher, and nut, as shown. (The free end of the wire will be connected to the ground bus on the circuit board later.)

Drill the five holes in the plastic case as shown in Fig. 6. The central hole in the case must align with the hole in the cover plate. Install the RCA-type phono cable jack J1 in one hole, and insert a ¼-inch ID rubber grommet in the other hole.

Insert the end of the ten-foot, two-wire shielded cable in the grommet and strip the jacket to permit making the three connections as shown in Fig. 6.

Connect the center conductor of jack J1 (A to A in Fig. 6) to the PC board with about 2¾ inches of shielded cable. Keep the unshielded part of the center wire as short as possible on each end. Connect the shield to the ground connection on J1 and the other end to the ground bus on the board. Solder the wire from the solder lug on the cover to the circuit board (F to F in Fig. 6). (The leads from the loop antenna will be soldered later.) SET the tuner amplifier aside.

Remote tuning control—The case for the remote tuning control is a stock project case measuring 2$^{11}/_{16}$ × 1$^{11}/_{16}$ × 1$^{3}/_{16}$ inches. Drill a hole in the aluminum cover to admit the lens of the miniature red LED1. Drill the holes as shown in the mechanical assembly diagram Fig. 7 for the switch S1, jacks J3 and J4, and potentiometer R12. Mount those components in the walls of the case.

Complete all of the hookup wiring between the circuit board and the off-board components with No. 22 insulated wire. (Different colored insulation will make troubleshooting easier.) Cut and strip the ends of the wires to lengths that are long enough to permit removing the circuit board without breaking any connections.

When all of the soldering is complete, invert the board and fasten it to the inner stud with a single panhead sheet metal screw as shown in Fig. 7. Cement LED1 in place with its lens projecting through cover with epoxy, and clamp the leads to underside of the cover with an insulating adhesive strip. Close the cover and fasten it with four screws. Set the unit aside.

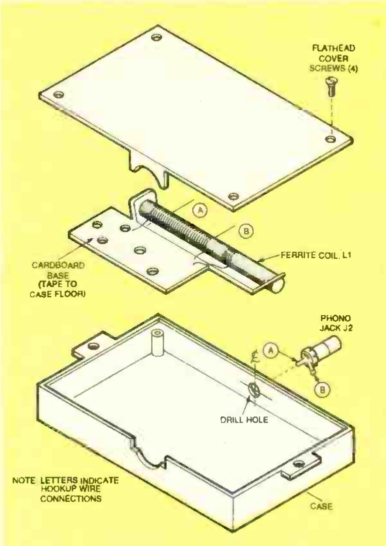


FIG. 8—ASSEMBLY DIAGRAM for the loading coil. Unit is located in or near the host AM radio.

Loading coil. The plastic case for the loading coil measures 4¼ × 2⅛ × 1-inch deep, and it has a plastic cover. Drill a hole for mounting RCA phono jack J2 in one wall of the plastic case, as shown in Fig. 8. Mount the jack in position as shown. Cut, strip, and solder the hookup wires as shown in Fig. 8, from the coil to J1.

Fasten the coil base in the bottom of the case as shown in Fig. 8 with double-sided adhesive tape.(The coil might or might not have a cardboard base.) Close the cover and fasten it with four screws. Set it aside.

Making the loop antenna

The loop antenna is made by winding insulated magnet wire on the outside of the inner hoop of a pair of standard wooden 10-inch embroidery hoops. (They have an outside diameter of about 10⅜ inches.) The inner hoop serves as the coil form, and the outer loop serves as a protective cover. These hoops are available in sewing supply and craft shops as well as five and ten and department stores, typically for less than $2.

The complete loop antenna will be clamped inside a "C-" shaped support bracket with screws and nuts that will permit it to be moved through almost 360° in either direction, inhibited only by the interference of the attached cables. The antenna is fitted to the bracket with two adapters and screws that form poles 180° apart on the outer hoop, as discussed later.

Obtain a piece of soft wood that measures about ¾ × ¾ inch, about a foot long for making the two adapter blocks shown in the detail of Fig. 9. There are many ways to transfer the contour of the outside of the outer crochet hoop to the end of the wood stock. However, you can carefully position the hoop over the end of the wood and trace part of its circumference directly on the wood with a pencil to obtain an accurate pattern.

Clamp the end of the wood in a vise and carefully cut out the shallow arc with a sharp knife, coping saw or both. Then, using

PARTS LIST

All resistors are ¼-watt, 5%.
R1—220,000 ohms
R2, R5—270 ohms
R3—1000 ohms
R4, R6, R7—1,800 ohms
R8—100 ohms
R9—3000 ohms
R10—240 ohms
R11—1,500 ohms
R12—50,000 ohms potentiometer, PC board mounting

Capacitors
C1, C2, C3, C4, Cr, C6—0.01µF, radial-leaded, Mylar, 50 volts
C7—22µF, 35 volts, aluminum electrolytic
C8—0.01µF, ceramic disk, 100 volts
C9—100µF, 50 volts, aluminum electrolytic

Semiconductor
IC1—LM317T voltage regulator, TO-220 package, Motorola or equivalent
Q1, Q2, Q3,—N-channel JFET, NTE 312 or equivalent
D1—varactor, NTE 618 or equivalent
D2—1N4007 silicon diode
D3—light-emitting diode, red, T1 or miniature axial lead.

Other components
J1, J2—RCA jacks, panel mounting
J3—audio jack for two-conductor shielded audio cable
J4—jack to mate with 24-volt AC input plug from wall-outlet mounted transformer
L1—loading coil, high-Q ferrite, (see text)
PL1—plug for two-conductor

the hoop as a form, place sandpaper on the outside, grit side up, and carefully sand the cutout arc so that it conforms closely to the hoop's outside diameter.

Measure in ¾ inch from the end of the wood and drill a hole at right angles to the flat edge of the wood through the center of the curved surface with a No. 28 drill bit. Countersink the hole as shown in Fig. 9 to admit a flat head No. 6-32 machine screw so that the end of the screw is completely below the contoured surface when seated.

Cut off a 1½-inch length squarely from the contoured and drilled end of the wood and mark it "A" lightly in pencil. Then repeat the entire process to make a second adapter. Mark

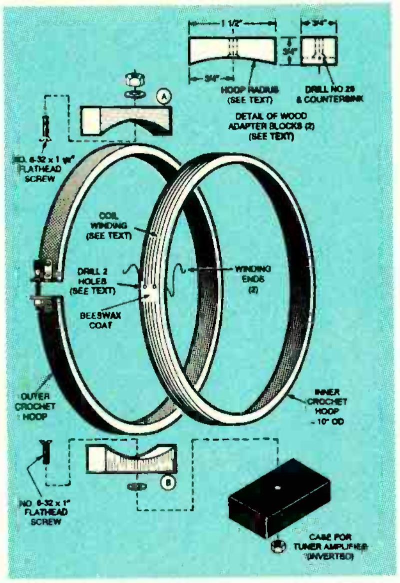


FIG. 9—LOOP ANTENNA construction. The outer hoop protects the coil windings.

the second adapter "B."

Insert a No. 6-32 × 1½-inch flat head machine screw in the adapter marked "A" and a No. 6-32 × 1-inch flat head machine screw in the hole of the adapter marked "B." Apply epoxy around the countersunk parts of the holes of both adapters to seat the screws. Avoid getting epoxy on the exposed external threads. Temporarily put a washer and nut on the ends of both screws until the epoxy sets.

When the epoxy has set, remove the clamping nut from adapter "A" and add a second washer, ¼-inch standoff, lockwasher and nut on the screw. Glue the adapters to the outside surfaces of the outer hoop 180° apart but 90° away from the thumbscrew clamp with wood glue, as shown in Fig. 9. Clamp the adapters and set the outer hoop aside for at least 12 hours.

After the glue on the adapters has set, you can paint, lacquer, or varnish both the inner and outer loops. Be sure there is no metallic pigment in any of the finishes you choose.

Winding the coil

Drill two holes just large enough to accept the No. 26 AWG wire winding ends through the inner hoop as shown in Fig. 9. They should be drilled close to the outer rim but not close enough to weaken the rim edges.

Before starting the coil winding, apply a coating of heated beeswax to the outer surface of the hoop to keep the winding from sliding off. The wax can be obtained from sewing supply stores.

Insert the first 6 inches of a 50-foot length of No. 26 AWG enameled magnet wire in one hole, and bend it back so that it will not slip out. Wind on 16 turns of wire (in either diection) around the outside of the hoop as shown in Fig. 9, pushing the turns close together in the wax layer as you wind.

After you have completed winding the turns on the rim of the hoop, insert the free end in the second hole and allow another 6 inches before cutting off the rest of the wire. Apply more heated beeswax to both ends of the two drilled holes to secure the wire in position.

Insert the inner hoop inside the outer hoop. Clamp the hoops together with the thumbscrew clamp mechanism on the outside of the outer hoop. Shape the two ends of the magnet wire so they lie over the side of the lower adapter.

Loop supporting bracket

Attach the tuner amplifier case to the No. 6-32 × 1-inch screw on adapter "B" with a lockwasher and nut. Thread the ends of the antenna loop wires through the holes drilled for them in the bottom of the case. Dress the wires to the sidewall of the case, opposite the jack J1 end, allowing enough slack to permit the circuit board to be removed and inverted, but keeping them as short as practical. When you have determined a satisfactory length, cut the wires and strip the insulating varnish back from their ends.

Secure the wires to the outside of the adapter and to the inside end wall of the case with hot beeswax. Solder them as shown in parts-placement diagram Fig. 4 and assembly diagram Fig. 6. Invert the circuit board and fasten it in position inside the case with two sheet

shielded audio cable

S1—toggle switch, SPST, panel mount

T1—transformer, 120-VAC to 24-VAC, 100 mA or greater, wall outlet-mounted with output cable and plug

Miscellaneous: PC board for tuner-amplifier; PC board for remote tuning control; shielded phono cable terminated with RCA plugs, both ends, 6 feet; two-conductor shielded audio cable, 10 feet; metal shelf-mounting channel, 3 feet (see text); two spacers, ¼ long; tuner-amplifier case with cover (see text); remote tuning control case with cover (see text); loading coil case with cover (see text); knob for potentiometer; No. 6-32 machine screws, nuts, lockwashers (see text), epoxy cement; wood glue; double-sided adhesive tape; solder; beeswax.

Note: The following parts are available from Allen A. Gault, 2012 Citrus Avenue, Jessup, MD 20794:

- **Drilled PC boards for tuner amplifier and remote tuning-control unit—$8.95**
- **High-Q loading coil with mounting tape—$3.95**
- **No. 25 magnet wire, 50 feet—$1.95**
- **Kit of all items listed above–$13.95**

Add $1.50 for shipping and handling, Maryland residents add local sales tax.

metal screws. (Use an insulating washer if the screw short circuits any traces on the circuit board when the board is fastened in position.) Assemble the cover to the case with the four panhead sheet metal screws.

Accurately measure the distance between the centers of the heads of the No. 6-32 nuts as shown in Fig. 9 by setting the completed loop antenna on a piece of paper and marking the points on the paper. This is the overall assembly height dimension. Record that measurement. (It should be approximately 13⅞ inches with the 10-inch loop and case specified.)

Then measure the distance from the supporting screws to the rim of the loop antenna, add 1 inch and record that measurement. This dimension should be about 5½ inches. Record that measurement.

Obtain a 3-foot length of ⅝-inch wide, stamped channel stock for mounting light shelving to walls from a hardware or building supply store. Measure off the two arm length dimensions and one length equal to the height of the antenna and tuner amplifier assembly on the channel stock and cut it to length.

Drill ⅛-inch holes close to both ends of the channel to accommodate No. 6-32 machine screws. Cut 90° vee-cuts 5½ inches in from both ends on both edges of the channel stock so the ends can be bent into the C-shaped mounting bracket, as shown in Fig. 10. Carefully bend the stock into the right shape to form the bracket.

Temporarily assemble the loop antenna-tuner amplifier assembly to the bracket to be sure that it fits correctly and there is no interference fit when the loop antenna is turned past the bracket. Once you have determined that the bracket is sized correctly and that the antenna loop-tuner amplifier assembly moves freely, you can remove the assembly from the bracket and paint the bracket.

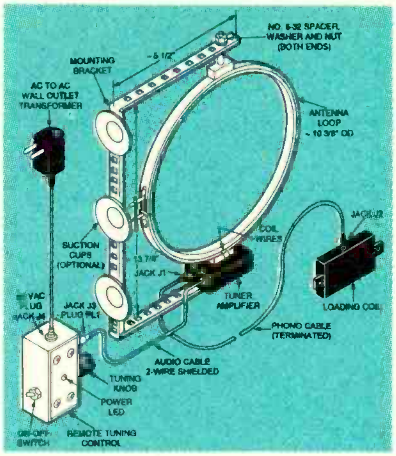


FIG. 10—SYSTEM ASSEMBLY DIAGRAM. The antenna-tuner amplifier assembly rotates within wall-mounted C bracket.

After the paint is dry, apply either suction cups, a picture-hanging hook, or adhesive pads for mounting the completed assembly on the wall.

Interconnections

Refer to mechanical assembly diagram Fig. 10. Assemble the mounting bracket to the loop antenna and tuner-amplifier with washers and nuts. Be sure the connection is secure but loose enough to permit the loop to be rotated.

Terminate the two-conductor shielded audio cable with plug PL1 that mates with jack J3. Plug the cable from the tuner amplifier in jack J3 of the remote tuning control. Plug one of the plugs of the six-foot length of shielded phono cable in jack J1 of the tuner amplifier and the one at the other end into jack J2 in the loading coil.

Operating the Power Loop

Plug wall-outlet transformer T1 into the 120-volt AC outlet and insert the 24-volt AC output plug into the jack J4 on the remote tuning control unit. Turn on the power switch. The LED power indicator should light at thie time.

Tune in a weak AM station on your AM radio. Place the loading coil near the AM radio and rotate the knob on the potentiometer in the remote tuning control to peak the signal. Orient the loop to the best reception position.

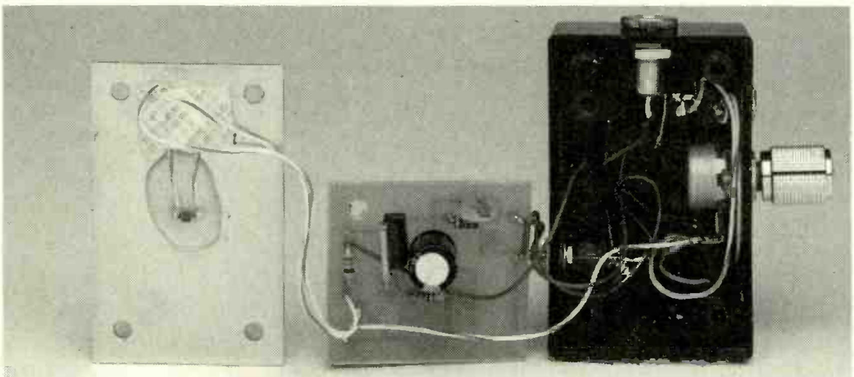
Find the best location for the loading coil with respect to your AM radio. It could be taped to the back of the radio or fastened to the wall with the back of the radio positioned against it. Overall Power Loop gain should be about 350.

The received signal should be noticeably improved as long as the desired signal strength is less than the *desensitize* level of the receiver's automatic gain control (AGC), but greater than the existing "noise floor" level. When the AGC starts to reduce the sensitivity of the receiver, no additional signal enhancement will be evident.

To prevent possible oscillations due to feedback, position the loop antenna-tuner assembly on the wall at least two feet away from the loading coil.

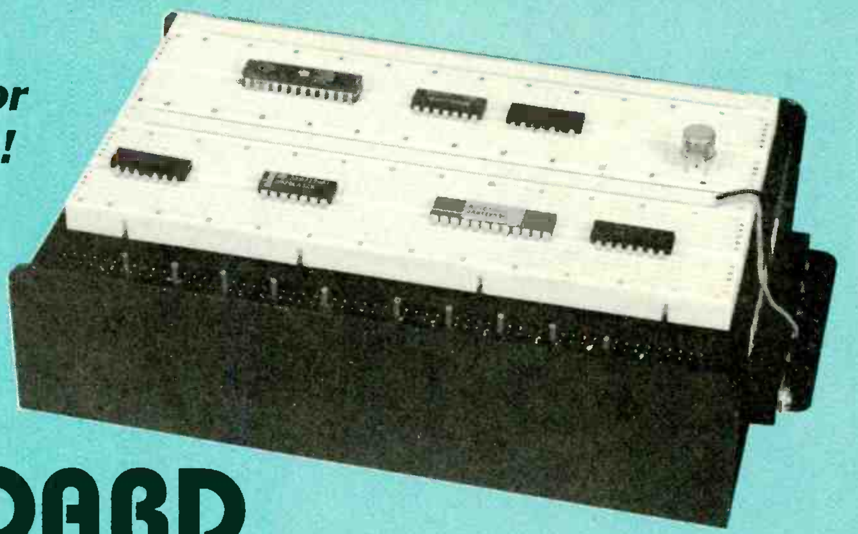
If the system does not work as expected, carefully re-examine all of your work. Check to make sure that there are no loose or open connections.

You can also measure the voltages at the test points indicated by voltage readings in schematics Figs. 2 and 3. Compare your measurements with the values shown. Any significant variations should indicate a fault and help you to isolate it. Correct any faults revealed by this test. Ω



REMOTE TUNING CONTROL.

Build this addictive breadboard system for your PC—for peanuts!



BUILD THIS PC I/O BREADBOARD

DAVE DAGE

BUILD THIS SIMPLE, STRAIGHTFORWARD circuit that lets you breadboard circuits and control them with your personal computer. The circuit consists of three parts: a parallel-interface card, an external breadboard platform, and a cable to connect them. You can control your designs with BASIC, C, assembly language, or any other language that gives you direct access to input/output ports.

This project will be presented as three articles. Part 1 details building and testing the circuit. Part II discusses programming and provides examples in BASIC, Quick C, and assembly language (using DOS's DEBUG program). Part III provides a practical example of using the circuit for a practical application: EPROM programming.

The interface card has only four standard ICs; the decoding and buffering circuit in the breadboard box has only three ICs, plus ten octal latches—one for each for the ten input and output ports. This article presents complete construction diagrams, including the PC board artwork. In addition, complete and partial parts kits are available, as mentioned in the Parts List.

Overview

The interface card is designed to operate in any standard 8- or 16-bit IBM PC or compatible expansion slot. The primary purpose of the card is to buffer and decode the signals necessary for driving a set of 32 I/O ports accessible beginning at a jumper-configurable address (0100h, 0120h, 0130h, . . . 01C0h). A DB-25 cable connects the interface card to the breadboard.

Within a given block of 32 I/O ports, the breadboard circuit decodes only the lowest eight. In addition, the input and output ports are accessed at the same addresses. For example, 260 (decimal) is the address of input port 4; it is also the address of output port 4.

Of the 16 decoded read and write ports, ten (five inputs and five outputs) are latched; the decode strobes for the remaining six (three inputs and three outputs) are available for your projects. To power your projects, the breadboard provides ±5- and ±12-volt power, which is supplied by the host computer.

A 126-pin interface connector is positioned along the top edge of the breadboard; it provides access to all the buffered and decoded I/O port signals, as well as selected computer-bus and control signals. The five independent input ports and five independent output ports, each eight bits wide, are also available at that connector. You can access all I/O ports directly at their actual I/O addresses, rather than following some translation routine, as is done for some breadboard circuits.

The breadboard provides access to useful bus signals including reset, several interrupt lines, decoded I/O read and write signals, and buffered copies of the low-order address lines (A0–A3). With that background od the I/O breadboard in mind, consider the details of the circuit.

Interface card

Microprocessors in the Intel CPU family provide a 16-bit I/O address space, allowing for 65,536 I/O ports. However, IBM's original PC design decoded only the ten lowest address bits, thereby limiting the maximum number of ports to 2^{10}, or 1024.

Within that range, many ports are reserved for controlling such functions as disk drives, video cards, serial and parallel ports. However, a large block of ports (0100–01CFh) has been set aside for I/O interfacing. Actually, that address range is undocumented in the PC/XT but specifically set aside for I/O use in the PC/AT. Anyway, this design lets you select one of seven 32-port blocks in that range.

As shown in Fig. 1, IC2 decodes address lines A4–A9 into seven groups of 16 ports. The $\overline{\text{Y0–Y6}}$ outputs of IC2 provide the base address of each block. Jumper JU1 allows you to configure the base address so that conflicts are avoided in your system. This article and the

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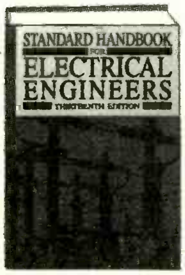

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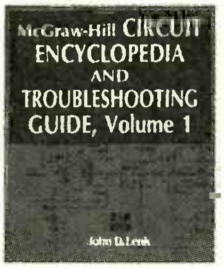

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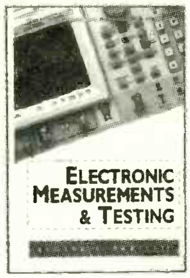

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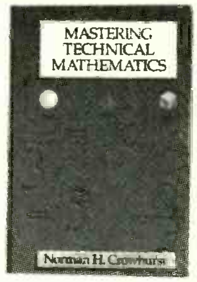

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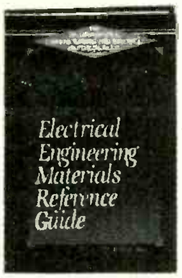

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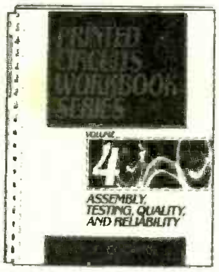

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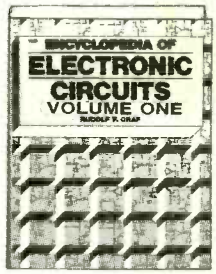

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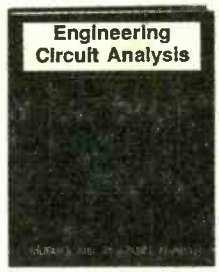

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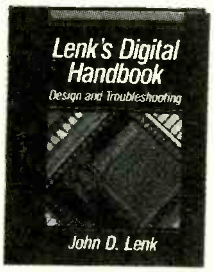

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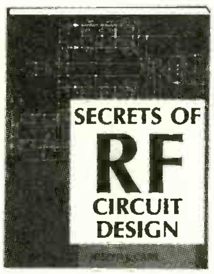

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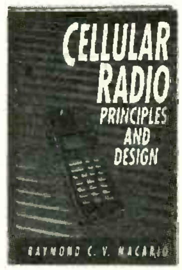

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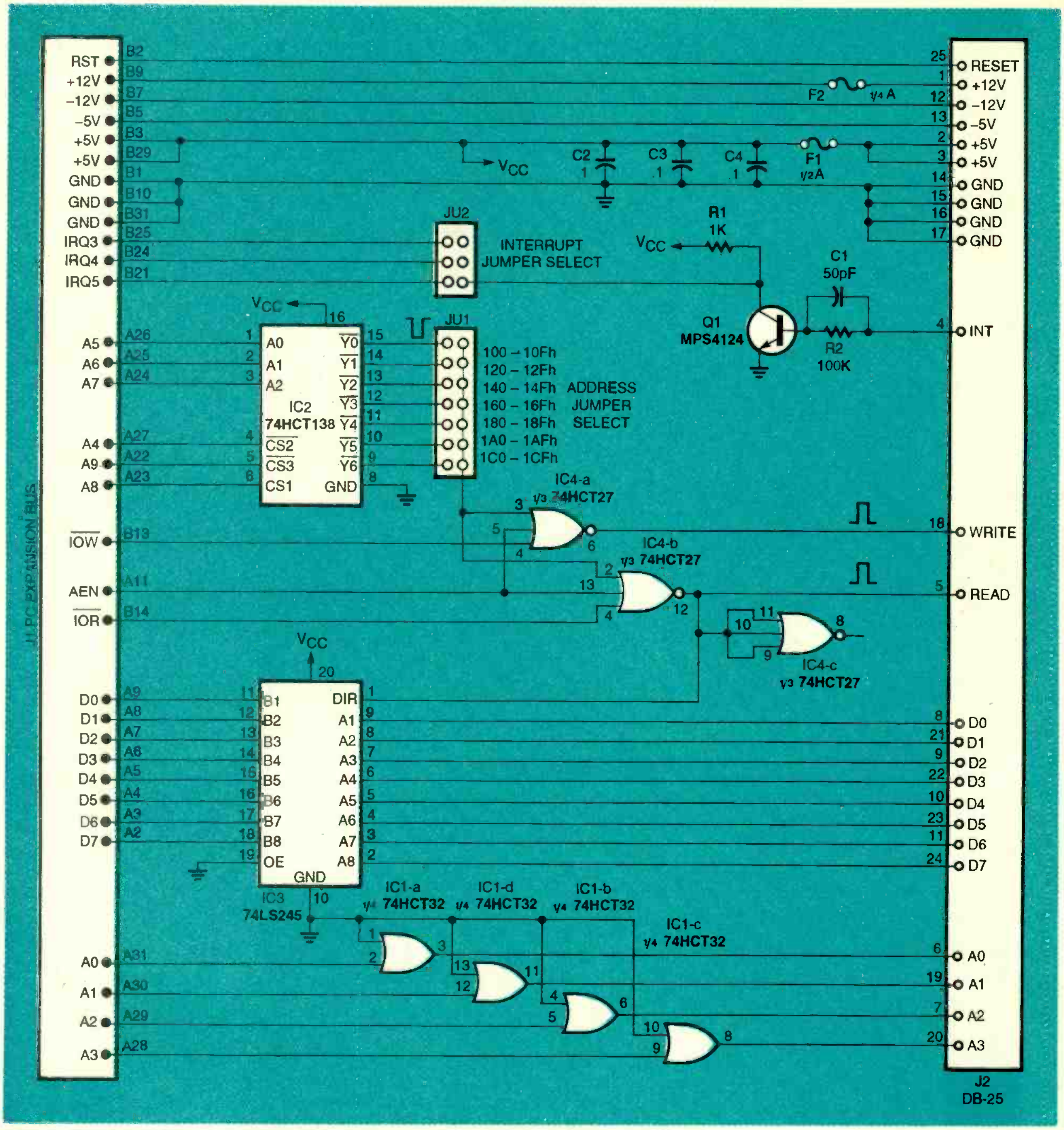


FIG. 1—THE PC INTERFACE CIRCUIT is built around four ICs that decode a 32-byte block of I/O ports, provide a buffered data bus, and buffered low-order address lines. The circuit also provides an interrupt input.

others in this series assume that you will use the lowest address block, 0100–010Fh, or 256–271 decimal.

Conflict is unlikely because all standard PC I/O ports appear at higher addresses. However, if there is conflict, you can help to resolve it by making an index card that lists all the I/O ports, memory addresses, interrupts, and direct-memory access (DMA) channels used by the cards in your computer. Keep the card in a safe place—perhaps taped to the side of the computer—and update it whenever you add a peripheral or change the system configuration in any way. Thus, if you want or need to use a different set of addresses, the circuit lets you do it.

The selected output pulse from address-decoder IC2 drives IC4-a and -b. These NOR gates function as negative three-input AND gates that provide high-going READ and WRITE pulses, respectively. The WRITE pulse occurs whenever the host CPU writes to a port in the selected range, and no DMA operation is occurring (i.e., AEN is low). Similarly, the READ pulse occurs when the host CPU performs a read operation.

The interface card provides an interrupt input. Turning on transistor Q1 with a high-going signal drives an interrupt line on the host PC low. Jumper JU2

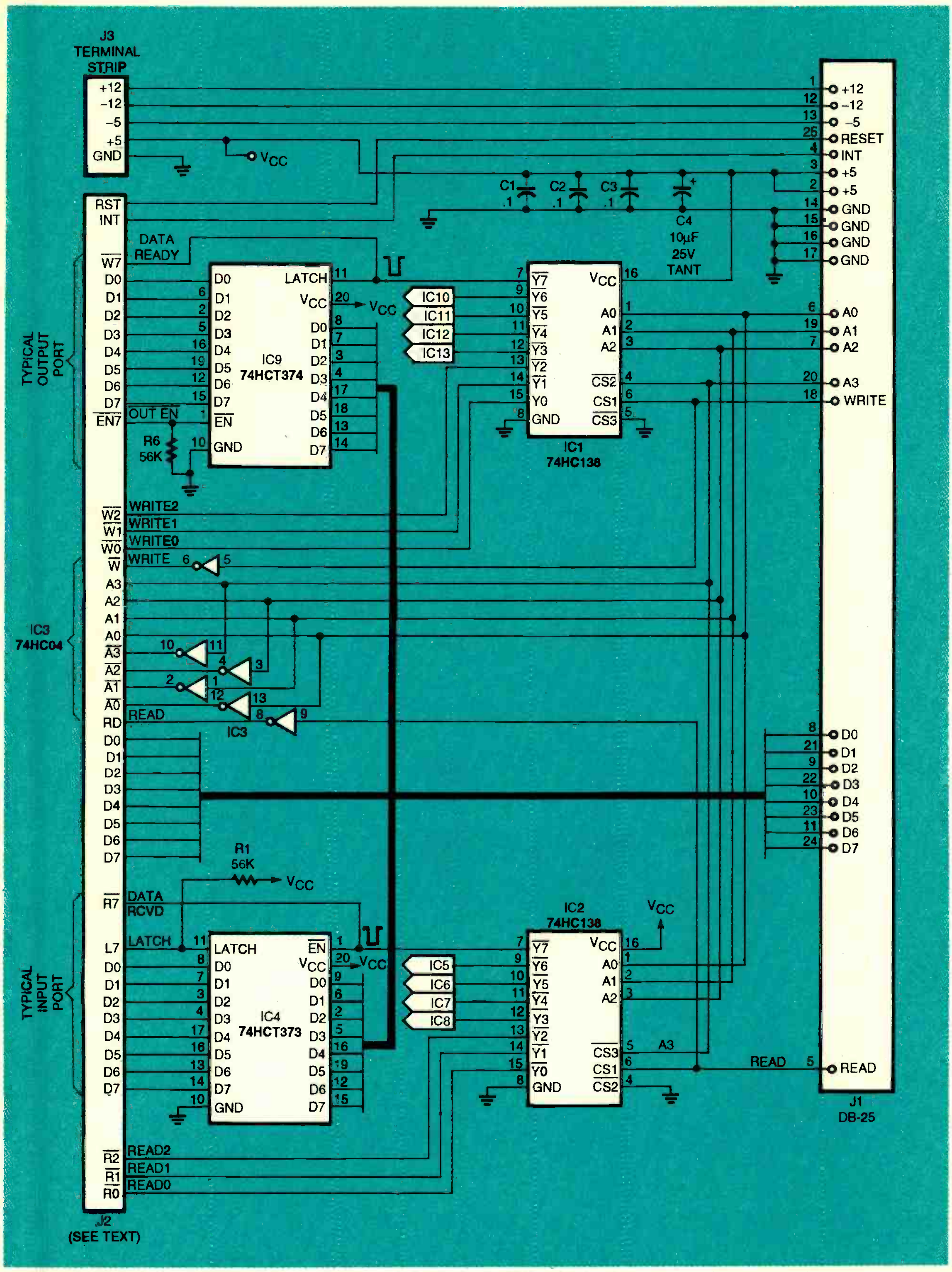


FIG. 2—BREADBOARD CIRCUIT decodes input ports and eight output ports, and latches five of each. To conserve space, only one output latch (IC9) and one input latch (IC4) are shown. The remaining latches connect directly to the data bus; the enable input of each latch connects to the corresponding output of IC1 and IC14.

allows you to select one of three interrupt lines: IRQ3 (usually used by serial port COM2, if present), IRQ4 (COM1), or IRQ7 (reserved for the printer, but seldom used).

Although the interrupt circuitry is simple, the software is complicated. The process of doing interrupts under DOS is involved and that process differs between the PC/XT and PC/AT architectures. Nevertheless, interrupt programming is not difficult, but many pages of text would be required to cover the subject adequately. At this time leave JU2 disconnected.

The circuit provides an 8-bit data-bus interface through IC3, a 74HCT245 octal transceiver. Data direction (into or out of the CPU) depends on the state of pin 1 of IC3. Pin 1 is normally low, which corresponds to a write from the CPU to an I/O port. When an I/O read occurs, pin 12 of IC4-b goes high, which in turn drives pin 1 of IC3 high, thereby reversing the direction of the data.

The gates in IC1 buffer the CPU address lines A0–A3. The breadboard card uses the address lines for decoding and it also makes them available for project use.

Nine of the 25 wires in the connecting cable supply power to the breadboard. Four lines carry ground, two lines carry +5 volts, and one line each carries −5 volts, +12 volts, and −12 volts. Notice that the +5-volt and +12-volt lines are fused with 0.5- and 0.25-ampere fuses, respectively. The fuses protect the wires in the cable. If your projects require more power, make up a separate cable assembly. Connect it directly to a spare four-conductor power connector at the computer end.

Breadboard circuit

Figure 2 shows the breadboard circuit. Overall signal flow is from right to left. Inputs come from 25-pin D connector J1, and outputs go to J2, which provides two 63-pin rows, labeled A and B, yielding a total of 126 connections. The pins are 0.025-inch square that are mounted on 0.1-inch centers. The pin numbers for J2 appear in Fig. 3, which depicts a top view of the connector as viewed from its normal operating position. Mount the pins on the foil side of the PC board, which is positioned upside down in the case. Notice that the Row A pins mount on the outermost edge of the PC board, and the Row B pins are closer to the center.

Refer again to Fig. 2, and notice that the low-order address lines feed I/O port decoders IC1 and IC2, which drive the write and read ports, respectively. The eight outputs of decoder IC1 provide inverted write pulses, all of which are available on J2. Five of the decoded outputs also drive latches IC9–IC13. To conserve space, only one latch (IC9) is shown, but the other four are similarly connected.

Similarly, the IC2 decoder outputs appear on J2 and drive

PC INTERFACE PARTS LIST

R1—1000 ohms, ¼ watt, 5%
R2—100,000 ohms, ¼ watt, 5%
C1—50 pF, ceramic
C2–C4—0.1 µF, ceramic
IC1—74HCT32 quad 2-input OR gate
IC2—74HCT138 3-to-8 line decoder
IC3—74LS245 octal bus transceiver
IC4—74HCT27 triple 3-input NOR gate
Q1—MPS4124 transistor
F1—0.5 A
F2—0.25 A
J2—25-pin female D connector, right angle, PC mount

BREADBOARD CARD PARTS LIST

R1–R10—56,000 ohms, ⅛ watt, 5%
C1–C3—0.1 µF, ceramic
C4—C10 µF, 25 volts, tantalum
IC1, IC2—74HC138 3-to-8 line decoder
IC3—74HC04 hex inverter
IC4–IC8—74HCT373 octal D latch
IC9–IC13—74HCT374 octal D flip-flop
J1—25-pin male D connector, right angle, PC mount
J2—128 wire-wrap pins, 0.025" square × 0.75" long
Other—25-conductor, 4-foot, male-to-female cable; solderless breadboards; 5-position terminal block; chassis; PC board guide; rubber feet; mounting hardware.

Note: The following items are available from Dage Scientific, P.O. Box 144, Valley Springs, CA 95252, (209) 772-2076:

- **Complete kit including manual and all parts (model ST-1)—$119**
- **Set of 2 PC boards and manual (model ST-2)—$40**

All orders add $3.95 shipping and handling. CA residents add sales tax.

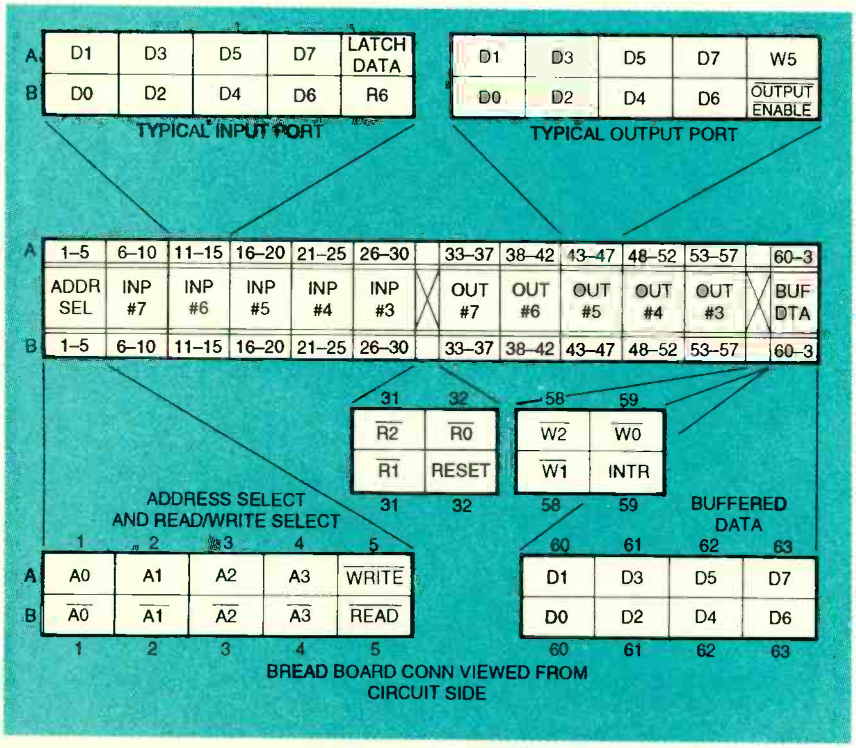


FIG. 3—BREADBOARD INTERFACE CONNECTOR J2 is shown here. There are six groups of pins: address and read/write lines, five input ports, input strobes and reset, five output ports, output strobes and the interrupt input, and the buffered data bus.

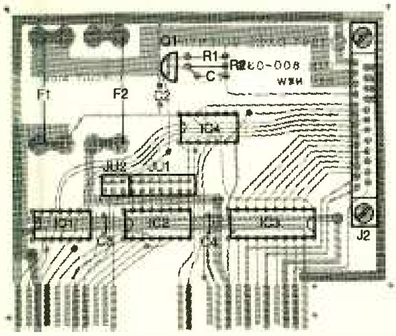


FIG. 4—INTERFACE CARD parts-placement diagram.

IC4–IC8. Only IC4 is shown. Notice that J2 provides true and inverted versions of the low-order address lines. It also provides true and inverted versions of the READ and WRITE lines from the interface card. The power lines from J3 connect to a five-position terminal strip that mounts on the opposite side of the case from J3. Use extreme care to avoid feeding any incorrect voltages to the breadboard circuits or back into J2.

Construction

The use of printed-circuit boards is recommended, particularly for the PC interface card. A breadboard circuit can be built with any accepted point-to-point wiring technique, but the PC board shown here will simplify assembly and make it easier to locate errors. The only point-to-point wiring required on this board is five wires from the board to the power strip J3.

To test this circuit and subsequently for building other circuits, you'll need several jumper wires. The connection of J2 calls for wires terminated with female pin sockets on one end and solid (or tinned stranded) wire on the other. You'll also need solid-wire jumpers for interconnecting components on the breadboard.

Referring to the parts-placement diagrams shown in Figs. 4 and 5 as guides, assemble both boards. Remember to mount the J2 pin strips on the foil side of the board. Figure 6 shows the relationship between the PC board, the J2 pins, the case, and the breadboard strips.

Check your soldering and correct any mistakes and remove any solder bridges. Install a ½-ampere fuse in the 5-volt supply line and a ¼-ampere fuse in the 12-volt supply line. Install a jumper at JU1 to select an address range that is available in your computer (assume the default address range, 0100–010Fh). Leave interrupt jumper JU2 disconnected at this time. Mount the breadboard card in a case that measures about 7.0 × 4.5 × 1.25 inches. Mount the D connector on one end of the box and the power terminal on the other. Cut a slot for accessing the J2 pins, and mount several rows of 62-pin solderless breadboard strips with double-sided tape.

Install the interface card in any available 8- or 16-bit slot of your computer. Be sure to seat the card firmly. Connect a 4-foot long, 25-conductor cable between the interface card and the breadboard assembly.

Testing

BASIC will be used for the test programs, and you'll also need a logic probe. The advantage of BASIC is its simplicity and its availability. You can use any version of MS-DOS or PC-DOS BASIC, including BASIC (on real IBMs), GW-BASIC (on older versions of MS-DOS), or QBASIC (on DOS 5.0 and later). Two BASIC statements provide access to the project's I/O ports. The first reads the value of the specified port that is read into variable N.

```
N = INP (PORT)
```

The second writes N to the specified port.

```
OUT PORT, N
```

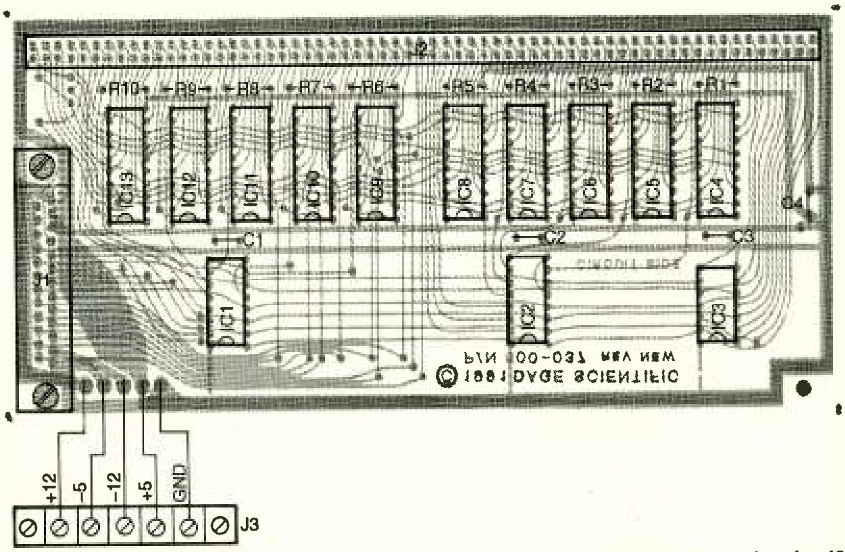


FIG. 5—BREADBOARD CARD parts-placement diagram. All 126 of the pins in J2 mount on the solder side of the board.

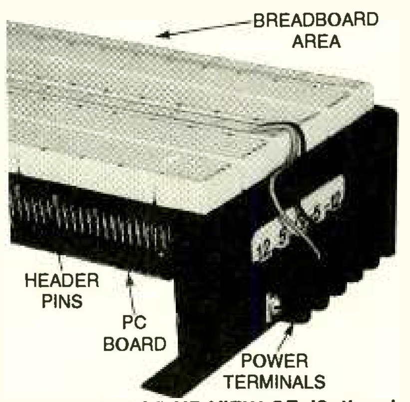


FIG. 6—CLOSE-UP VIEW OF J2, the circuit board, chassis, and breadboard strips.

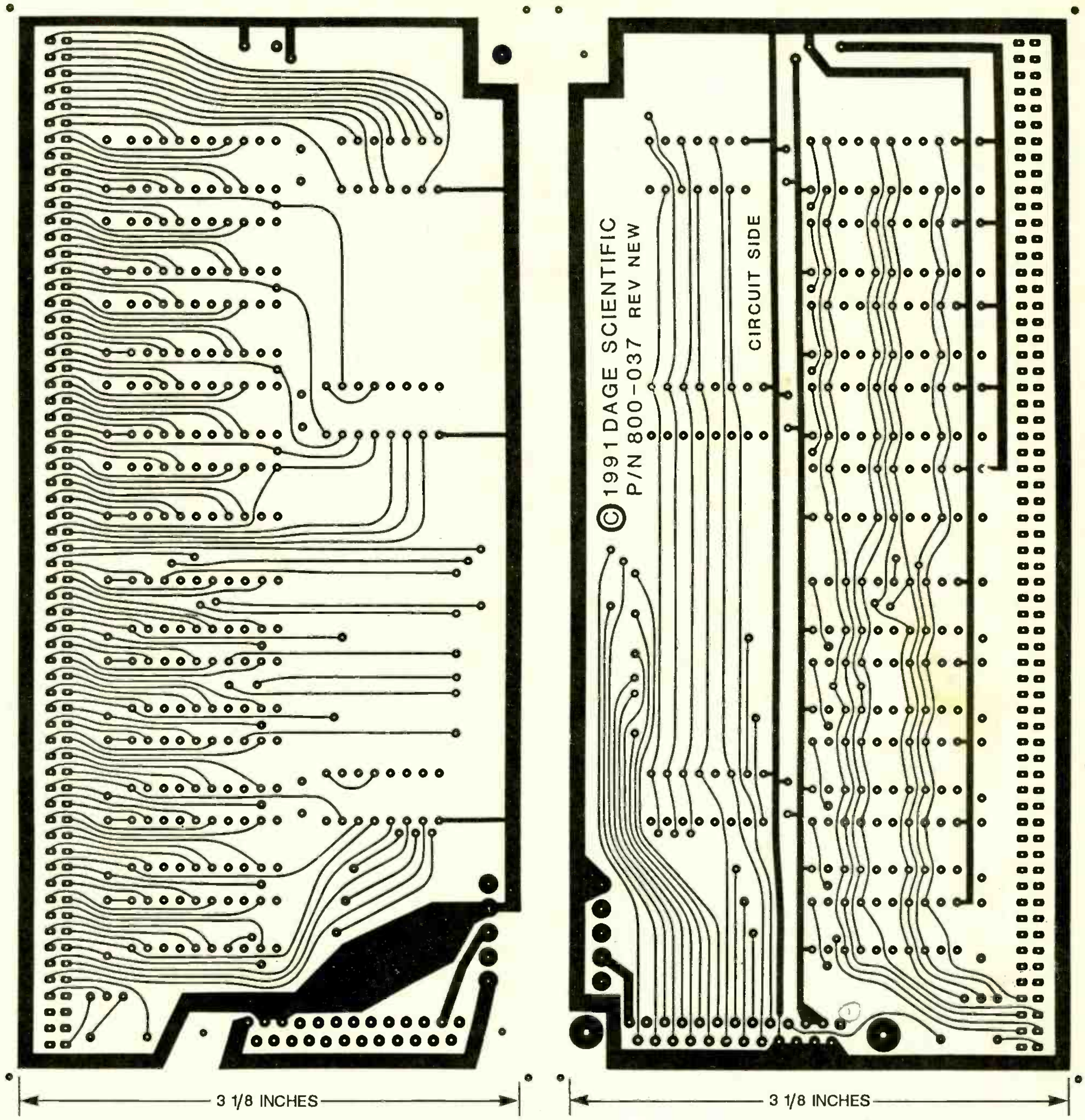
For both input and output statements, BASIC requires decimal values. For example, you could read the current value of the first port (residing at the default base address) as follows:

```
N = INP(256)
```

You could also write the current value of N to the same port as follows:

```
OUT 256, N
```

Table 1 provides quick reference information for port numbers and their corresponding decimal and hexadecimal addresses. The five fully decoded I/O ports are 3–7. Ports 0–2 pro-



FOIL PATTERNS FOR THE PC I/O BREADBOARD shown actual size.

vide only the strobe signals.

Listing 1, FLIPOUT.BAS, is a simple BASIC program that exercises many circuit elements. Load BASIC, then enter and run the code shown in the listing. The program works with output port 7. It successively flashes all outputs sequentially off, then on again. You will find it instructive to trace the signal all the way through the circuit.

As shown in Fig. 1, pin 15 of IC2 goes low whenever the CPU accesses any I/O port 0100–010Fh. That signal combines with the CPU's $\overline{\text{IOW}}$ and AEN signals to create the WRITE signal for the circuit. That signal, in turn, travels via pin 18 of the interface cable to the breadboard circuit, where it strobes the pin-5 input of hex inverter IC3. Pin 6 of that IC delivers a buffered WRITE signal to pin 5A of J2. Verify this operation with the logic probe to "catch" pulse activity there. If the circuit is working, the logic probe will blink. If the probe is not blinking, trace back through the circuit to find where the signal stops, and repair the error.

The WRITE signal also drives the CS1 input of decoder IC1. When the CPU addresses port 7, pin 7 of IC1 goes low, which in turn latches any signals the CPU put on the data bus into IC9's outputs. The latch signal and the eight data bits appear on pins 33A–37B and 33B–36B of J2. Verify that all nine signals are toggling with the logic probe.

Listing 2, CYCLEOUT.BAS, provides a more comprehensive test. It cycles all output ports, all write pulses, and address lines

TABLE 1—PORT ADDRESSES

Port Number	Hexadecimal Address	Decimal Address
0	100	256
1	101	257
2	102	258
3	103	159
4	104	260
5	105	261
6	106	262
7	107	263
8	108	264
9	109	265
A	10A	266
B	10B	267
C	10C	268
D	10D	269
E	10E	270
F	10F	271

LISTING 1 FLIPOUT.BAS

```
10 OUT 263,0
20 OUT 263,255
30 GOTO 10
```

A0–A3. While the program is running, check to see the activity on J2 pins 33A–59A and 33B–58B. Notice that in this and the preceding test, the output enable pins (37B, 42B, 47B, 52B, and 57B) should not cycle because they are held low by 56K resistors R6–R10. The output enable pins are made available at J2 in the event that a breadboard circuit might have to disable the outputs of a latch integrated circuit.

The signals on the data-bus pins (J2 pins 60A–63A and 60B–63B) are subject to change, as will the true and inverted address lines A0–A3 (J2 pins 1A–4A and 1B–4B). However, both the data and address lines will be cycling much faster than the output ports. This occurs because they indicate what is happening in the computer, not just at the I/O ports. The address and data lines should be cycling as long as the computer runs. By contrast, the I/O lines should cycle only when the CPU accesses an I/O port in the range specified by JU1.

Input ports

Check the input ports in a different way. For example, check

LISTING 2—CYCLOUT.BAS

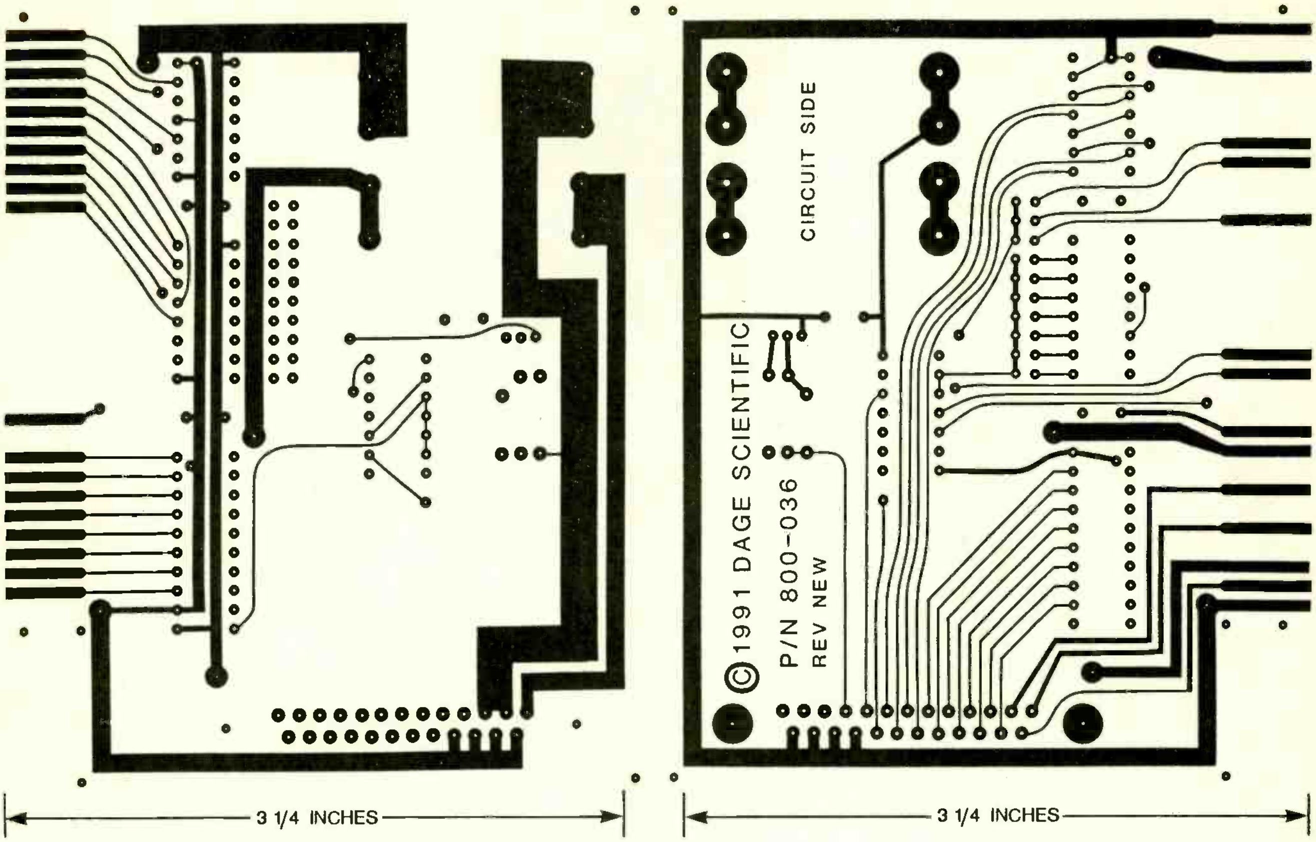
```
100 REM * for ST-1 Purpose: cycle each output data line for IC's 9 - 13, plus
110 REM * cycle all write pulses W0 - W7 and the base 'write' pulse.
120 REM * Hardware: Logic probe to check pulse activity.
130 REM ******************************************************************
140 REM * BA base address, T offset port address, C counter
150 REM ******************************************************************
160 CLS :REM * START
170 INPUT "Enter base address in decimal (for example - 256) ";BA:PRINT:PRINT
180 PRINT"WORKING":PRINT
190 PRINT"Use cntl/break to quit!"
200 FOR C=1 TO 4 : REM cycles clock        *****LOOP1*****
210 REM cycles all 8 outputs with 0's and 1's
220 FOR T=BA TO BA+7 : REM        *****LOOP2*****
230 OUT T,0 : OUT T,255
240 NEXT T : REM                  *****LOOP2*****
250 REM runs clock so that you know program is running
260 LOCATE 4,10
270 IF C=1 THEN PRINT"³"
280 IF C=2 THEN PRINT"/"
290 IF C=3 THEN PRINT"Ä"
300 IF C=4 THEN PRINT"\"
310 NEXT C : REM                           *****LOOP1*****
320 GOTO 200
```

LISTING 3—INP2CRT.BAS

```
100 REM * for ST-1. Purpose: to diplay an input port on screen.
110 REM * Hardware: Switch to set input, resistors.
120 REM ******************************************************************
130 REM * AI address input port, T counter, A$ any key, N input byte
140 REM * BP bit position during printing
150 REM ******************************************************************
160 CLS : REM *START
170 INPUT" Enter input port address in decimal  ";AI
180 PRINT:PRINT" Press Cntl/Break to exit!
190 REM * Draw 8 boxes at center screen to display input byte ***************
200 LOCATE 9,26 : PRINT"#7  #6  #5  #4  #3  #2  #1  #0"
210 LOCATE 10,25 : PRINT"Ú";
220 FOR T=1 TO 7 : PRINT"ÄÄÄÂ"; : NEXT T : PRINT"ÄÄÄ¿"
230 LOCATE 11,25 : FOR T=1 TO 8 : PRINT"³   "; : NEXT T : PRINT"³"
240 LOCATE 12,25 : PRINT"À";
250 FOR T=1 TO 7 : PRINT"ÄÄÄÁ"; : NEXT T : PRINT"ÄÄÄÙ"
260 REM * GET PORT AND DISPLAY ***********************************************
270 BP=27 : REM used as pointer for bit print        *****LOOP1*****
280 N=INP(AI)
290 FOR T=7 TO 0 STEP -1 : REM              *****LOOP2*****
300 LOCATE 11,BP
310 IF N AND 2^T THEN PRINT"1" ELSE PRINT"0"
320 BP=BP+4:NEXT T : REM                    *****LOOP2*****
330 A$=INKEY$ : IF A$="" GOTO 270 : REM              *****LOOP1*****
340 GOTO 270
```

LISTING 4—LOOPBACK.BAS

```
100 REM * for ST-1 Purpose: to check I/O ports by feeding a test byte from
110 REM * an output to an input and comparing. Three tests are made:
120 REM * bits stuck high or low, bits tied together, and everything else.
130 REM * Hardware: Loopback plug.
140 REM ******************************************************************
150 REM * AO address output port, AI address input port, BC bit counter
160 REM * TB test byte, SH switch halt on section error, S1 switch temp
170 REM * S1 switch one of two errors, T counter
180 REM ******************************************************************
190 CLS: SH=0 : REM * initialize soft switch
200 INPUT " Enter output port address in decimal  ",AO
210 INPUT " Enter  input port address in decimal  ",AI
220 PRINT:PRINT"Program checking for bits stuck high or low.":PRINT
230 REM * test for bits stuck high ****
240 OUT AO,0
250 TB=INP(AI)
260 FOR BC=7 TO 0 STEP -1
270 IF (TB-2^BC)>=0 THEN PRINT"bit ";BC;" is stuck high":TB=TB-2^BC:SH=1
280 NEXT BC
290 REM * test for bits stuck low ****
300 OUT AO,255
310 TB=INP(AI)
320 FOR BC=7 TO 0 STEP -1
330 TB=TB-2^BC
340 IF TB<0 THEN PRINT"bit ";BC;" is stuck low":TB=TB+2^BC:SH=1
350 NEXT BC
360 IF SH=1 THEN GOTO 560
370 LOCATE 4,50:PRINT"** PASSED **"
380 PRINT:PRINT"Program checking for bits stuck together.":PRINT
390 FOR BC=0 TO 7
400 S1=0:REM loop switch; set to one on any fault
410 OUT AO,     2^BC:TB=INP(AI): IF TB<>     2^BC THEN S1=1
420 OUT AO,255-2^BC:TB=INP(AI): IF TB<>255-2^BC THEN S1=1
430 IF S1=1 THEN PRINT" check bit";BC:SH=1
440 NEXT BC
450 IF SH=1 THEN GOTO 560
460 LOCATE 6,50:PRINT"** PASSED **"
470 PRINT:PRINT"Checking all bit combinations. Please wait!":PRINT
480 FOR T=0 TO 255
490 OUT AO,T
500 TB=INP(AI)
510 IF TB<>T THEN PRINT"Error at";T:SH=1
520 NEXT T
530 IF SH=1 THEN GOTO 560
540 LOCATE 8,50:PRINT"** PASSED **"
550 PRINT:PRINT"Test done, loopback good!":PRINT:GOTO 570
560 PRINT:PRINT"Program halted. Bit error.":BEEP
570 END
```



FOIL PATTERNS FOR THE INTERFACE CARD shown actual size.

input port 4, which is located at address 260 decimal. Start by tying all eight inputs (J2 pins 21A–24A and 21B–24B) to ground through 1-Kilohm resistors. Then run the test program INP2CRT.BAS, shown in Listing 3.

The program first asks you to enter the address of the port under test. The binary value of this port will then be displayed dynamically in the center of the screen. All bits have been tied low, so you should see eight "0's." Connect a 100-ohm resistor to V_{CC} and touch the input lines one at a time. As you touch each input, the corresponding value on the screen should change to a 1. Verify that each bit changes, and verify that the correct bit is the one changing (e.g., bit 7 is bit 7 and not bit 6). Also verify that only the bit you touch goes high.

At this time you have cycled all output ports, and you have performed a rather detailed test on one input port. However, a fully functional circuit is not yet guaranteed. For example, the output-port test cycled all the output bits on, then off. The problem was diagnosed as two or more bits shorted together, but the test could still be completed successfully.

A truly comprehensive test would examine all possible input and output combinations individually. It is not difficult to do that. The solution calls for some additional circuitry and software. The circuitry consists of a loopback plug that connects all eight bits of an output port to the corresponding eight bits of an input port. The software is shown in Listing 4, LOOPBACK.BAS.

Build an eight-wire loopback plug, or use eight separate wires. Connect all eight bits from one input port to the corresponding bits of an output port (bit 0 goes to bit 0, bit 1 goes to bit 1, and so on). Next run LOOPBACK.BAS. The program will ask you the addresses of the input and output ports before it will start testing.

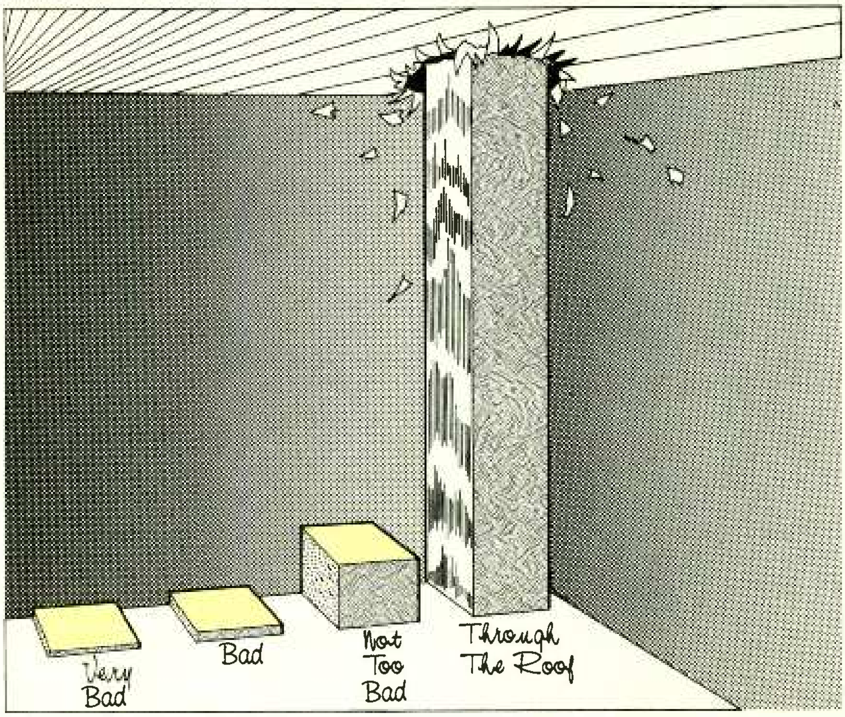
The program performs three tests: 1) Bits stuck low or high, 2) Bits shorted together, and 3) Bit independence. Bit independence means the ability to read and write all binary combinations of bits (i.e., every number from 0 to 255). For the first two tests, the program halts if an error occurs. If a bit is stuck low or high, the program will display the faulty bit number and halt. The program will not proceed until the problem has been corrected.

The second part of the program senses bits that are shorted together and displays them by number. Again it will stop until the fault is corrected.

By the time the port has passed the first two tests, it should be fully functional. However, just to be sure, the third part of the test checks all possible bit combinations. In the unlikely event that a fault occurs, the program displays the incorrect value, but in this case the program keeps on running. After running LOOPBACK.BAS against all five input and output ports, you can be confident that the circuit works properly.

Build your breadboard circuit and interface card and debug it. Next month more details on programming the circuit will be published. Ω

TJ BYERS



COMPUTER BENCHMARKS

Benchmarks are more than yard sticks—if used properly, they can help you wring every drop of performance from your computer system.

BENCHMARKS ARE STANDARDS FOR evaluating all aspects of our lives. They grade everything from academic achievement and fuel efficiency, to the size and color of the eggs we eat. The origin of the term is the marks made for measuring objects on a craftman's bench. Later it came to mean a surveyor's mark made on a permanenet landmark of known position and altitude, designated by a bronze plaque. Computer benchmarks are designed to do two things: gauge the relative speed of different computers, and to fine tune a computer system for maximum performance.

While it's nice to know how fast your PC is compared to other models, it's more important to know how to make the most of your present system. For example, the same PC that demonstrates blazing speed doing DOS spreadsheets might slow to a snail's pace when confronted with a computer-aided design (CAD) drawing. Maybe all it takes is a change in the size of the cache or a new video card to bring it up to speed, but you won't know what variables to change or how much improvement is made without a benchmark.

Over the years, many benchmarks have been developed for testing computers. Some gauge the speed of the central processing unit (CPU), while others indicate the performance of the cache or measure the data throughput of the hard disk drive.

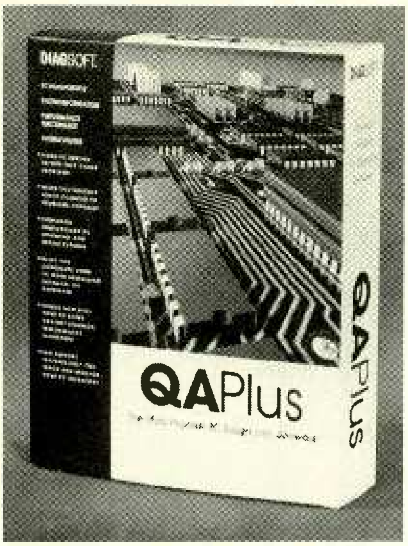
This guided tour of PC benchmarks considers the traditional benchmarks—such as the very popular Whetstone and MIPS—and tells you exactly what part of the PC each tests and how to use the results. Some of the newer benchmarks, such as *WinBench* that measures Windows graphics performance, are also explored. Moreover, you can learn how to write your own benchmarks.

Benchmark primer

Benchmarks are divided into two broad categories: kernel-level operating system and user-level application. Kernel-level benchmarks measure the speed, efficiency, and capacity of a computer's hardware as it relates to its operating system. Programs such as Norton's *System Info* and MIPS are kernel-level benchmarks.

User-level benchmarks measure the performance of a computer running software applications under normal conditions. User-level benchmarks are generally a more accurate gauge of a system's performance, and are indispensable for comparing applications running on different CPU architectures. An example is comparing a PC with an Intel Pentium microprocessor to one with an Intel 486 microprocessor.

User-level benchmarks are divided into natural, synthetic, and hybrid classes. Natural benchmarks consists of commonplace applications that are configured to run in a scenario that is typical for the application. For example, you might call up a *1-2-3* spreadsheet, load it with real data, and measure the amount of time it takes the PC to solve the problem. To obtain accurate results from a benchmark, it must be run repeatedly over a long period of time (hours or days) with the results averaged.



QAPlus is a complete package of PC diagnostic software.

Synthetic benchmarks simulate the actions of a natural benchmark with an algorithm or formula. The algorithm is derived from statistical analysis of the target application, according to the workload the application places on the various hardware components of the computer. These benchmarks are easily created, execute quickly, and are accurate enough, if you know how to analyze the results. The majority of benchmarks in use today are synthetic user-level ones.

Hybrid benchmarks—also called modeling benchmarks—are a combination of natural and synthetic routines. Instead of basing them on an actual application, the modeling benchmarks integrate run-time versions of popular word-processing and drawing applications, such as *WordPerfect* or *Paintbrush*, with statistically balanced routines. Hybrids are easier to create, they run faster than natural benchmarks, and they provide greater accuracy than a synthetic benchmark. But because hybrids are compiled programs with fixed routines, they can't be reconfigured like a natural benchmark.

The most popular computer benchmarks are in the public domain as freeware or shareware, and they can be found on most bulletin boards, including the *Electronics Now BBS* (516-293-2283, V.32, V.42bis).

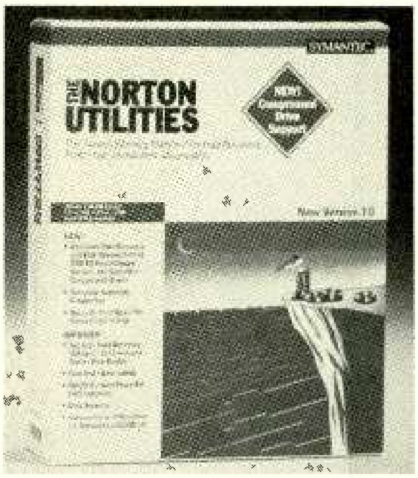
Measuring CPU speed

The most popular measure of a PC's performance is its CPU speed test. The most widely used benchmarks for measuring CPU speed are MIPS, Whetstones, Dhrystones, and the Sieve of Eratosthenes. However, each depends on a different method to arrive at its results. Where one test reports blazing speed, another may report only lukewarm results.

MIPS—A term that's virtually synonymous with computer speed is MIPS, for millions of instructions per second. The benchmark was originally created to measure the processing speed of mainframe and supercomputers, but it has since found wide use in desktop PCs.

The MIPS benchmark is a kernel-level program that pushes instructions through the CPU and measures the rate at which they are processed. This benchmark consists of one million instructions, usually made up of a string of null or no-op commands. The time it takes the CPU to process the one million instructions is measured and converted into an equivalent number of operations per second. One million instructions per second equals 1 MIPS.

Unfortunately, MIPS is a measure of unprocessed capacity and not one of useful work done. Moreover, it's impossible to compare MIPS speeds measured from an Intel microprocessor-based PC to those of a reduced instruction set computer (RISC) machine or Macintosh computer because of the differences in their CPU architectures. Despite its popularity, MIPS tells us very little about a PC's performance.



Norton Utilities aids in data recovery, protection, and system diagnostics.

Whetstone—A better measure of CPU speed is the Whetstone benchmark. Developed in 1976, this public-domain benchmark is among the most referenced benchmarks in the computer industry. It is often called the *MegaFlop* benchmark.

The Whetstone is a user-level synthetic benchmark designed to simulate arithmetic-intensive applications. It is particularly applicable to scientific and engineering programs such as SPICE and *MathCAD*, where floating-point calculations and Fast-Fourier Transforms (FFT) are extensively used. So it's not the one to use if you're trying to improve your word processor's speed.

Whetstone instructions are completely CPU intensive. The benchmark has no input/output (I/O) or system calls. However, it will take advantage of a math coprocessor if one is installed in the computer, giving you a measure of the coprocessor's speed, too.

As is true for MIPS, the time it takes to complete one million Whetstone instruction cycles is measured and converted into a *throughput rate*. The rate is expressed in KWhet/sec (thousands of cycles per second) or MegaFlops (millions of cycles per second). The greater the number, the faster the speed. Both single- and double-precision versions of the Whetstone benchmark are available.

Dhrystone—The Dhrystone is another very popular user-level synthetic benchmark that's widely quoted for stating PC performance. The benchmark is most commonly written for computers with Windows and Unix operating systems.

Unlike the Whetstone, the Dhrystone benchmark is a measure of integer processing rather than mathematical performance, and it paints a slightly different picture of CPU performance. The Dhrystone requires that the system run several different kinds of operations, including assignment, arithmetic, and control. For the operations, the benchmark uses integer, character, pointer, string, array, and record operands. All the operations are CPU intensive, with no floating-point calculations, I/O operations, or system calls.

Because the Dhrystone instructions run in a loop, the benchmark is subject to *data caching*. Once the benchmark has been loaded from slow main memory into the faster cache memory, it can run up to four times faster than it does on a computer without caching. While some people complain that this isn't a true measure of CPU speed, it's representative of several programs, such as database applications, that are improved by data caching.

With the Dhrystone benchmark, there is no set number of operations to be performed as with MIPS and Whetstone. Instead, the benchmark begins on a timer and runs until the timer times out. The number of operations that occur during the elapsed time are counted and expressed as Dhrystones per second (Dhry/s). Higher Dhrystone numbers indicate better performance.

Sieve of Eratosthenes—The Sieve of Eratosthenes is a kernel-level benchmark that measures the looping, incremental, and logical properties of the CPU. The Sieve uses an algorithm devised many centuries ago by the Greek mathematician Eratosthenes to find the prime numbers between 1 and 14,000. It basically consists of a loop that increments the number under test by one, beginning with the number three. With each increment, the new number is tested for prime properties by comparing it to the previous numbers. The amount of time it takes to complete the cycle is called the Sieve's figure of merit. The smaller the number, the faster the CPU.

As is true for the Dhrystone, the Sieve is susceptible to data caching. The Sieve is also dependent on the CPU's architecture because of its limited scope of operations. Sieve operations are quite narrow, with looping being their primary function. This benchmark is neither statistically balanced nor representative of any particular kind of application. The result is an esoteric figure of merit that should be used in comparing PCs for raw CPU speed. Figure 1 shows system-performance results from *QAPlus Advanced Diagnostics*.

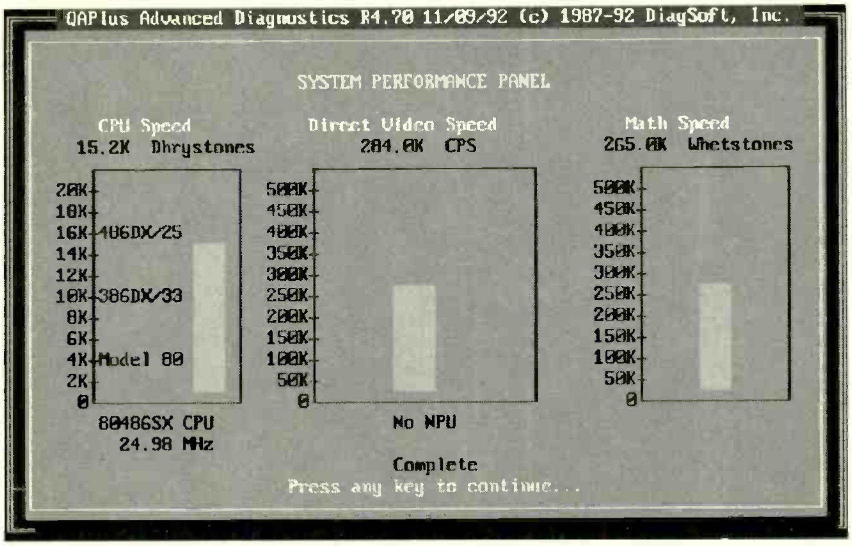


FIG. 1—THE DHRYSTONE AND WHETSTONE benchmarks are available in *QAPlus*. The diagnostic software can also measure hard-disk drive performance and it comes with a CMOS editor.

While the benchmark can be found in the public-domain, it's just as easy to create your own with the BASIC program shown in Listing 1. The benchmark runs the Sieve ten times, then averages the results for improved accuracy. However, ten iterations take about six minutes on a PC with an Intel 286 microprocessor, so you might want to decrease the number of iterations by modifying line 130 in the listing.

Measuring disk performance

Disk drives are the easiest of all computer devices to benchmark because the standards for rotating media were established many years ago. While several factors influence the time it takes to access data from a disk drive, the disk industry has standardized on a trio of benchmarks that closely predict the drive's performance under conditions normally experienced when running typical

LISTING 1
SIEVE OF ERATOSTHENES

```
100 SIZE=7000
110 DIM FLAGS(7001)
120 CLS:KEY OFF
130 ITER = 10
140 PRINT "RUNNING THE SIEVE OF ERATOSTHENES";ITER "TIMES"
150 T1=TIMER
160 FOR X = 1 TO ITER
170 COUNT=0
180 FOR I=0 TO SIZE
190 FLAGS(I)=1
200 NEXT I
210 FOR I=0 TO SIZE
220 IF FLAGS(I)=0 THEN 310
230 PRIME=I+I+3
240 ' PRINT PRIME;
250 K=I+PRIME
260 IF K>SIZE THEN 300
270 FLAGS(K)=0
280 K=K+PRIME
290 GOTO 260
300 COUNT=COUNT+1
310 NEXT I
320 NEXT X
330 T2=TIMER:BEEP
340 T3=(T2-T1)/ITER:PRINT "Sieve run time =";T3;"seconds"
350 PRINT COUNT;" PRIMES FOUND"
```

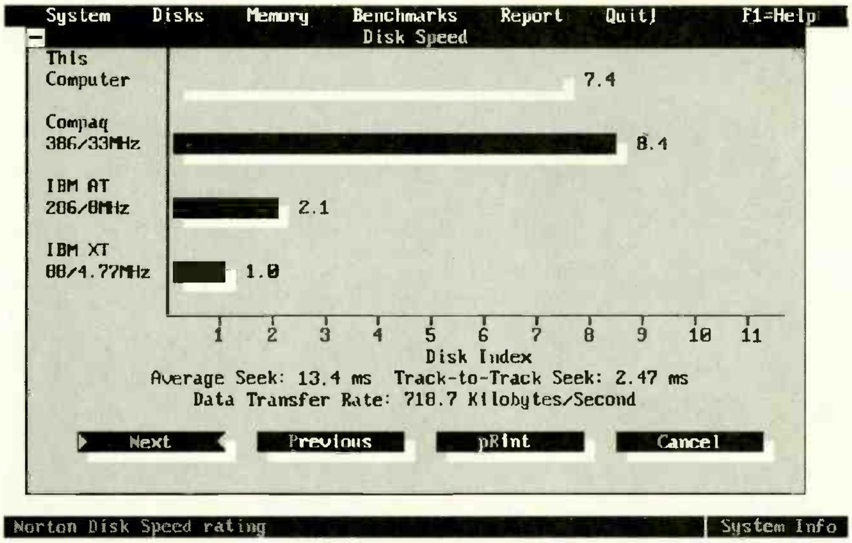


FIG. 2—MOST DISK-CARE PRODUCTS, including *The Norton Utilities* pictured above, have a utility for measuring disk drive access times and data throughput.

PC applications. The three benchmarks are track-to-track, seek, and average access times.

Disk Access Times—The track-to-track test measures the amount of time it takes for the head to read the contents of an entire data track, then move to the next track and read it. This benchmark simulates the way a program, such as a database, might access a large file from the disk—by doing it in contiguous sectors.

However, most disk files are fragmented because of the way DOS allocates sector assignments: first come, first served. That means that large files are often broken up into two or more blocks of contiguous data sectors. To measure the disk drive's performance under these conditions, the industry uses a modified track-to-track benchmark called *seek* time. It samples track-to-track readings from four widely separated areas of the disk, including the inner and outer extremes, and averages the time it takes to read them.

The worst case scenario occurs when one tries to access a single sector from a large number of scattered tracks, as would be the case with a badly fragmented disk. For this task, the benchmark randomly jumps from sector to sector in search of data. The total time required to perform this test is divided by the number of operations to derive an *average access time*—the most quoted benchmark for disk drive performance.

Utilities containing these benchmarks are readily available at little or no cost. There are many free programs on BBSs, or you can use Norton's *System Info* program (see Fig. 2) that is included with all of the Norton products.

Data Throughput—Unfortunately, the access-time numbers don't tell the whole story. Sure, they tell you what's happening inside the drive, but they don't tell you how fast you could expect the data to move from the disk to your program. That time is a function of the data transfer rate between the disk drive and the disk controller. For example, a standard IDE (intelligent drive electronics) drive has a maximum data transfer rate of 2.5 MB/s (megabytes per second), while a SCSI-2 (small computer systems interface) drive can transfer data at a rate as high as 10 MB/s. That means your new SCSI drive has the ability to move data up to four times faster than an IDE drive, althrough they both might have the same average access time.

Generally speaking, the actual data throughput is much lower than the speeds adver-

LISTING 2
HARD DISK DATA THROUGHPUT

```
10 CLS : KEY OFF
100 B$ = "12345678"
110 C$ = B$ + B$ + B$ + B$
120 A$ = C$ + C$ + C$ + C$
130 PRINT "WRITING TO THE DISK"
140 OPEN "C:TEST1.RE" FOR OUTPUT AS #1
150 OPEN "C:TEST2.RE" FOR OUTPUT AS #2
160 OPEN "C:TEST3.RE" FOR OUTPUT AS #3
170 OPEN "C:TEST4.RE" FOR OUTPUT AS #4
180 OPEN "C:TEST5.RE" FOR OUTPUT AS #5
190 T1 = TIMER
200 FOR I = 1 TO 5000
210 PRINT #1, A$
220 PRINT #2, A$
230 PRINT #3, A$
240 PRINT #4, A$
250 PRINT #5, A$
260 NEXT I
270 T2 = TIMER
280 CLOSE
290 T3 = (T2 - T1) / 5
300 BPSW = 650000! / T3
310 PRINT
320 PRINT "WRITE SPEED IS"; INT(BPSW); "BYTES PER SECOND"
330 PRINT
340 PRINT "READING FROM THE DISK"
350 OPEN "C:TEST1.RE" FOR INPUT AS #1
360 OPEN "C:TEST2.RE" FOR INPUT AS #2
370 OPEN "C:TEST3.RE" FOR INPUT AS #3
380 OPEN "C:TEST4.RE" FOR INPUT AS #4
390 OPEN "C:TEST5.RE" FOR INPUT AS #5
400 T4 = TIMER
410 FOR I = 1 TO 500
420 RE1$ = INPUT$(1280, 1)
430 RE2$ = INPUT$(1280, 2)
440 RE3$ = INPUT$(1280, 3)
450 RE4$ = INPUT$(1280, 4)
460 RE5$ = INPUT$(1280, 5)
470 NEXT I
480 T5 = TIMER
490 CLOSE
500 T6 = (T5 - T4) / 5
510 BPSR = 650000! / T6
520 PRINT
530 PRINT "READ SPEED IS"; INT(BPSR); "BYTES PER SECOND"
540 BPSTHRU = (650000! * 10) / (T5 - T1)
550 PRINT
560 PRINT "THROUGHPUT SPEED IS"; INT(BPSTHRU); "BYTES PER SECOND"
570 SHELL "ERASE C:TEST?.RE"
```

tised, simply because most controllers can't keep up with today's hard disk drives. That's why disk caching utilities such as DOS's *SmartDrive* are required for aacceptable peroarmance.

Finding the right cache size for your system, however, takes some experimenting. Usually, 1MB of cache is all you need, even for Windows. But in many situations a 256K cache will work nearly as fast, freeing up a lot of memory for applications. But you won't know until you test it. As in access-time benchmarks, data throughput benchmarks can be found on almost any BBS. They are bundled with all disk utility programs such as *Norton Utilities* and *PC Tools*.

For your convenience, the BASIC program in Listing 2 is a synthetic user-level benchmark that measures the read, write, and throughput speeds of a hard disk in bytes per second. The higher the numbers, the faster the hard disk. The benchmark also measures the speed of your disk caching software, allowing you to optimize the disk cache size for its fastest performance. To run the program with BASICA or GW-BASIC, you must use the /F:5 switch when starting the BASIC interpreter (example: BASICA/F:5 or GWBASIC/F:5). QBASIC doesn't need the switch.

Video and graphics

The most elusive PC benchmark is video performance because of the many variables involved. It's easy enough to ask how long it takes the video controller to draw a line on a screen—but what kind of line? Is it straight or curved? How many pixels make up the line? Are the parameters for the line defined or do they have to be calculated prior to drawing the line? All of these are complex questions indeed.

The answer is further complicated by the wide variety of video controllers available for the PC, which range from monochrome to SuperVGA. To test all the features the video controller has to offer, the benchmark must be specifically written for the controller—something that's not currently done in graphics benchmarks. Most graphics benchmarks break down video testing into two areas: text and graphics.

Text Speed—Text performance is the easiest to measure because the PC text format of 80 columns by 25 rows is common to all video controllers. There are two ways to print characters on the screen. One is to call up the characters via the BIOS, and the other is to read the character from a software program. Of these two, the BIOS-oriented benchmark is the easiest to create. You'll generally find them in DOS-based programs such as *LandMark*.

The BASIC program shown in Listing 3 measures the scrolling speed of DOS text. The results are in characters per second (cps), so the higher the number the better. The benchmark can be used to compare the speeds of different video controllers to see how much speed is gained when you enable BIOS relocation (where the system and video BIOS are copied from slower ROM to faster RAM). If the BIOS relocation speed doesn't improve performance by 10 % or more, the RAM memory that relocation requires would be better put to use if it were freed up for running applications.

Graphics Speed—Gauging the performance of graphics is not as easy or as accurate as it is for text. Typically, graphics controllers paint screens with either pixels, vectors, or primitives (such as circles or ellipses). Whether you consider the screen at the elementary level, defining the display pixel by pixel, or whether you define the picture as a montage of primitives makes a big difference in performance. Adding to the di-

BENCHMARKS ON THE BBS

All the public domain benchmarks mentioned in this article, plus several others, are available from the *Electronics Now BBS* (516-293-2283, V.32, V.42bis) in the Benchmark library. Several of the files are compressed with PKZIP, and are identified with the .ZIP extension. To uncompress a downloaded ZIP file, type PKUNZIP *filename* and press Enter. Keep in mind that a compressed file might contain many other files, including documentation. So it's best to do the uncompression in a temporary directory.

Here's a list of the benchmarks posted, sorted by function:

CPU BENCHMARKS
BBENCH22.ZIP
LANDMARK.ZIP
MEGAFLOP.ZIP
MIPS.COM
WINDRY.ZIP
DISK BENCHMARKS
BBENCH22.ZIP
CORETEST.ZIP
VIDEO BENCHMARKS
3DBENCH.ZIP
BBENCH22.ZIP
DISPMATE.ZIP
LANDMARK.ZIP
TORQUE.ZIP
VGASPEED.ZIP
VIDSPEED.EXE
WINBENCH.ZIP
WINTACH.ZIP
ELECTRONICS NOW BENCHMARKS
DISK.BAS
SIEVE.BAS
VIDEO.BAS

LISTING 3
VIDEO TEXT SPEED

```
10 CLS:KEY OFF
100 T1 = TIMER
110 FOR I = 1 TO 400
120 PRINT
130 NEXT I
140 T2 = TIMER
150 T3 = T2-T1
160 CLS
170 T4 = TIMER
180 FOR I = 1 TO 400
190 PRINT "THE NUMBER YOU SEE AT THE END OF THIS TEST
 IS THE TEXT SPEED OF YOUR VIDEO CARD"
200 NEXT I
210 T5 = TIMER
220 T6 = T5-T4-T3
230 CLS
240 CPS = 32000/T6
250 PRINT "YOUR VIDEO BOARD CAN WRITE";INT(CPS);
 "CHARACTERS PER SECOND (CPS) TO THE SCREEN"
260 PRINT "Elapsed time =";T6 "seconds"
```

lemma is the recent introduction of graphics coprocessors, such as Intel's 82786 and Texas Instrument's 34010, which have their own programming language. Add to that local-bus video, and the picture becomes even more complex.

The best way to answer these questions is to write the benchmark for Windows, which handles graphics in a way that's supported by virtually all PC products. Consequently, you need only one graphics benchmark instead of a different one for each video controller or screen resolution.

The most popular graphics benchmark is *WinBench*. It's a user-level synthetic benchmark that measures the graphics processing power of Windows. It makes use of a combination of lines, boxes, colors, and fonts to arrive at a figure of merit called a WinMark. WinMark numbers are expressed in pixels per second. However, video-equipment manufacturers learned a long time ago how to adjust their video drivers to produce higher-than-normal WinMark results. That shouldn't be a problem, except that not all vendors do it. Thus the published WinMark numbers you see in product reviews aren't always indicative of accurate speed comparison. Nevertheless, *WinBench* is a good benchmark for fine tuning your system.

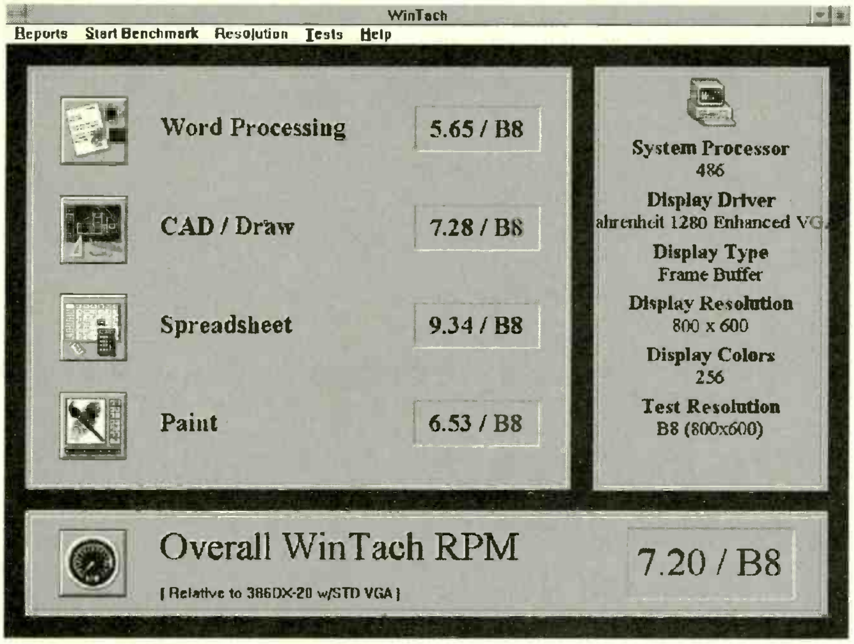


FIG. 3—THE FUTURE OF PC BENCHMARKS is seen in user-level hybrids that depend on run-time versions of popular applications integrated with statistically-balanced routines.

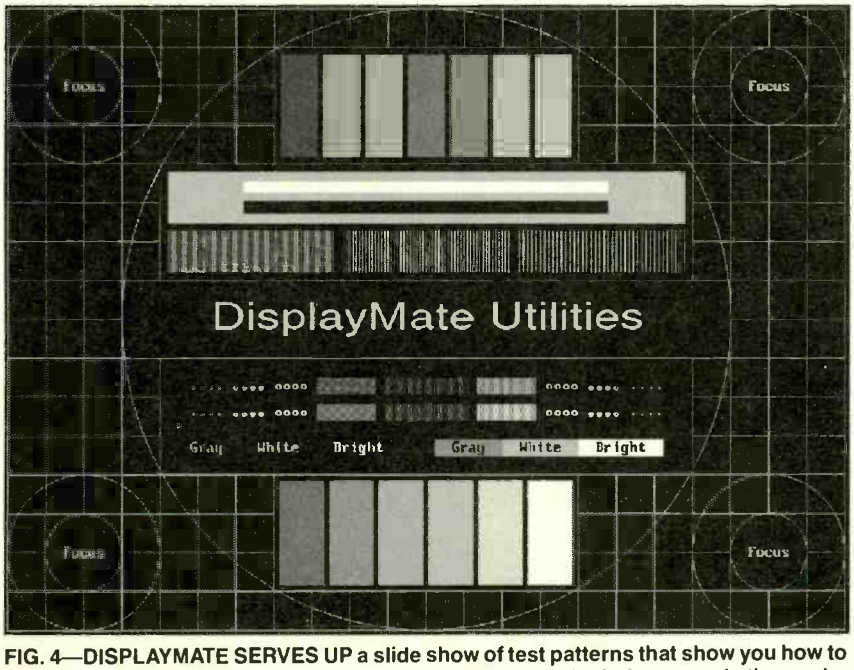
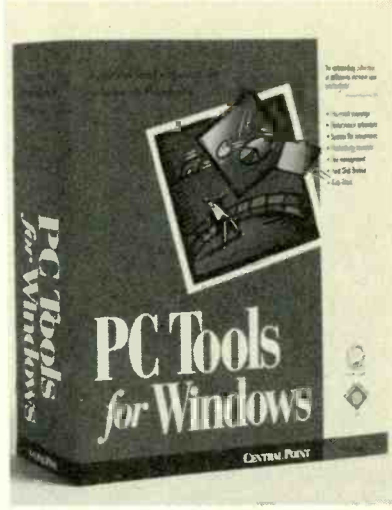


FIG. 4—DISPLAYMATE SERVES UP a slide show of test patterns that show you how to adjust your monitor for optimum brightness, contrast, color balance, and other variables for the best possible image.

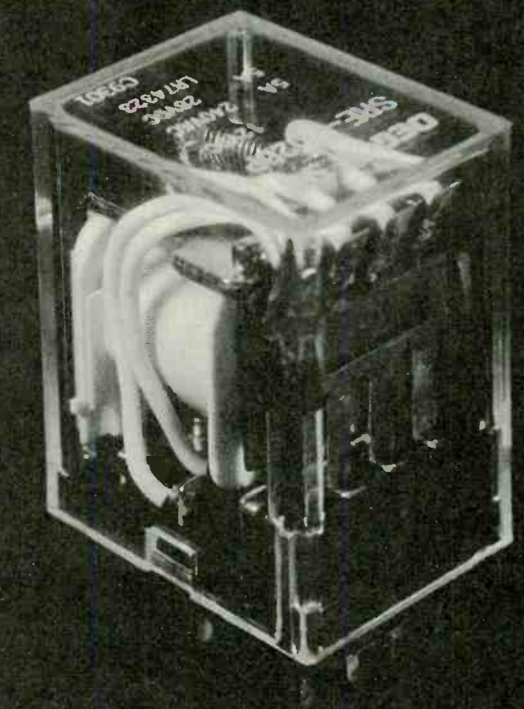


PC Tools For Windows is another useful package of software utilities.

Another excellent graphics benchmark is *WinTach* from Texas Instruments. This user-level hybrid benchmark measures the performance of *Word Perfect* word processing, a drawing CAD program, *QuatroPro* spreadsheet, and *Paintbrush* applications. Numbers are reported for each individual application and an overall rating is compiled (see Fig. 3). The help file explains the weighting given to each of the application's functions. This makes it easy to see which system components have the most impact on the application. Once your PC is properly tuned and working as efficiently as possible, it's important that your monitor be properly adjusted. *DisplayMate*, shown in Fig. 4, can help you properly adjust your monitor, and it can also help you to troubleshoot monitor problems.

Continued on page 82

ALL ABOUT RELAYS



Learn about different kinds of relays, remote switches and CMOS bilateral IC switches and how to apply them.

RAY MARSTON

A RELAY IS A DEVICE THAT PERMITS power or signals to be switched remotely by an electrically isolated input circuit. Relays today are broadly classed as either electromechanical (EM) *coil and contact* and solid-state (SS) with virtual coils and contacts.

There are ongoing requirements for both small-signal and power relays in electronics. While electromechanical power relays have changed very little over the past 25 years, small-signal EM relays have shrunk to the size of sugar cubes. Solid-state relays can switch power, but miniature versions are adept at switching small signals. Various switch functions can now be created by wiring special switching ICs.

The classic electromechanical relay can be traced back to the last century when it was invented for extending the range of telegraph circuits. Although the concept of closing contacts remotely with an electrically isolated circuit has not changed, the possible variations in size, shape, function, and operating principle are astronomical.

Figure 1 shows a classical general purpose EM relay adapted for use in electronic circuits. A miniature assembly, it includes a coil with an iron core in the input circuit and silver or silver-alloy contacts that open and close in its output circuits. The moving contacts are mounted on a spring-loaded, insulated armature.

EM relay basics

When the coil (input circuit) is energized, the armature "pulls in" against the tension of the spring. This closure switches the moving contacts on the ends of metal strips (called *poles*), from one set of fixed contacts to an alternative set. Armature pull-in can either energize or de-energize the relay's external circuits, depending on how they are wired.

The relay illustrated is a double-pole, double-throw (DPDT) unit. The transparent plastic dust cover that protects the assembly is not shown. Relays of this kind are available for circuit-board or socket mounting.

These factory-manufactured products are offered in a wide range of sizes and electrical ratings for AC or DC operation. UL recognition and CSA certification assures that the relay has met safety requirements for applications where potentially lethal AC and DC voltages might be encountered.

Figure 2 illustrates two common graphic symbols for relays that are likely to appear on schematic diagrams. Figure 2-*a* is the symbol for a single-pole, double-throw relay; the rectangle represents the iron core and the dotted line represents the control of the coil on the contacts. In Fig. 2-*b*, the coil of the same relay is shown as a transformer primary.

EM Characteristics

The principal characteristics of a relay are given in its coil (input) and contact (output) specifications. Coil characteristics include input ratings in AC or DC volts, power consumption in volt-amperes (VA), and input impedance. The DC value will differ from the AC value because of coil impedance.

Contact characteristics include their arrangement (e.g., single-pole, single-throw, normally open (SPST-NO)), composition (e.g., silver or silver-palladium), and AC or DC rat-

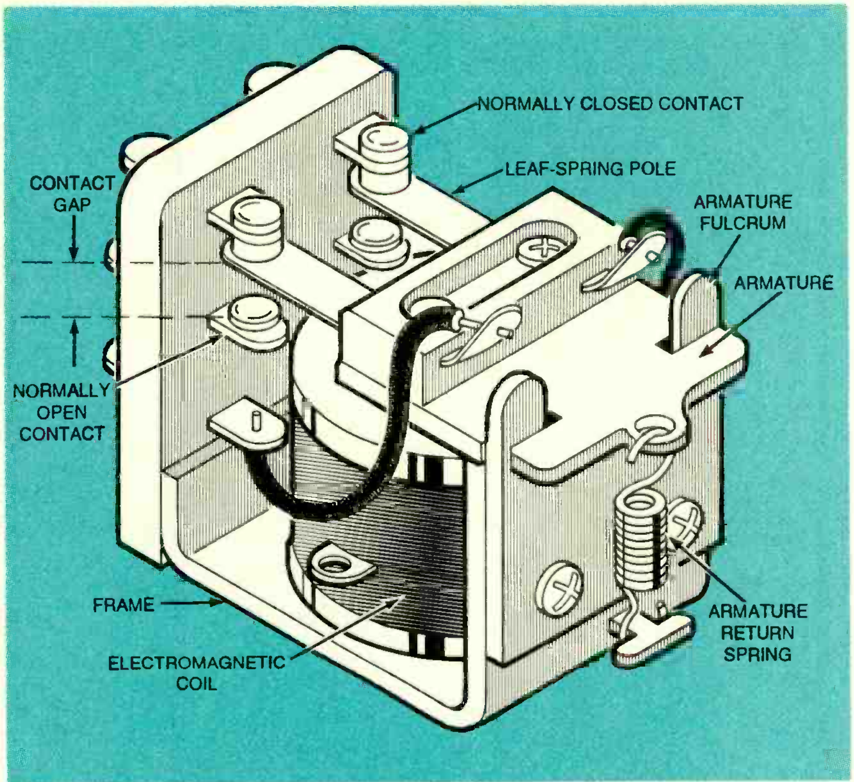


FIG. 1—GENERAL PURPOSE ELECTROMECHANICAL RELAY has DPDT contacts. It is usually protected with a clear plastic dust cover.

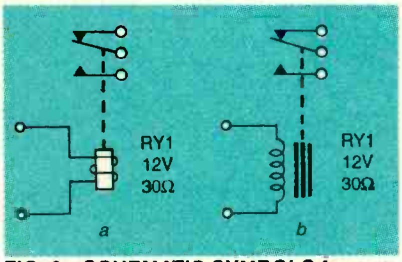


FIG. 2—SCHEMATIC SYMBOLS for a relay: Coil is represented as a winding on a core (*a*), and coil is represented as an iron-core inductor (*b*).

ings (e.g., current at a specified AC or DC voltage).

Figure 3 shows the graphic symbols for five common contact arrangements, identified by Forms A through E. In this figure, NO means normally open, NC means normally closed, and *make* and *break* refer to the opening and closing sequence of the contacts.

Most EM relays have more than one set of contacts and poles and they are usually *ganged*. *Single pole* (SP) means that the relay has only one pole, *double-pole* (DP) means two, and 3P and 4P mean three and four poles, respectively. Contacts for EM relays are rated lower for switching DC than AC, and these values can differ significantly. (DC current at a lower value than AC current can weld the contacts closed.)

DESIGN	SEQUENCE	SYMBOL	FORM
SPST-NO	MAKE (1)	1	A
SPST-NC	BREAK (1)	1	B
SPDT	BREAK (1) - - MAKE (2)	2 1	C
SPDT	MAKE (1) - - BEFORE BREAK (2)	2 1	D
SPDT (B-M-B)	BREAK (1) - - MAKE (2) BEFORE BREAK (3)	3 2 1	E

FIG. 3—RELAY CONTACT SYMBOLS showing five different contact arrangements, sequence, and form.

EM relay circuits

Figures 4 to 9 show practical EM relay circuits. Figure 4 shows a relay with SPDT contacts connected so that it will not latch. Switch S1 is in series with the relay's coil and its power supply so that the relay will be actuated only when S1 is closed.

Figure 5 shows how a nonlatching two-pole relay can be made self-latching by wiring switch S1 between one set of contacts. The NO contacts of one pole are wired in parallel with energizing switch S1. Thus both sets of contacts are normally off, but as switch S1 is closed, it causes the contacts of both poles to close and lock the output set of contacts in the ON state, even if S1 is subsequently re-opened. Once the relay is latched on, it can be turned off again only by opening the connection between the supply and the relay coil.

Figure 6 shows how a relay can be organized to perform AND logic. The relay will be actuated only when all of the series-connected switches S1, S2, and S3

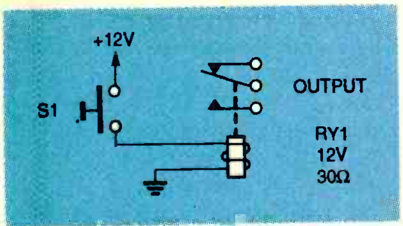


FIG. 4—NON-LATCHING RELAY schematic. Switch S1 is in the coil circuit of this relay.

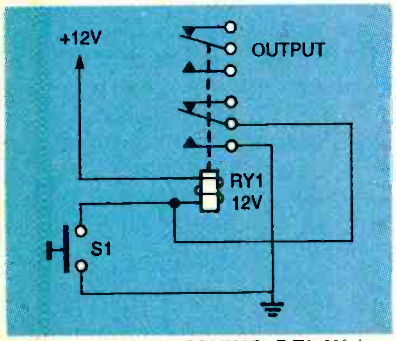


FIG. 5—SELF-LATCHING RELAY is a two-pole relay with a switch wired in parallel with one set of contacts.

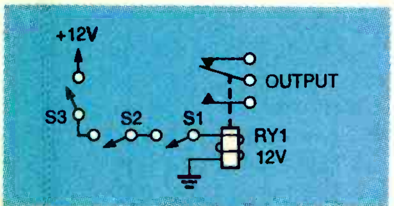


FIG. 6—AND LOGIC CIRCUIT based on an electromechanical relay.

are closed. Figure 7 shows how a relay can be organized to perform OR logic. The relay is actuated when at least one of the parallel-connected switches S1, S2 or S3 are closed.

Figure 8 shows how the basic circuits of Figs. 5 to 7 can be combined to make a simple but useful self-latching intrusion alarm that can be activated with any one of the contact or micro-switches S1 to S3. (There is no theoretical limit to the number of switches that can be wired in parallel in these positions.) The alarm can either be enabled or turned off with switch S4.

When the alarm is enabled, it can be turned on by briefly closing any one of switches S1 to S3. These can be special, unobtrusive miniature switches which are activated by opening a window or door or treading on a mat. When any one of these switches is closed, the relay self-latches one set of contacts and activates the alarm bell with the second set.

Figure 9 shows how a relay and a capacitor form a low-frequency oscillator or lamp flasher. The operation of this circuit depends on the inherent (and substantial) difference between the relay coil's *pull-in* voltage (the minimum value for contact closure) and its *drop-out* voltage (when the contacts re-open).

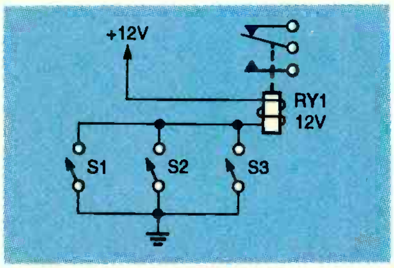


FIG. 7—OR LOGIC CIRCUIT based on an electromechanical relay.

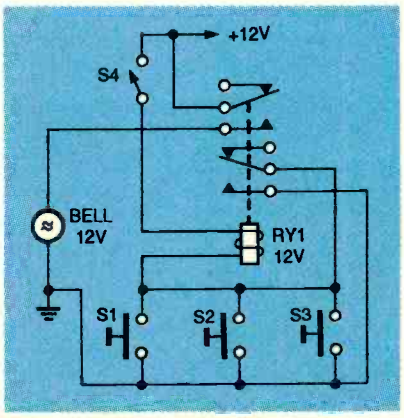


FIG. 8—BURGLAR ALARM that includes a self-latching relay.

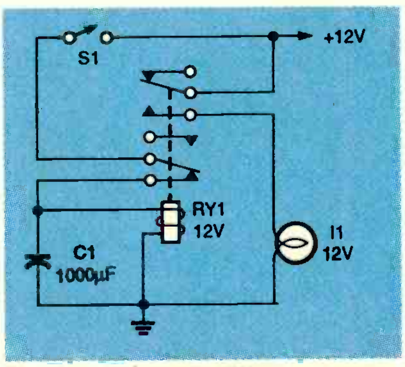


FIG. 9—LOW-FREQUENCY oscillator-flasher includes a self-latching relay.

A general purpose 12-volt relay might pull-in at about 10 volts and drop-out at about 5 volts. Under these conditions the circuit in Fig. 9 operates as follows:

When S1 is closed, C1 charges rapidly through the first (normally closed) set of contacts on relay RY1 until the relay's coil voltage reaches its pull-in value, causing the relay's second set of (normally open) contacts to close, turning on incandescent lamp I1. At that time, C1 discharges into the relay coil, holding the contacts open until C1's voltage falls to the drop-out value of the coil. When that value is reached, the normally closed contacts close again, causing C1 to recharge, starting the whole timing sequence again.

The relay contacts repeatedly open and close (oscillate) at a rate determined by the values of C1, the resistance of the coil, and the threshold voltage levels of coil pull-in and drop-out.

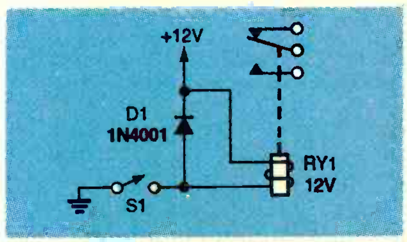


FIG. 10—SINGLE-DIODE RELAY coil damper is a diode across the relay's coil windings.

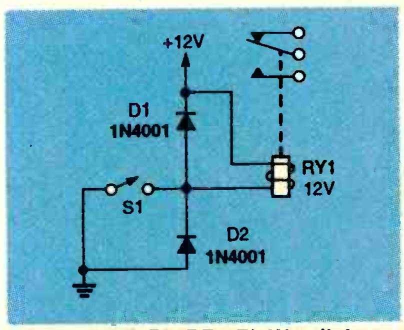


FIG. 11—TWO-DIODE RELAY coil damper has one diode across the coil and the other across the switch

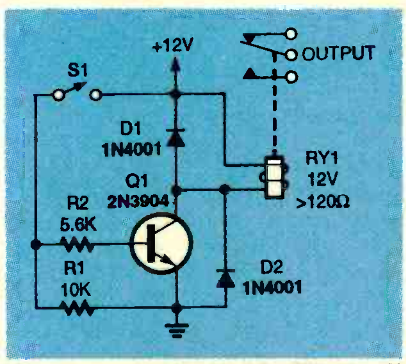


FIG. 12—TRANSISTOR-DRIVEN RELAY with a coil damper.

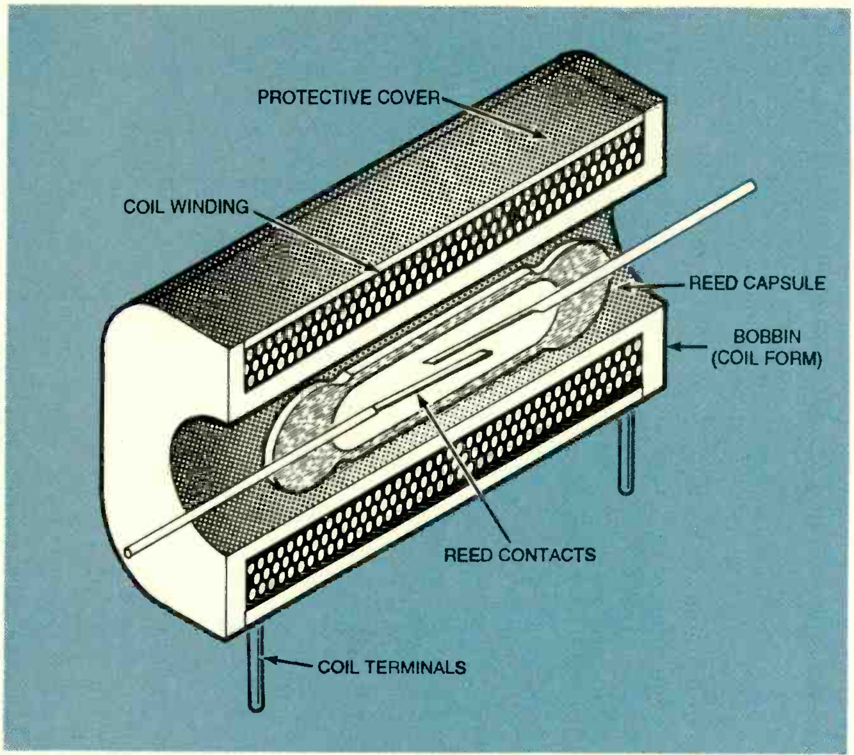


FIG. 13—CUTAWAY VIEW OF A REED RELAY showing section views of the energizing coil and reed-switch capsule.

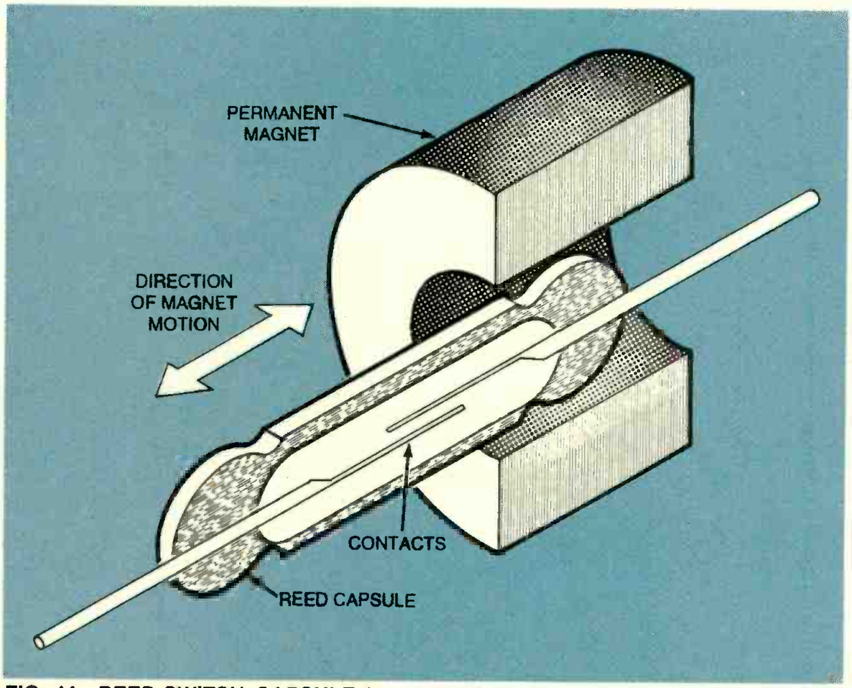


FIG. 14—REED-SWITCH CAPSULE is actuated by the movement of a permanent magnet with respect to the reeds.

Coil damping

Because relay coils are inherently inductive, they can generate large back electromotive forces (EMFs) or voltages if their coil-current conductors are suddenly opened. A typical 12-volt coil can produce a peak back EMF of about 200 volts. These high unwanted voltages can easily damage switch contacts or electronic components connected in the coil circuit.

To prevent damage from back EMF, it is advisable to *damp* relay coils with protective diodes. In Fig. 10 this damping is provided by reverse-connected diode D1, often called a *snubber* diode. It prevents back EMF caused by coil switch-off from driving the junction between the RY1 coil and switch S1 more than 600 millivolts above the positive supply value. This protection is adequate for most relay circuits.

In situations where extra damping would prove beneficial, a pair of protective diodes can be installed. Diodes D1 and D2 in Fig. 11 ensure that the junction between the RY1 coil and switch S1 cannot swing more than 600 millivolts above the positive supply or below ground level. A diode pair is recommended in circuits where switch S1 has been replaced by a transistor or other solid-state switch.

The transistor in Fig. 12 increases the *sensitivity* of relay RY1's coil. If the coil were controlled directly by the switch, S1 would have to conduct a switching current of at least 100 milliamperes. With transistor Q1 functioning as a current amplifier between the S1 and the RY1 coil, the switching current can be reduced to less than 4 milliamperes.

Reed relays and switches

Reed relays are a second major class of electromechanical relays. Unlike the general purpose EM relay, reed relays are almost exclusively found in electronic circuits for signal-level switching in medical instruments, telecommunications equipment, and automated test equipment (ATE). The reed relay is based on a reed capsule that includes the contacts.

Figure 13 is a cutaway view of a reed relay. It consists of a reed capsule mounted within a coil wound on a bobbin. The reed capsule is an hermetically sealed, inert gas-filled glass tube with a pair of thin iron-alloy strips or reeds sealed inside. The cantilevered ends of the reeds overlap but they do not touch.

The Form A or SPST-NO contact arrangement shown in Fig. 13 is a popular form of reed capsule. When the capsule is not in a magnetic field, a small gap exists between the reed ends. However, if the reed capsule is mounted within a coil that is energized, the resulting magnetic field causes the reed ends to close, completing or *making* an external circuit.

The reed capsule offers very high isolation (10^{12} ohms) when off and a very low resistance (0.75 ohm) when on. Because the reeds are hermetically sealed, the contact area (usually precious-metal plated) remains clean and free of oxidation. The reeds will open and close reliably for millions of operations.

A reed relay capsule with a single pair of reeds is a single pole unit. Multipole reed relays can be made by inserting two, three, or more capsules in a single coil. The capsules are also available with Class C SPDT contacts.

Reed relays are now packaged in flatpacks and dual-in-line and single-in-line packages (DIPs and SIPs) for PC board mounting. Standard coil voltages are 5, 6, 12 and 24 volts DC. Mercury is added to some reed relay capsules to damp out contact bounce or chatter.

Reed switch

The reed capsule can also be switched by moving the capsule with respect to a permanent magnet, as shown in Fig. 14. Contact switching is accomplished either by moving the capsule close to a magnet or moving a magnet close to the capsule. Assemblies that include both of these parts are actually reed switches rather than relays, but they perform remote switching. The reed keyswitch was widely used in military-style keyboards because the contacts were protected from hostile environments.

Figure 15 illustrates an application for reed switching with a permanent magnet. The magnet can be concealed in the edge of the door or window, and a reed capsule can be recessed in the door or window frame. An alarm can be set off if an intruder or unauthorized person opens a closed door or window.

A reed relay can be substituted for a general purpose

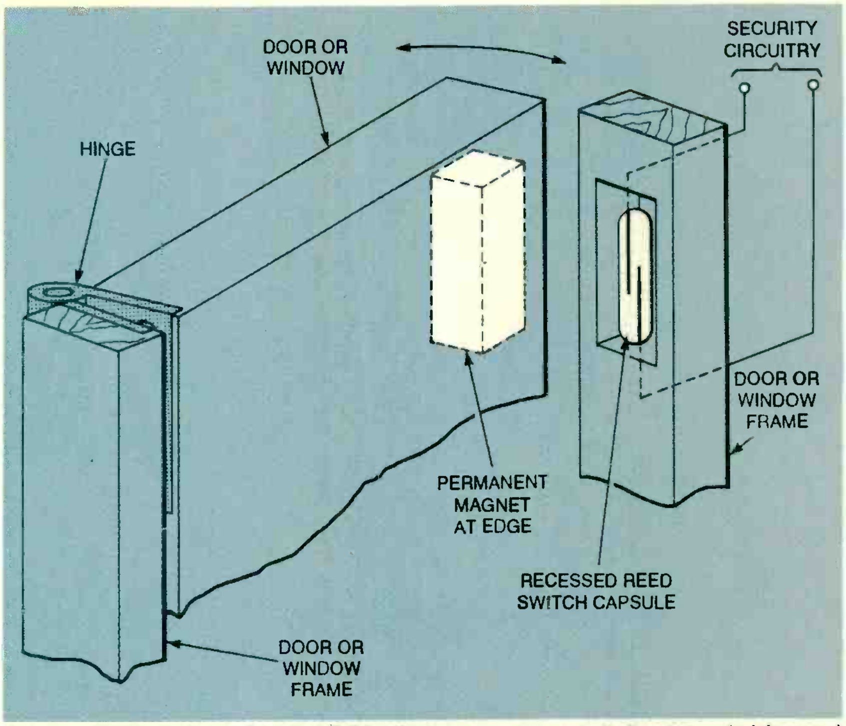


FIG. 15—REED-SWITCH CAPSULE RECESSED in a door or window frame is triggered by a permanent magnet recessed in the door or window edge. Together they function as an input switch in an intrusion detection system.

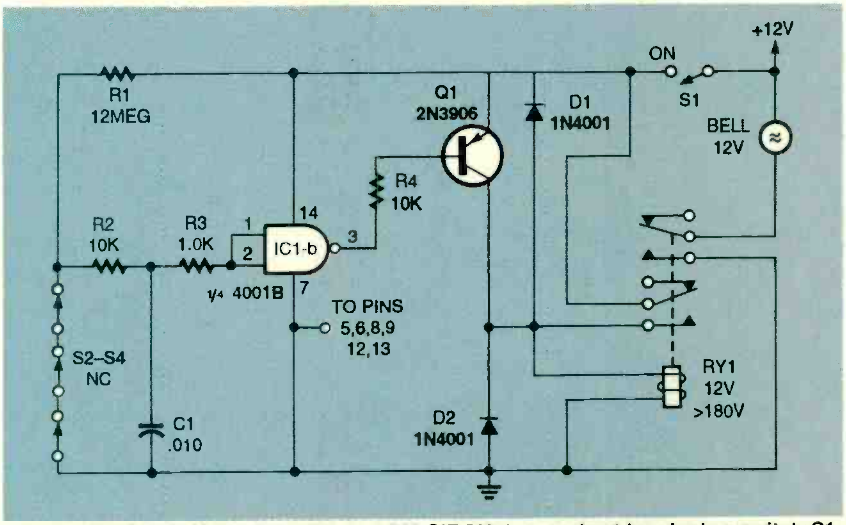


FIG. 16—INTRUSION DETECTION ALARM CIRCUIT, energized by closing switch S1, can be triggered by opening any of the normally closed reed switches S2 to S4.

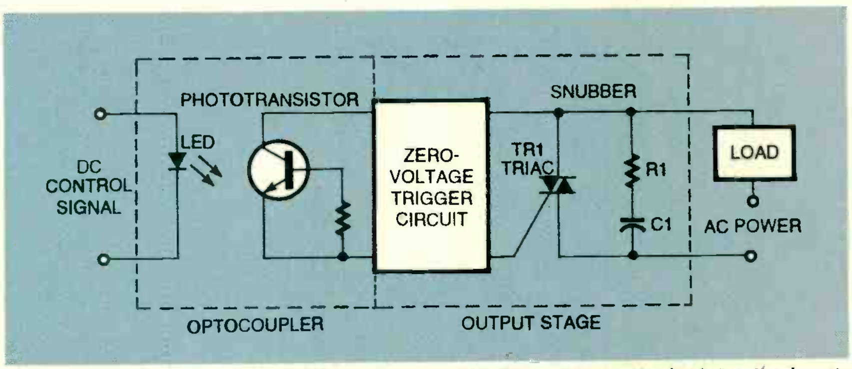


FIG. 17—SOLID-STATE RELAY BLOCK DIAGRAM. The optocoupler isolates the input circuit (coil) from the triac (contacts). The zero-voltage circuit protects the triac.

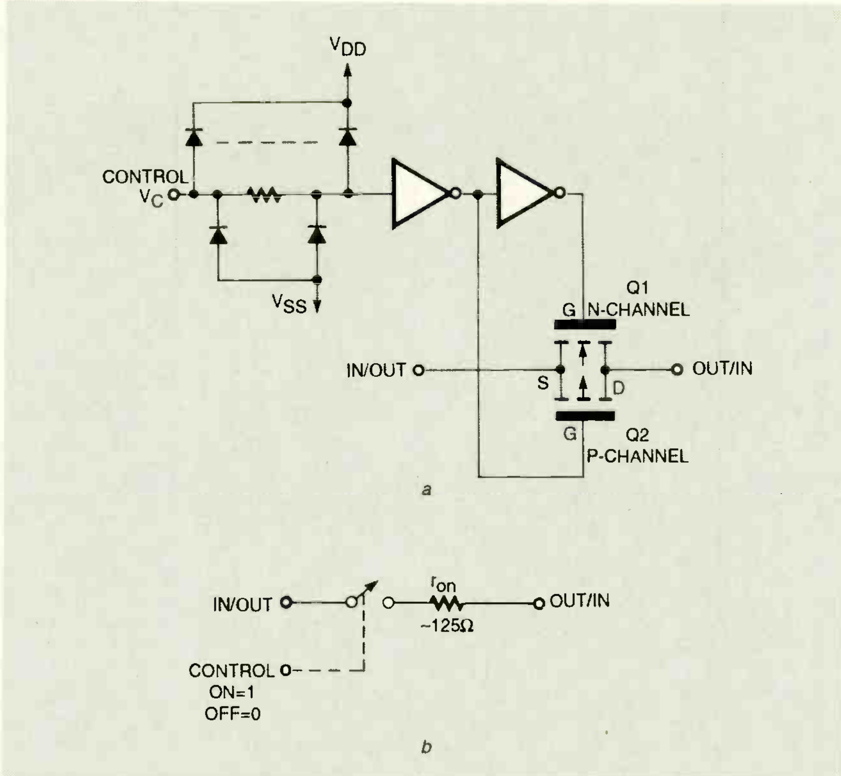


FIG. 18—CMOS BILATERAL SWITCH functional diagram (*a*) and a simplified equivalent circuit (*b*).

relay in the circuits from Figs. 4 to 9. and its coil can damped by the diodes as shown in Figs. 10 to 12. To compete with the reed relay in many applications, some manufacturers have introduced ultrasensitive, miniature PC-board mounted EM relays. Others have introduced miniature, solid-state, PC-board mounted relays billed as "reed relay replacements."

The intrusion detection alarm circuit of Fig. 16 draws a quiescent current of only 1 microampere when it is in the "standby" mode with control switch S1 and all of the series-connected sensor switches S2 to S4 closed.

When any of the S2 to S4 switches are open, a "high" voltage is applied to the input of the quad 2-input NOR gate, a CMOS CD4001B. It is wired as an inverting buffer to drive relay RY1 on through transistor Q1. When RY1 turns on, it self-latches with one set of contacts and sounds the alarm bell with its second set of contacts.

The network of resistors R2 and R3 and capacitor C1 acts as a transient-suppressing filter to protect the alarm against false activation from transients caused by man-made or natural electrical sources.

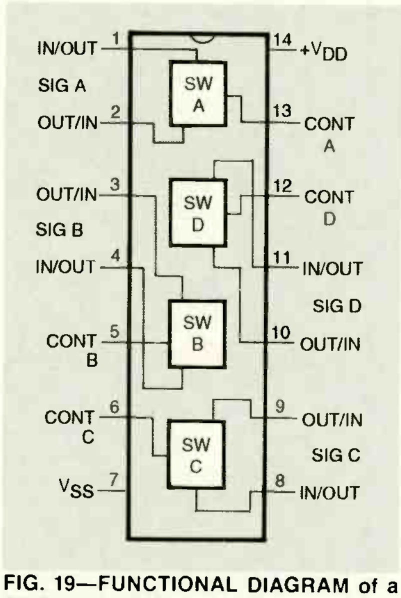


FIG. 19—FUNCTIONAL DIAGRAM of a CMOS CD4066B quad bilateral switch.

Solid-state relay

A solid-state relay (SSR) is an electronic circuit with no moving parts that consists of a signal-level trigger circuit coupled to a power semiconductor switch.

An SSR's classification is based on its input circuit and method of achieving isolation between the input and output circuits. True SSRs include optocouplers for isolation, but hybrid SSRs depend on reed capsules or transformers for isolation. The input circuit of an SSR acts as the coil of an EMR. It is electrically isolated from the power semiconductor that acts as the contacts.

SSRs for switching AC have either two inverse-parallel (back-to-back) silicon controlled rectifiers (SCRs) or an electrically equivalent triac as its contacts. However, if DC is switched, either a power bipolar transistor or MOSFET (metal-oxide semiconductor field-effect transistor) will function as the contacts.

Either AC or DC signals can be applied at the input circuit of an SSR with a block diagram as shown in Fig. 17. The first stage of this circuit is an optocoupler with an infrared-emitting diode matched to a photodetector. (See *Optocoupler Devices*, August 1992 *Electronics Now*, page 44.)

The signal output from the photodetector (phototransistor or phototriac) triggers the output triac so that it switches the load current. The zero-voltage detector assures that the triac will be triggered only when the AC voltage crosses the zero reference. This minimizes the effect of surge currents that occur when the triac is switched. Surge currents result from switching loads such as incandescent lamps or capacitors.

The triac, once triggered, will

Continued on page 82

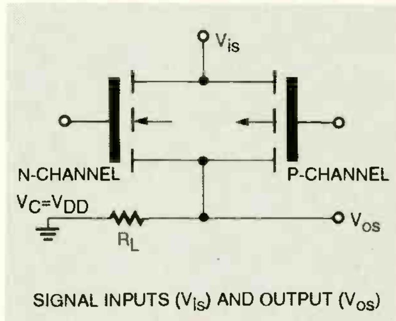
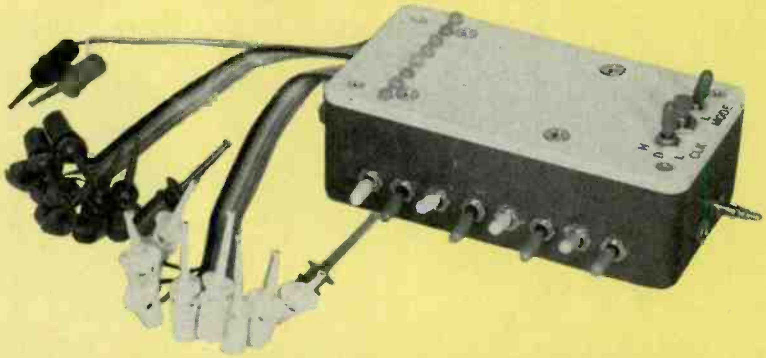


FIG. 20—CD4066B BILATERAL SWITCH power connections for digital and analog signals.

Build the Digilyzer: It performs some digital analyzer functions, but it costs a lot less— and it fits in the palm of your hand.



BUILD THE DIGILYZER

JOHN YACONO AND MARC SPIWAK

A DIGITAL ANALYZER IS AN EXtremely useful instrument for troubleshooting digital circuitry. Unfortunately, digital analyzers are usually priced beyond most hobbyists' budgets. However, the Digilizer, the subject of this article, can perform some of the functions of a digital analyzer. And the best thing about the Digilyzer is that you can build it for less than $50—a lot less than the purchase price of a factory-made analyzer.

The Digilyzer monitors the logic levels at eight of its inputs (called the *test inputs*), and when they match a user-set bit pattern, it latches the binary data present at its other eight inputs (called the *data inputs*). Once data has been latched, it is displayed on the unit by eight tri-colored LEDs. Digilyzers are end-stackable so that multiple units can monitor 16, 24, or 32-bit wide buses—this makes them quite versatile.

One of the most popular applications for the Digilyzer is monitoring the input and output from an integrated circuit to verify its operation. However, the Digilyzer performs many other complex tasks such as monitoring any memory location on a bus.

To use the Digilyzer you start by connecting the test inputs to the address bus, connect the data inputs to the data bus, and set the bit pattern for the address you want to observe. When the Digilyzer next encounters that address, it latches onto the data.

The Digilyzer also offers other options that make it especially suitable for troubleshooting. For example, you don't have to define all the bits that make up the bit pattern. Some can be left in a "don't care" state. This is useful for checking computers with faulty buses that have an intermittent line. It also permits you to observe what is occurring over a wide range of addresses.

The Digilyzer has two modes of operation: *latch* and *free run*. In the latch mode, the unit latches onto data when the test inputs match the user-set bit pattern, and it ignores subsequent matches. In the free-run mode, the latched data is updated each time there is a match.

The Digilizer is fitted with a BNC output that can trigger an oscilloscope when it detects a match. That feature allows the oscilloscope to display the serial data produced by a device such as an RS-232C port when its control and data lines are at user-specified values. This feature is particularly useful for testing parallel-to-serial converters, checking the protocol of serial ports (you'll be able to "see" the stop, parity, and data bits), and determining the handshaking lines being used by a device.

The match detector

The schematic shown in Fig. 1 shows three main sections: a match detector, a match-signal processor, and a data buffer that performs double duty as a display driver. An 8-bit identity comparator, IC1, accepts two 8-bit words (denoted A and B) and compares them.

If each bit of the two words match, the output pin 19 goes low; if any corresponding bits in the words don't match, the output remains high. Moreover, when a match is found, the output will go low only if the enable input (EN pin 1) is low. When the enable input is high, the output remains high.

The bits that form the A word input to IC1 are supplied by TEST inputs TP1 to TP8. Each of the eight bits for the B word can be user set by switches S1 to S8. Each of the SPDT center-off switches can be set in one of three positions:

- the *low* position that ties a B input to ground
- the *high* position that allows a B input to float high through a pull-up resistor
- the "don't care" position that ties a B input to its corresponding A input, ensuring a match regardless of the A bit's value.

The ENABLE input functions as part of an optional *clock* input (TP9). If used, it gives IC1 the ability to sense the clock of the device-under-test (DUT). That feature can prevent false

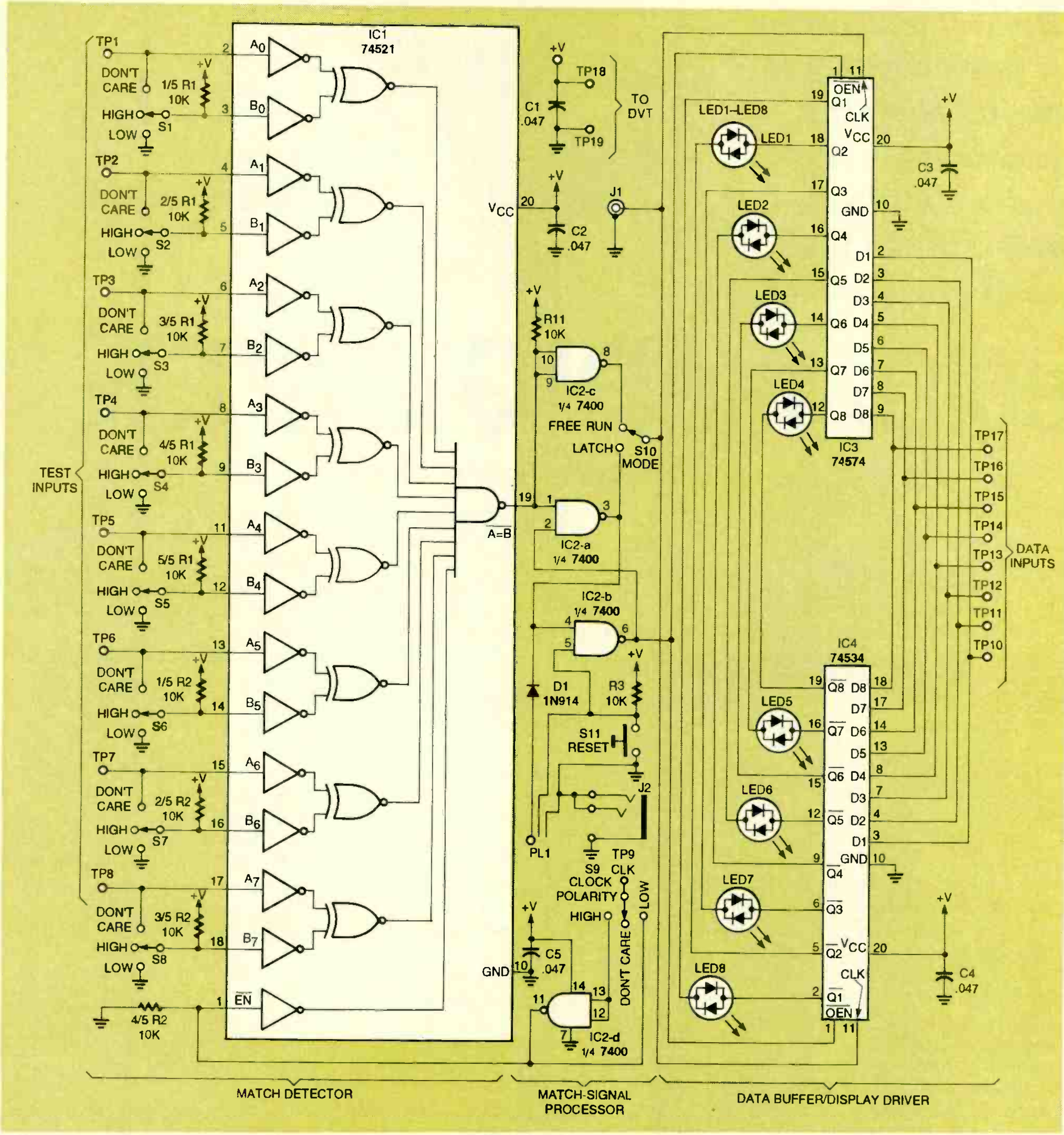


FIG. 1—THE DIGILYZER HAS THREE FUNCTIONAL SECTIONS: a match detector, a match-signal processor, and a data buffer that performs double-duty as a display driver.

triggering of the match detector because of the presence of *unsettled* test inputs, such as might occur when a parallel-printer port or a multiple-bit bus is being tested.

The clock pulses from TP9 enter SPDT center-off switch S9, which allows you to determine how the clock pulses will be treated. If a valid clock pulse is low-going, it can be passed directly to the enable pin by setting S9 to the low position.

If you want to ignore the clock input, placing S9 in the "don't care" position allows R9 to pull the enable pin low, causing IC1 to test data continuously. Putting S9 in the high position allows IC2-d to invert the incoming clock pulses so that a high clock signal will enable IC1.

The match-signal output from IC1 is passed to the match-signal processor. It maintains an internal clock line (CLK) and an output-enable line ($\overline{\text{OEN}}$) used by the data buffer. (The clock line generated by the match-signal processor should not to be confused with the external clock pulses from the device under test or DUT.)

An explanation of the data buffer/display driver will be helpful in explaining the overall function of the clock and output-enable lines before the discussion of the match-signal processor is completed.

The data buffer

The data buffer/display driver is composed of two complementary octal D-type flip-flops, IC3 and IC4. Test points TP10 to TP17, collectively called the DATA inputs, are connected to the inputs of both flip-flop ICs. As a result, for each flip-flop in IC3, a complementary (inverting) flip-flop receives the same data in IC4. Input data from the DATA inputs is clocked into both flip-flop ICs when there is a positive transition of the match-signal processor's CLK line.

Data contained in the flip-flops (whether inverted or not) is presented to the outputs of the two ICs only when the output-enable ($\overline{\text{OEN}}$) lines are low. If these lines are high, the flip-flop outputs go into high-impedance mode, neither sinking or sourcing current. When enabled, both ICs are capable of sourcing and sinking enough current to drive the LEDs.

Each complementary pair of flip-flop outputs is connected across a tri-color LED, which contains a red-emitting die and a green-emitting die. The dice in each LED are connected anode-to-cathode so that when the LED is biased in one direction, it emits red, and when biased in the opposite direction it emits green. However if it is powered by alternating current, yellow light is emitted.

It will be helpful if you understand the operation of one pair of complementary flip-flops and their associated LED. For example, if TP17 is low, that low is presented to D8 of IC3 and to D8 of IC4. When the flip-flops are clocked and the $\overline{\text{OEN}}$ lines are low, Q8 of IC3 presents a low to LED8, while Q8 of IC4 inverts the data and presents a high to LED8. The LED is oriented so that its green element is forward-biased (emits) under those conditions.

Had TP17 been high when the flip-flops were clocked, the LED would have been biased in the opposite direction, thus turning it red. So the color of an LED will indicate the logic level presented to its corresponding data input: red for high, green for low. The LEDs can also emit yellow, but only under conditions that won't be apparent to you until more of the circuit's operation has been explained.

The entire display is disabled when the flip-flop's OEN lines are held high. Moreover, the match-signal processor holds that line high until it receives a low match signal from the match detector. That keeps the display inactive until relevant data has been latched by the flip-flops.

Match-signal processor

The match-signal processor is responsible for clocking the flip-flops and enabling the display on receipt of a low from the match detector. Furthermore, it allows multiple Digilyzers to work in unison for 16-, 24-, and 32-bit wide data analysis. It also sets the unit for either a free-running mode or latched mode, which will be described later. The clock signal it generates is available as an input to the oscilloscope through J1, which will also be explained later.

Despite its many functions, the match-signal is composed of only three three NAND gates and a few support components. Two of those gates (IC2-a and IC2-b) form an R-S latch. One input of the latch receives the output of the match detector, and the other latch input is held high through R10. To simplify this, consider the latch input connected to the match detector, the S input, and the other latch input, the R input. That makes the output of IC2-a the Q latch output and the output of IC2-b the $\overline{\text{Q}}$ latch output.

Consider that the mode switch S10 is in the latched position. That puts the output of IC2-a in control of the clock line. The output of IC2-b is always in control of the output-enable line, regardless of the mode that is selected.

Follow the operation of the latch with Table 1 as a guide. To begin, assume that the match detector is high, indicating that there is no match between the switch settings and the incoming test data. Now press reset button S11, which forces the latch into the reset state: Q is low, $\overline{\text{Q}}$ is high. Now the clock line is low (ready to make a positive transition), and the output-enable line is high (turning off the display). When S11 is released, the R input goes high, but the CLK and $\overline{\text{OEN}}$ lines remain the same.

When IC1 detects a match between the switch settings and the test-data bits, and the external-clock input enable is in the right state, the S input to the latch goes low, and the latch sets; clock line Q goes high, and the output-enable line ($\overline{\text{Q}}$) goes low. That causes the positive-edge triggered flip-flops to take the data bits at the data inputs and display them. Because the latch is set, any further transitions of the match detector are ignored. Pressing S11 will reset the latch, again turning off the display and allowing the process to repeat.

If S10 is in the free-run position and the unit is reset, the display is initially off because the latch still controls the $\overline{\text{OEN}}$ line. However, a NAND-implemented inverter controls the clock line. Because the inverter is not part of the latch, it is free to make a positive transition (a flip-flop clock pulse) upon receipt of each match signal. Thus in the free-run mode, the display is initially off; it turns on with the first match, and re-

TABLE 1—LATCH OPERATION

Input			Output		
Activity	Match Detector (S)	Logic At Pin (R)	CLK-Line Logic Level (Q)	OEN-Line Logic Level ($\overline{\text{Q}}$)	Response
Depressing SII	High	Low	Low	High	Reset
Releasing SII	High	High	Low	High	No change
Data Match	Low	High	High	Low	Latch
Data Mismatch	High	High	High	Low	Still Latched

mains on to be updated by each match that follows.

If matches occur frequently while the Digilyzer is in the free-run mode, one or more of the LEDs might emit yellow. That means its corresponding data input(s) is changing rapidly from high to low and back again. This can't be achieved in the latched mode because the flip-flops are latched and cannot change state.

Whether or not the unit is in free-run or latch mode, the CLK line is available for external applications through BNC connector J1. The connector permits the Digilyzer to be connected to an oscilloscope's trigger input so that the oscilloscope can display serial data when user-set conditions have occurred.

Ganged operation

As explained earlier, the latch also allows two or more Digilyzers to be connected together and operated in unison. This feature is desirable when you want to monitor 16-, 24-, and 32- bit data/address lines. The units must be interconnected to prevent them from latching until all of them have found the right data at their respective test inputs. The Digilyzers are connected by means of plug PL1 and jack J2.

When connecting only two Digilyzers together, plug PL1 of one unit into J2 of the second, and vice versa. When connecting three units, mate the plug of the first unit with the jack of the second, and mate the plug on the second unit with the jack of the third, and connect the plug of the third unit with a short cable length back to the jack on the first Digilyzer.

Notice that the units are connected together in what amounts to a ring formation. You can insert a fourth unit into the ring 32-bit analysis.

Figure 2 shows the electrical connections made between the latches of two interconnected units. There can be more units in the series, but describing the operation of two should be sufficient to give you an understanding of what occurs when there

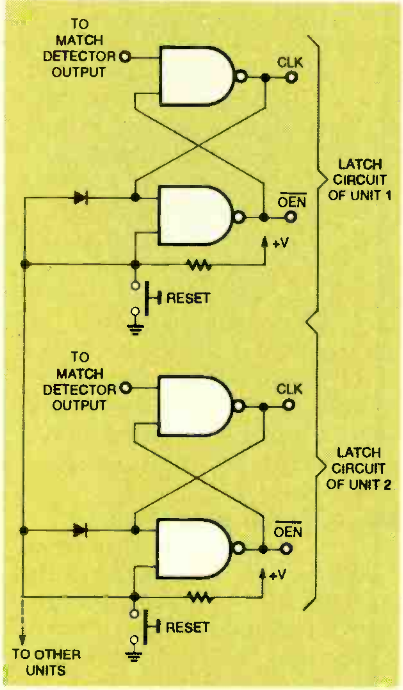


FIG. 2—THESE ELECTRICAL CONNECTIONS are made between the latches of two interconnected Digilyzers.

are three or four. The plugs and jacks were deliberately omitted from the drawing for clarity. Notice that the simplified wiring looks like a bus connecting one unit to another, but is actually not "ring-like" at all. That effect is achieved with clever wiring in the jacks.

Assume that one unit detects a match, but the other unit does not. It would not be desirable for either unit to latch because only one unit has detected a match; the latches must be inhibited in some way. For example, if unit 1 doesn't detect a match, the match-detector signal in that unit is high. The resulting CLK signal must be low, regardless of the reset input value (examine Table 1 to verify this).

That action pulls the reset inputs of both latches low through the diode in unit 1, which puts both latches in their *metastable* state, effectively inhibiting them. As soon as both (all) units detect a match, the diodes will be reverse-biased, and all the latch-reset inputs will be pulled high via their 10K resistors. All the units will latch data, and their displays will be activated.

Some might find that technique objectionable because conventional wisdom suggests that applying two lows to a NAND-implemented R-S latch is forbidden or disallowed. In rigorous mathematical terms, those adjectives are correct because the state cannot be defined with the rigid rules of logic. In short, if you try to determine the output of a metastable latch, you will be unable to arrive at a definitive answer.

However, latches are not mathematical constructs; they are practical components. Therefore, they must produce an output, and they do. Moreover, that output is definitive and consistent. In this situation, both outputs are high. The high on the clock line latches new data into the flip-flops, but the high on the $\overline{\text{OEN}}$ line prevents the display of the irrelevant data.

However, the output changes as soon as the latch is removed from the metastable state. This instability of the state justifies the term *metastable*. Thus the

LISTING 1

```
10 CLS
20 PRINT "If you want this procedure to auto-repeat press Y:"
30 AUT$=INPUT$(1)
40 INPUT "How many test values are there";N
50 DIM TEST(N-1)
60 FOR I= 0 TO N-1
70 PRINT "What's the #";I+1;"value";
80 INPUT TEST(I)
90 NEXT I
100 PRINT "Downloading dummy value. Press the reset button on the
Digilyzer"
110 PRINT "to begin test proceedure."
120 LPRINT CHR$(0)
130 FOR I= 0 TO N-1
140 LPRINT CHR$(TEST(I))
150 NEXT I
160 IF AUT$="Y" OR AUT$="y" GOTO 100
170 PRINT "The proceedure has ended. To repeat the procedure press Y:"
180 ANS$=INPUT$(1)
190 IF ANS$="Y" OR ANS$="y" GOTO 100
200 END
```

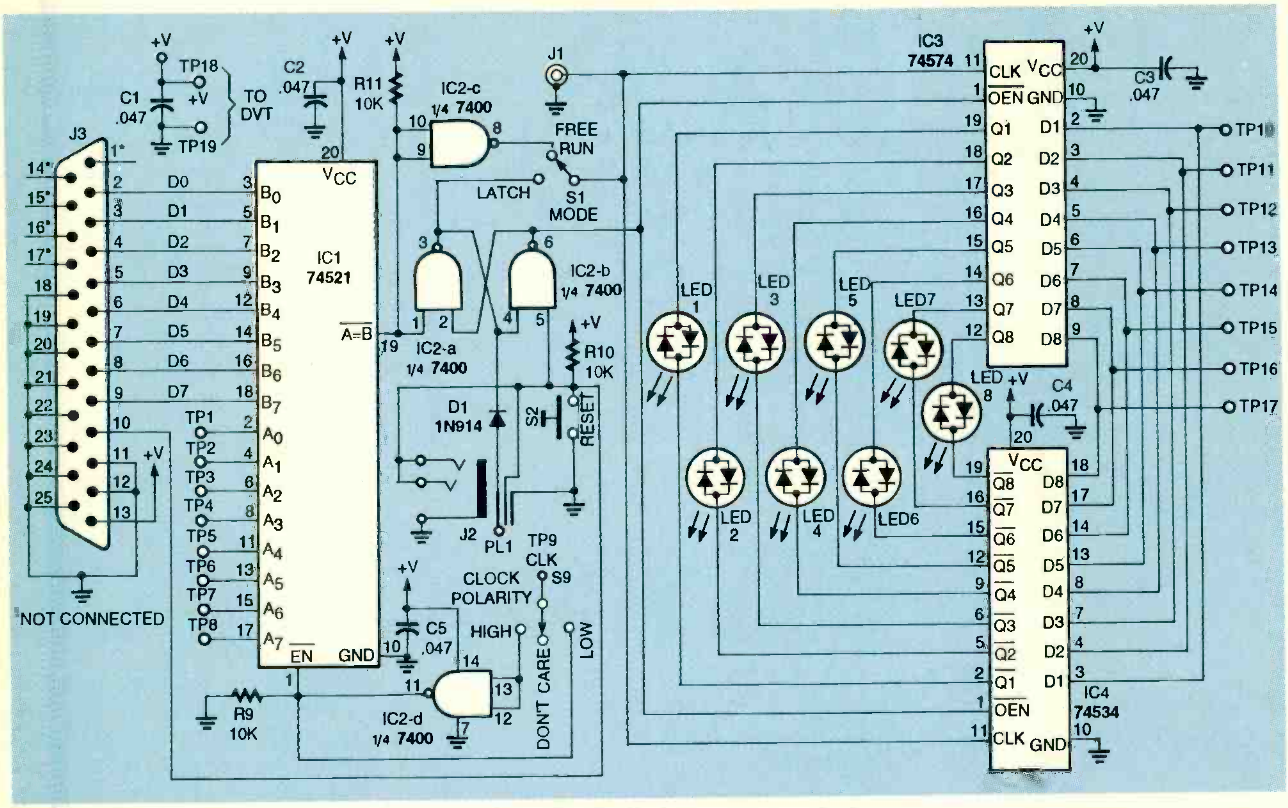


FIG. 3—AUTOMATED TESTING CAN BE PERFORMED: The Digilyzer can be controlled by a computer's parallel printer port. Here the computer downloads successive values of user-set test data.

instability allows the device to avoid premature latching so it can latch valid data.

Computer interface

If you plan to do automated testing, it will be easy to control the Digilyzer from a personal computer's parallel printer port. Figure 3 is a schematic diagram for computerized operation of the Digilyzer. In this application, the computer performs the often laborious task of downloading successive values of the user-set test data to the data-match detector. That permits you to avoid the need for setting the switches to one value after another.

The user-set (in this situation user-programmed) bits are sent to IC1 through pins 2 to 9 on the DB-25 connector shown. The 8-bit word contained on those lines provides the Digilyzer with the information that would have been provided by switches S1 to S8 in the manually-operated unit shown back in Fig. 1. Of course, none of those bits can be set to a "don't care state," but that restriction can be overcome by judicious use of the program, as will be described.

Notice that the clock-polarity setting is still switch- operated. There is no reason for automating that feature. You will probably never want to use more than one clock-polarity setting on a given Digilyzer. It will usually be a "set and forget" switch.

Each time the computer provides the unit with the eight user-programmed switch values, it waits to see an acknowledge signal (a low-going pulse) on pin 10. Of course, the analyzer will only respond to it if you key the reset button.

That allows you to read the LED display and reset the unit before allowing the computer to download the next value. This, and some special features of the program, allow you to forego the computer keyboard after all the test values have been entered, and control the pace of the test procedure from the Digilyzer's console.

The program (shown as Listing 1) is a specialized data-entry procedure. While the program is running, it will ask you to enter the decimal equivalent of the binary number that will be sent to the parallel port. Of course, each bit of that binary number will replace a switch, with D0 (the least-significant digit) as S1, and D7 (the most-significant digit) as S8. This data is called the *test data*.

Initially, the program asks if you want the list of test values you'll enter to be run automatically and repeatedly. That is a useful option for testing many identical Digilyzers because it frees you from having to return to the computer after you test each one.

Next, you will be asked how many test values you will be entering. That allows the program to allocate enough memory for all the values and set the size of two for/next loops: one for input and one for output. During the input loop, you will be asked to provide each of the test values in decimal form. That means that you will enter the decimal equivalent of the binary number formed by the eight user-set switches described earlier. If you are an adventurous programmer, you might want to create a subroutine that accepts binary values.

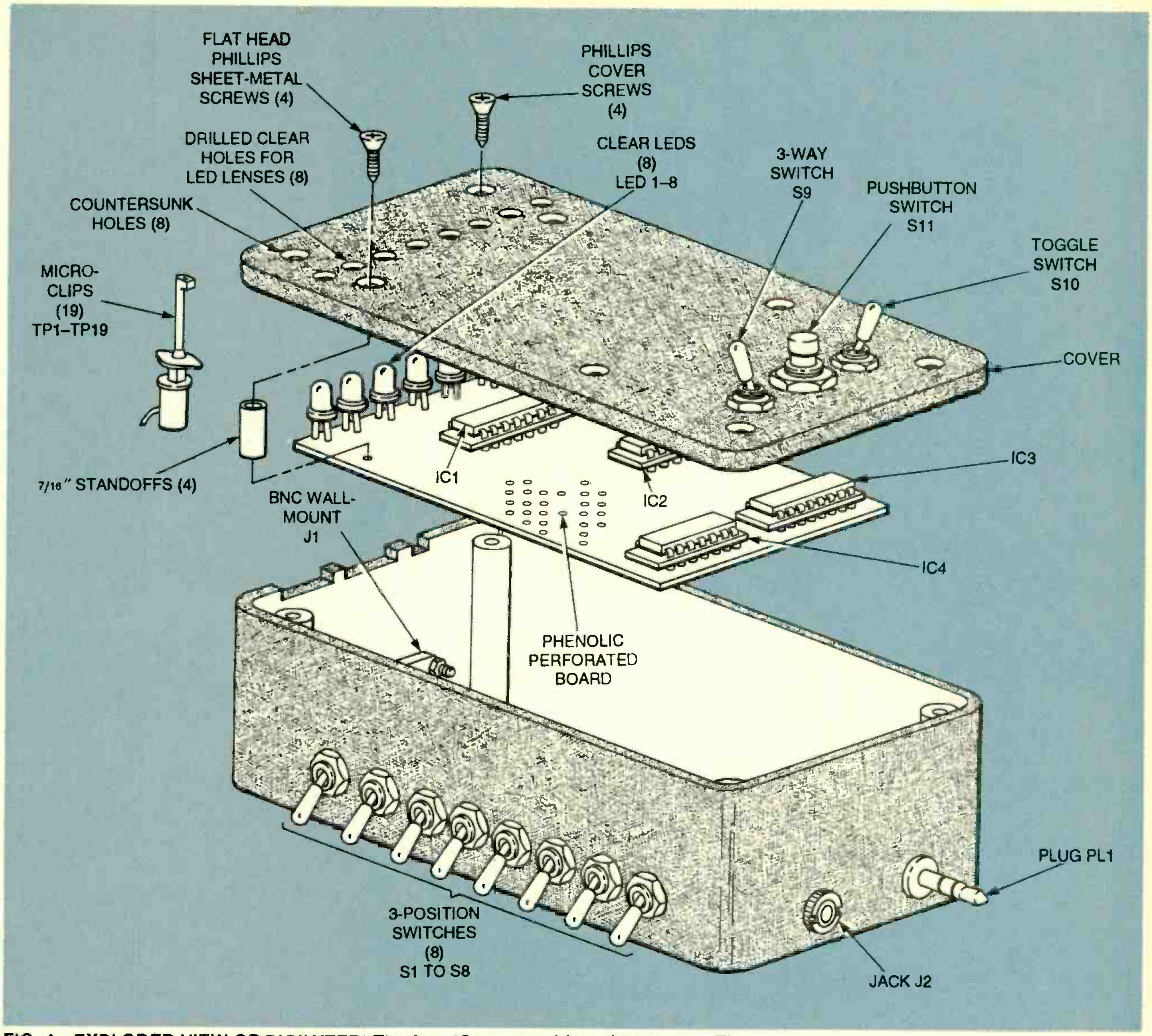


FIG. 4—EXPLODED VIEW OF DIGILYZER: The four ICs are positioned as shown. The circuit board is fastened under the cover with four sheet-metal screws and spacers. The LED lenses project through matching holes in the cover.

After all the test values have been entered, the program sends the NUL ASCII character to the Digilyzer. That action locks up the computer until you indicate that you want it to proceed by pressing the reset button. Once the button is pressed, the first test value is downloaded. When the LED display lights up, you can examine the latched data and get the next test value by depressing the reset switch.

If, for some reason, the DUT fails to generate a match to the programmed user setting in a reasonable length of time, the test value can be skipped by depressing the reset button. Thus, if the DUT fails, you can still continue your diagnosis without returning to the computer.

When all the test values have been run, the program checks to see if you chose the automatic mode of operation. If you did, the program produces the NUL character again. That locks up the computer and gives you a chance to connect another device that you want to test. Once you depress the reset button, it proceeds to run through the test values again, as before, and you don't have to return to the computer.

If you did not choose automatic mode, you are asked if you'd like to run through the list of test values again. It is a useful feature if you believe the results of the first test were unclear. If you don't want to rerun the procedure, the program will terminate. Although the computer might be locked, the program can be terminated at any time by pressing CTRL-BREAK on the PC keyboard.

As was previously explained, you can test devices as if you programmed in a "don't-care state." Enter two test values for each bit in the "don't-care state." One test value should have the ambivalent bit low and the other should have it high.

While multiple don't-care bits can make data entry a chore because you must consider all the combinations, the program can be modified to handle don't-care states and arrive at suitable test values on its own.

PARTS LIST

All resistors are 1/4-watt, 5%, unless otherwise specified.

R1, R2—10,000-ohm five-resistor, single-in-line network (see text)
R3—10,000 ohms

Capacitors

C1–C5—0.047 µF, polyester

Semiconductors

D1—1N914 small-signal silicon diode, 75 PIV
IC1—74521 8-bit identity comparator circuit
IC2—7400 quad NAND gate
IC3—74574 flip-flop, D-type, octal, positive-edge triggered, three state
IC4—74534 flip-flop, D-type, octal, positive-edge triggered, inverting, three-state
LED1–LED8—tri-color light-emitting diode, T-¼

Other components

S1–S9—SPDT toggle switch w/ center-off position, miniature panel mount, Radio Shack No. 275-375 or equivalent
S10—SPDT toggle switch, miniature, panel mount, Radio Shack No. 275-635 or equivalent
S11—momentary pushbutton switch, normally open, miniature panel mount, Radio Shack No. 275-1547 or equivalent
J1—male BNC connector, chassis mount, type 1094, Radio Shack No. 278-105 or equivalent
J2—stereo jack, miniature
PL1—stereo plug, miniature
TP1–TP19—test clips, miniature (see text)

Miscellaneous: Project case (see text), perforated phenolic circuit board, 0.1×0.1 grid (see text), three 20-pin, one 14-pin wire-wrap IC sockets, ribbon cable (see text), wire-wrap wire, insulated wire 28AWG, four Phillips-flat-head sheet-metal screws, solder

Some other useful additions to the program that you might want to add include subroutines to write the test data to a file or the printer. Similarly, some means of test-data retrieval and editing might also be valuable.

Construction

Building the Digilyzer is relatively simple because, aside from the four ICs specified, the only other circuit components are two single-in-line (SIP) resistor networks, one discrete resistor, and one diode. The SIP networks simplify wiring. With the exception of a single 10K resistor that has one grounded lead, all other 10K resistors function as pull-up resistors, making it a straightforward network application.

The prototype circuit was built with point-to-point wiring on a perforated circuit board measuring 2½×3½-inches with 0.42-inch holes in a 0.1×0.1-inch grid. The dimensions of the circuit board were determined by the inside dimensions of the construction case: 4¾×2½×1½-inches. The case is large enough to contain the circuitry and internal wiring without crowding, yet the package is small and convenient to handle.

Refer to schematic Fig. 1 for wiring and exploded view Fig. 4 for a general layout of the integrated circuits IC1 to IC4. Start by wiring the circuit on the perforated board. Sockets are recommended for all four ICs. Leave the insertion and soldering of the eight LEDs as the last step.

When the circuit-board assembly is complete except for the LEDs, select four spacers to separate of the top surface of the perforated board from the underside of the case cover, as shown in Fig. 4. (The spacers in the prototype are ⅜-inch high, slightly higher than the upper surfaces of the ICs mounted in sockets.)

Mount and solder the eight LEDs at one end of the board at a height that will allow their lenses to project through holes drilled in the cover of the case with the spacers in place, as shown in Fig. 4.

After the circuit is complete, add labeled lengths of insulated wire to all points necessary for connecting the switches, jacks, and test leads. After all wiring is in place, solder the other ends to the correct terminals on the switches and jacks as shown in Fig. 1.

Next, solder approximately 7-inch lengths of ribbon cable to all test points. The prototype was wired with a 9-conductor multicolor ribbon cable for TP1 to TP9, and an 8-conductor multicolor ribbon cable for TP10 to TP17. Because the ribbon cable had 10 conductors, the remaining two-conductors removed were used for the V_{CC} and ground leads.

Because of the correspondence between the standard resistor color code and the colors of the wires bonded to the flat cable, the black wire in the nine-conductor cable, was assigned to test clip 1 (TP1) and the black wire in the eight-conductor cable was assigned to TP10.

Test the circuit at this stage in its construction before you mount any of the switches and jacks in the case. When you are satisfied that the circuit operates as described, complete the necessary hole drilling in the side walls of the case and its cover for mounting the switches and jacks.

Start first by marking the centers of the eight holes in a row in the side wall of the case

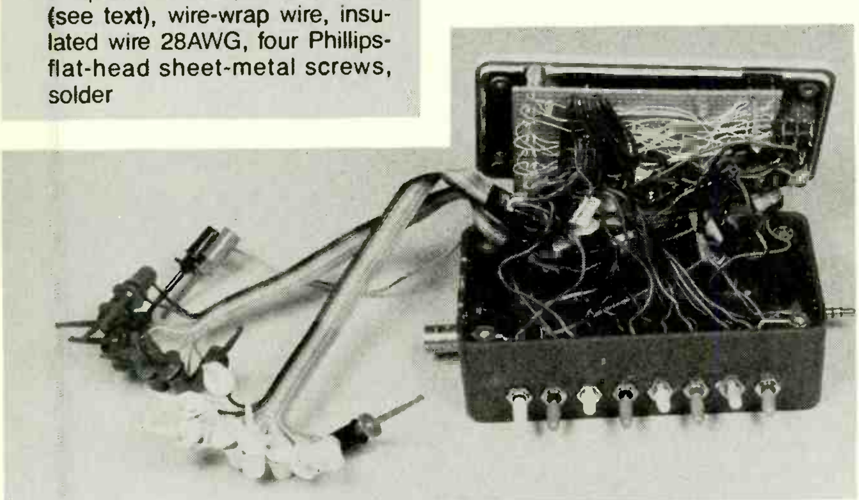


FIG. 5—DIGILYZER WITH COVER/CIRCUIT-BOARD ASSEMBLY REMOVED. The internal wiring is arranged so that the cover can be closed without interference.

row in the side wall of the case for switches S1 to S8, as shown in Fig. 4. You can simplify the task of drilling an even row of holes in the case for the switches by applying a strip of drafting tape to the case and marking the locations of the hole centers. Note: The ganged bodies of the eight switches selected occupied the space between the cover mounting posts inside the case.

Drill the eight holes for the switches as well as the holes for plug PL1 and jacks J1 and J2. Mount all the switches and the plug and jacks with the ring nuts provided or nut and bolt sets, as required.

Mark the locations of the eight holes in a row across the cover to admit the lenses of the LEDs. (In the prototype they were sized for the diameter of T1¼ LED lenses.) Tape a section of perforated board on the top surface of the cover and use the 0.1-inch matrix as a guide for locating the centers of the holes to be drilled. The spacing should correspond to the spacing of the LEDs on the circuit board.

Drill the eight holes for the LEDs, drill the four countersunk holes in the case cover for mounting the circuit to the underside of the cover, and drill the three holes in the cover for switches S9, S10, and S11, as shown in Fig. 4. You might want to apply decals to the cover to identify the switch functions.

Fasten the circuit board to the cover with the four spacers and suitable self-tapping screws. It will not be necessary to drill additional holes in the circuit board because the screws will pick up on matching holes in the board.

After fastening the circuit board to the case, attach the miniature test clips to the ends of the ribbon cables and separate twin lead. The test clips were color coded in the prototype: eight green clips on the eight-wire ribbon cable, eight white clips and one black and white clip on the nine-wire cable, and black and red clips to terminate the twin wires. The Digilyzer is now complete. Ω

RELAYS

continued from page 74

not stop conducting until the load current being conducted falls to zero. A resistor and capacitor in series, called a *snubber*, bypasses voltage transients that occur with inductive loads when current and voltage are out of phase. Triacs are the thyristors of choice for general-purpose AC SSRs with ratings up to 10 amperes at 120 to 240 volts.

Solid-state relays typically cost more than comparably rated EM relays, but their performance advantages over EM relays include:

- Longer-life and higher reliability
- Better compatibility with logic-level circuits
- Higher speed switching
- Higher resistance to shock and vibration
- Absence of moving mechanical contacts

Without moving mechanical contacts, the SSR is not a source of electromagnetic interference (EMI). Thus there is no contact bounce. The absence of

Continued on page 89

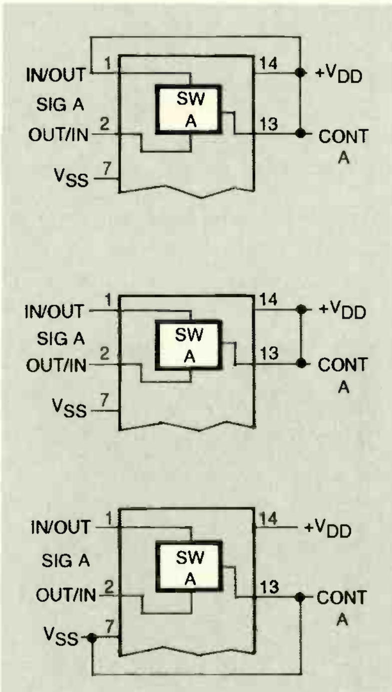


FIG. 21—THREE METHODS for disabling the unused sections of a CD4066B quad bilateral switch by connecting the control terminal with the V_{DD} or V_{SS} terminals.

PC BENCHMARKS

continued from page 68

Don't guess—test

The PC industry has struggled for years with the question of measuring computer performance effectively, but it looks as if resolution is in sight. User-level hybrid benchmarks are at the cutting edge of benchmark technology, and the next generation of hybrids should raise the level of PC testing by a quantum leap while simultaneously establishing sorely-needed benchmark standards.

It is unlikely that today's benchmarks are going to be obsolete any time soon. The Whetstone, Dhrystone, and MIPS are firmly entrenched in PC history. Ω

RESOURCES

PC Tools
Central Point Software
15220 Green Brier N.W. Pkwy.
Beaverton, OR 97006
800-964-6896

DisplayMate
Sonera Technologies
PO Box 565
Rumson, NJ 07760
908-747-6886

Lotus 1-2-3
Lotus Development Corp.
55 Cambridge Pkwy.
Cambridge, MA 02142
800-343-5414

MathCad
MathSoft Corp.
101 Main St.
Cambridge, MA 02142
800-628-4223
617-577-1017

Norton Utilities
Symantec Corp.
10201 Torre Ave.
Cupertino, CA 95014
800-526-4787

QAPlus
DiagSoft, Inc.
5615 Scotts Valley Dr. #140
Scotts Valley, CA 95066
408-438-8247

Quattro Pro
Borland International Inc.
100 Borland Way
Scotts Valley, CA 95067
800-336-6464

WordPerfect
WordPerfect Corp.
1555 North Technology Way
Orem, UT 84057
800-526-4787

HARDWARE HACKER

Tough audio amplifiers, obsolete-semiconductor sources, air-turbine opportunities, more on FM DX reception, and invention marketing scams.

DON LANCASTER

New ideas and opportunities are where you find them. So it pays to tune in to the widest possible range of sources you can. For instance, your local "molar mason" can be your key to new sources for ultra low cost...

Air turbines

Dentists are concerned about AIDS and related viruses. As a result, a lot of them are switching to newer "single use" dental tools that minimize health risk factors. This leads us to some new hacking opportunities.

What you call a dentist's "drill" is correctly known as a *handpiece*. One new series of throwaway disposable handpieces is now sold by *Oralsafe*. The handpieces have a list price of only $14 each, and they include a plastic handle, a high speed air turbine, and some "gee whiz" fiber-optic lighting.

Right out of the box, they make fine printed-circuit repair and rework tools. They are also great for model work and mockups. But what makes them really neat is that you can chop down the device to make a mini air turbine the size and mass of a plotter pen!

Figure 1 shows the innards of the Oralsafe air turbine. It consists of a plain old nylon pawl gear that acts as an impeller, the hollow shaft that holds the working tool by friction, two ball bearings, and some simple end-seal splash guards. The turbine works just like a child's pinwheel; you blow on it, it spins.

An air turbine is inherently a very high-speed, low-torque tool. It is useful for drilling very small holes in printed circuit boards or abrading copper foil. It is not suited for routing wooden signs or for the heavy milling of aluminum, but you conceivably could add a gear train to reduce the speed and increase torque. Odds are that you'd still be way ahead, compared to a motor-driven tool.

Now, compressed air does sound like a complication, but it doesn't have to be. Many hardware hackers already have shop air routinely available. If you do not, you'll need a compressor, an accumulator (or tank), an optional pressure gauge, and a regulator. Figure 2 shows the setup that some dentists use.

Normal working pressure at the handpiece is usually around 30 psi.

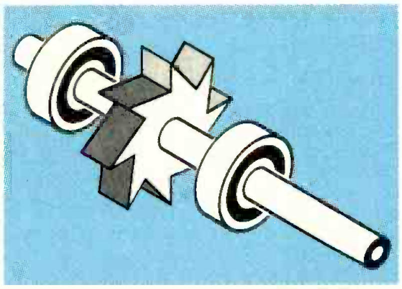


FIG. 1—THE $14 ORALSAFE DENTAL handpiece can be cut down to provide an air turbine the size and mass of a plotter pen. Air blown tangentally across the nylon pawl rotates the hollow shaft at extremely high speeds.

A dental office will usually have an air supply rated at about 90 psi from a compressor. Every dental work station has a local 60 psi regulator. A needle valve or other flow restrictor sets the pressure *at the handpiece* to 30 psi.

Some sort of valve is used to turn the drill on and off. For hacker uses, you could simply close the air flow all the way instead. Otherwise, a manual or electric valve can be used. Because the air turbine vents to atmosphere, only a two-way valve is needed.

Regulators, valves, and gauges are widely available for around $6 from *C & H Sales* or *American Science and Surplus*. Compressors are easily found at yard sales or in most electronic surplus sale advertisements. But note that aquarium pumps or spa blowers cannot supply the pressure needed. If all else fails, take a plain old truck tire and fill it to 100 psi. Or use a Scuba tank. Either one should give you many hours of operation.

Let's make a contest out of all this. Just tell me what you would do with an air motor the size and mass of a plotter pen, or build a low-cost something and tell me about your experiences using it. As usual, there will be a bunch of my *Incredible Secret Money Machine II* books going to the best entries, plus an all-expense-paid (FOB Thatcher, AZ) *tinaja quest* for the very best. As usual, be sure to send your *written* entries to me here at *Synergetics*, rather than to *Electronics Now* editorial department.

Even if these Oralsafe air turbines end up too short-lived or too wimpy for useful work, they seem like a superb starting point for solving the hacker's CAD/CAM cost hassles. Pneumatics look like a real winner here.

Disposable handpiece ads appear in the *Dental Products Report* and *Dentistry Today* trade journals. One low-cost tubing source is *Hygenic*.

Many thanks to Jim Saline, DDS for putting me on to these.

Bulletproof audio

National Semiconductor Corporation wants us to believe it has produced an indestructible power amplifier. Well, it won't take *Electronics Now* readers long to correct National's thinking here.

The new *Overture* series audio power amplifiers sure are up into the "fairly sturdy" range. And their specifications seem in excess of hi-fi quality. They're also cheap and easy to use. Free samples are sent with letterhead requests. So these do look like great new hacker chips.

Figure 3 shows one circuit. National made a pseudocomplimentary integrated bipolar power audio amplifier and then added some elaborate new *SPiKe* protection circuitry to it. Although the chip is a 100-watt amplifier, it really delivers only 40 watts of continuous average output power into the usual 8-ohm speaker load. The distortion at full power is a scant 0.06% and the signal-to-noise ratio is 95 dB.

The protection circuitry makes the chip new and exceptional. The chip rapidly shuts itself down on any short circuit, overload, or overtemperature, and it self-resets quickly. As a bonus, the amplifier does not start up until the supply voltages are high enough. A mute is also offered. Either of those features can eliminate transients that create annoying and possibly destructive thumps.

National says that you do not need regulated power supplies, because of their excellent power supply rejection ratio of more than 120 dB. Such a claim can cause problems if believed by hardware hackers. You'll still need a solid supply that stays within reasonable maximum and minimum limits and has enough energy storage to prevent dropouts or droop at all power levels.

By the way, *SGS-Thomson* offers a comparable device, the TDA7294, with MOSFET rather than bipolar outputs. The pinouts and circuitry are somewhat different. I'm not at all sure which one is the better choice for you.

FM DX again

Well, the dust has finally settled on the long-distance FM reception problems we've looked at several times in the past. As it turned out, there are lots of genuinely useful problem-solving products out there, but they sure are hard to find.

A few contest winners pointed out that *too much signal* can cause even more problems than too little. If you reduce the size of the input signals, you might keep any strong local station from overloading the receiver. *Radio Shack* has some low cost 10-dB attenuators you can try here for this.

If you have an exceptionally well designed receiver front end, you can also improve reception by reducing your receiver's IF bandwidth—the same way that a communication receiver offers several bandwidth options that trade off selectivity versus audio quality. In fact, the whole reason for an IF strip in the first place is to add some extra selectivity.

Most modern FM receivers use ceramic filters that typically have a bandwidth of 270 kilohertz. You can also get very low cost ($2) filters down to 90 kilohertz or less. *Murata* is one typical source. Such filters should, in theory, dramatically improve the rejection of unwanted signals. But reworking the IF bandpass on any commercial FM receiver is not a trivial task. You have to have special test equipment and know *precisely* what you are doing. And the stereo performance may drop badly.

There is a broadcast-quality FM tuner called the *Denon* TU-680 NAB. This one includes a switched narrow band IF option that has 75 decibels of rejection a mere 400 kilohertz away from the desired station. The price is around twice that of a better grade home hi fi tuner.

You can also pretend that you are a cable TV company and use head-end components instead. One leader here is *Cadco*, which offers a rack-mount FMP *Broadband FM Processor* that has 35 decibels of RF gain and strong rejection of out-of-band signals.

Cadco also has an FME *Broadband FM Equalizer* which includes one dozen premium and passive tunable traps. They let you balance out the signal levels from strong and weak stations. Also offered is a super rugged and no-nonsense FM-SSL-75 antenna with 12 decibels of gain. Considering that

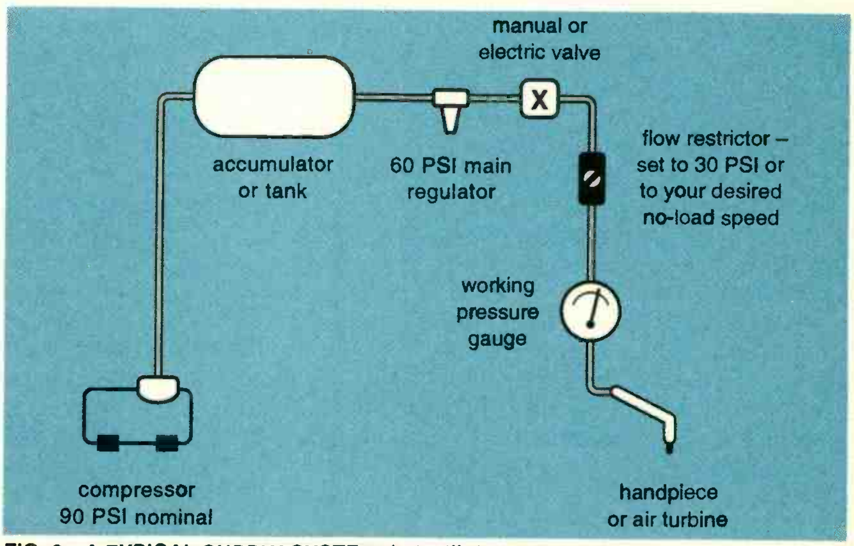


FIG. 2—A TYPICAL SUPPLY SYSTEM that will drive air turbines.

these receivers are as good as they come, the costs are not that bad—around $300 each.

Speaking of traps, several readers sent me some that just did not work. Sorry, but it is simply not possible to build a single-station passive FM trap using ordinary trimmer capacitors and plain old coils.

Yes, you can easily trash out the entire FM band. But you can't notch out a single station and still pass a nearby one. Active solutions usually won't work because of cross modulation.

Why? Look at the numbers: Say you are working with a system impedance of 75 ohms and want a bandwidth of less than 500 kHz at 100 MHz. That needs a loaded Q of 200, which takes an unloaded Q of 600 or higher. Go through the math, and you'll see that you need a tuning capacitance value of a tiny fraction of a picofarad. This is tricky to do in the real world. Not to mention the *extreme* problems you would have with temperature stability or mechanical vibrations.

Yes, you can build or buy narrow 75-ohm passive filters. And yes, they can reject single stations. But to do so, you have to use exotic techniques such as helical resonators, cavities, or transmission-line components.

I did manage to find several good FM trap solutions. The cheapest one is a pair of surplus cavities called a F-241/U and offered for $22 by *Fair Radio Sales*. Unfortunately, the unit must be modified in a machine shop before it will tune the FM band. No, a hack saw won't hack it.

There is also a F-243/U unit that is already in the right frequency range. Plug and go. But these are extremely hard to find. Figure 4 shows you what these look like.

TX-RX Systems offers bunches of fancy cavity systems that are stable enough to do the job. Responses are offered from variable notches on up through bandpass filters. In general, the larger the cavity, the higher the Q and the greater the stability. These go up to *ten inches* in size! Pricing of these cavities is in the "Don't ask—Don't tell" range.

A more economical alternative is offered by *Channel Master* as the Model 7008 dual trap. This one uses a pair of vernier helical resonators and lists for around $80. Insertion loss is only half a decibel. A second unit would be the *Jerrold* RFT-300 tunable FM trap.

Let me know what else you can come up with in tools and techniques for longer distance FM reception. A stable dual helical trap would make an interesting low-cost construction project. As would specific machining instructions for the surplus cavities.

Obsolete semiconductors

I sure do get a lot of helpline calls asking for sources of out-of-date or hard-to-find semiconductors. So, for our resource sidebar this month, I thought I'd run a short list of a few good sources.

The key point that most callers don't pick up on is that all devices become obsolete for very good reasons. Usually, there is some far better replacement or a newer technical approach that caused the obsolescence in the first place. The message here is simple: It is usually a total waste of time to chase after obsolete semiconductors—especially for new product designs. Even when repairing older circuits, the chances are that a much better and cheaper device is available. Almost any really ancient digital integrated circuit can be replaced by a $2.50 programmable logic device (PLD) or a PIC microcontroller these days.

Some comments on our listings: *Mouser* and *Digi-Key* stock a wide variety of modern parts; chances are you can locate a replacement here. *Circuit Specialists* typically offers the unusual and oddball parts of interest to hardware hackers.

Surplus Traders is likely to end up with just about anything, catch as catch can. *Rochester Electronics* and *RH Electronics* both specialize in warehousing obsolete parts and older MIL-spec semiconductors.

If the chip cannot be obtained at any price, *Sunset Silicon* will be happy to build you brand new devices from scratch. It specializes in buying up old circuit masks for remanufacture. Serious inquiries only, please. Your BMW will be required as a deposit.

The *IC Master* is a complete di-

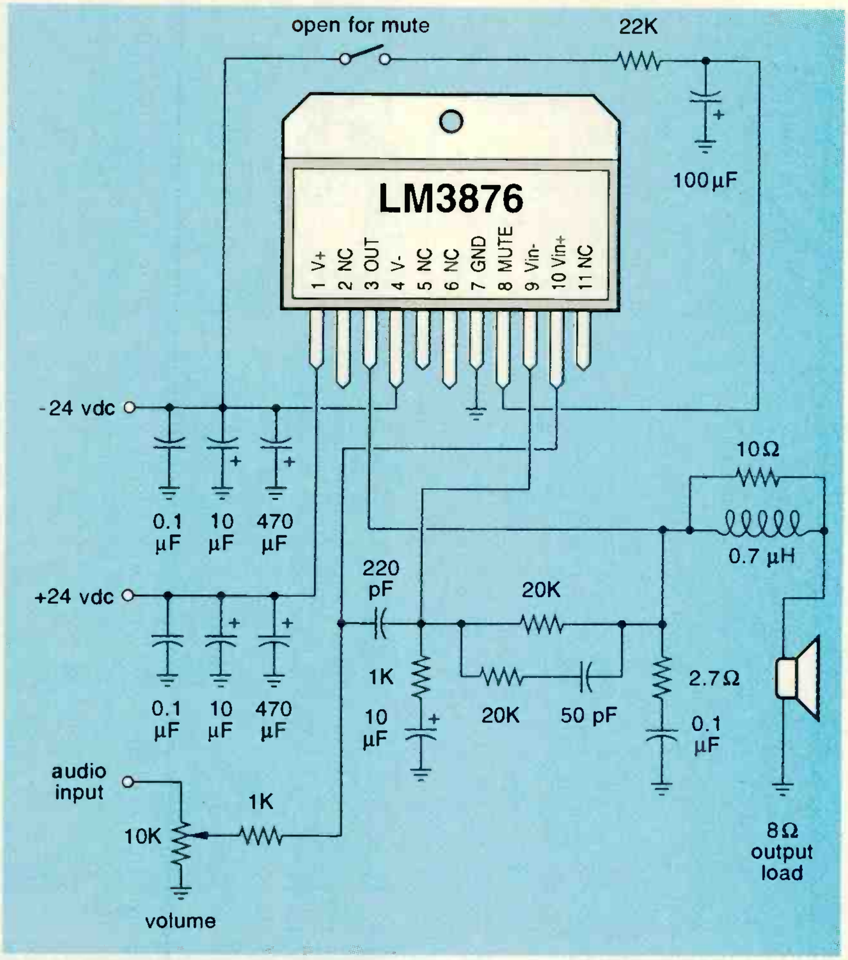


FIG. 3—NATIONAL SEMICONDUCTOR CORP. has a new line of exceptionally rugged Overture audio amplifiers. Here is a typical 40-watt circuit.

rectory for most integrated circuits ever manufactured anywhere in the world. ECG and NTE are the two best suppliers of consumer electronic replacement semiconductor devices.

Pure Unobtainium is a labor-of-love hacker operation that stocks problem parts for specific home-brew construction projects. Its catalog is one dollar, cash in advance.

Finally, *Fistells* specializes in old electronic organ chips, especially top-octave generators and keyers. It also builds modular workarounds for music parts that truly are impossible to get elsewhere. Let me know if I missed any of your favorites here.

Much more information on identifying unusual supply sources for parts appears in my *Resource Bin* reprints.

Invention marketing scams

I noticed that the February 11, 1994 issue of the *Wall Street Journal* had a column stating that the Federal Trade Commission had finally closed down the number one inventor-scamming bad guy. What really amazes me is that inventor scams are now a $114 million a year industry. What usually happens is that an unsuspecting and misguided "inventor" responds to a tiny classified ad, has his invention lavishily praised, and then typically pays $5000 or so in up-front fees to license or market his new invention. According to court records, less than one "customer" in 500 *ever* sees *any* positive cash flow.

Now, I believe that it is really dumb to refer to oneself as an "inventor" or even act like one. To do so opens you up to every scam in the book, plus a few that haven't made it into print yet. The playing field is *always* uneven any time the word "inventor" crops up.

On the other hand, there are hundreds of more-or-less legitimate inventor organizations that do think they provide useful services. These organizations are often local self-help clubs, school seminars, or regional "incubator" development programs. I've posted a long list of these as #538 INVENORG.PS to *GEnie* PSRT.

My own thought is that you will be vastly better off viewing yourself as a *purveyor of risk reduction* rather

OBSOLETE SEMICONDUCTOR RESOURCES

Circuit Specialists
PO Box 3047
Scottsdale, AZ 85271
(800) 528-1417

Digi-Key
701 Brooks Avenue South
Thief River Falls, MN 56701
(800) 344-4539

ECG
PO Box 3277
Williamsport, PA 17701
(717) 323-4691

EEM
645 Stewart Avenue
Garden City, NY 11530
(516) 227-1300

Fistells
7023 E Colfax
Denver, CO 80220
(303) 393-6000

Mouser
11433 Woodside Avenue
Santee, CA 92071
(800) 346-6873

NTE
44 Farrand Street
Bloomfield, NJ 07003
(201) 748-5089

Pure Unobtanium
13109 Old Creedmoor Road
Raleigh, NC 27613
(919) 676-4525

RH Electronics
4083 Oceanside Blvd, Ste G
Oceanside, CA 92056
(619) 724-2800

Rochester
10 Malcolm Hoyt Drive
Newburyport, MA 01950
(508) 462-9332

Sunset Silicon
402A Ridgefield Circle
Clinton, MA 01510
(508) 365-6108

Surplus Traders
PO Box 276
Alburg, VT 05440
(514) 739-9328

NAMES AND NUMBERS

American Science & Surplus
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Evanston, IL 60202
(708) 475-8440

C&H Sales
PO Box 5356
Pasadena, CA 91107
(800) 325-9465

Cadco
2405 South Shiloh Road
Garland, TX 75041
(800) 877-2288

Channel Master
PO Box 1416
Smithfield, NC 27577
(919) 989-2205

Chronicle of Philantropy
1255 Twenty-third Street NW
Washington, DC 20037
(202) 466-1200

Denon
222 New Road
Parsippany, NJ 07054
(201) 575-7810

Dental Products Report
Two Northfield Plaza, Ste 300
Northfield, IL 60093
(708) 441-3700

Dentistry Today
26 Park Street
Montclair, NJ 07042
(201) 783-3935

Fair Radio Sales
PO Box 1105
Lima, OH 45802
(419) 227-6573

GEnie
401 N Washington St
Rockville, MD 20850
(800) 638-9636

Hygenic
1245 Home Avenue
Akron, OH 44310
(216) 633-8460

MuRata
2200 Lake Park Drive
Smyrna, GA 30080
(404) 436-1300

National Semiconductor
475 Ellis Street
Mountain View, CA 94043
(800) 272-9959

Oralsafe
43529 Ridge Park Drive
Temecula, CA 92590
(800) 237-8825

Quality Semiconductor
851 Martin Avenue
Santa Clara, CA 95050
(408) 450-8063

SGS-Thomson
1000 E Bell Road
Phoenix, AZ 85022
(602) 867-6259

Short Circuit
PO Box 158
Stuart, FL 34995
(407) 229-5654

SSC
PO Box 55549
Seattle, WA98155
(266) 527-3385

Star Tech Journal
PO Box 1065
Merchantville, NJ 08109
(609) 662-1080

Synergetics
Box 809
Thatcher, AZ 85552
(602) 428-4073

TX-RX Systems
8625 Industrial Parkway
Angola, NY 14006
(716) 549-4700

Weight Engineering
PO Box 1043
Alton, IL 62002
(618) 377-9096

than as an inventor. This relates to moving a product or concept as far along on the incredibly steep *idea mortality curve* as you possibly can. Much more on this is posted in RISKDOWN.PS.

Both of those also appear as hard copy in my new *Case Against Patents* package from *Synergetics*.

Midnight Engineering magazine is a useful source of tested and proven smaller-scale product-development ideas. I've found it infinitely better than the "inventor" magazines.

New tech literature

A second source for those bus switches I discussed at in the last column is *Quality Semiconductor*, which has a bunch of low-cost and eminently hackable *QuickSwitch* products.

There are now zillions of Internet books coming out of the woodwork, typically priced at $300 a dozen or so. Of these, I like the $2.95 *Internet Public Access Guide* from

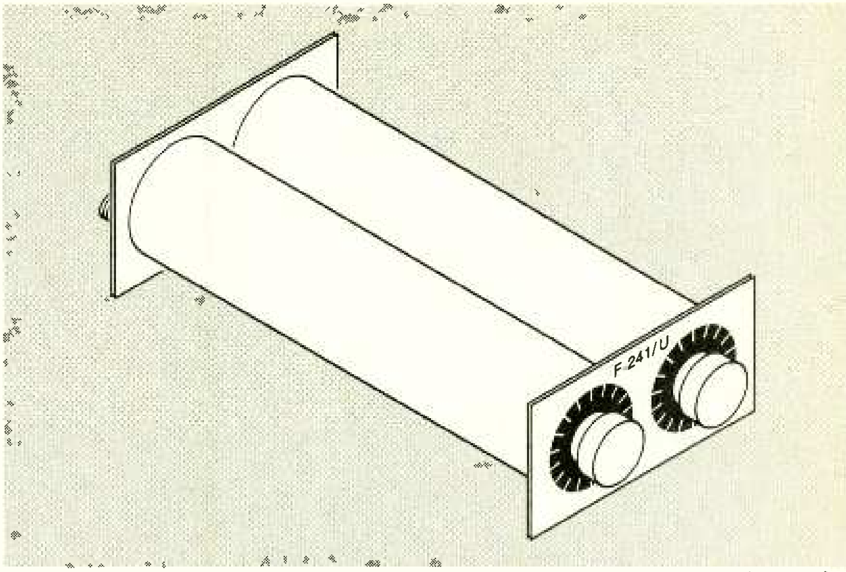

FIG. 4—SURPLUS F-241/U OR F-243/U TWIN CAVITIES are easily converted into tuning preselectors that can improve long-distance FM reception.

SSC the best.

If you are wondering who issues research grants for what publication, you might check *The Chronicle of Philanthropy*.

Very heavy matters are routinely covered in the *Weight Engineering* trade journal—such as scales that find out how heavy airplanes are.

Short Circuit is also the *Newsletter of Engineering Empowerment*. Free samples are offered. This looks like the sort of thing I'd normally favor. Sadly, I believe its writing style totally fails to communicate.

The *Star Tech Journal* is a publication that focuses on insider technical solutions for arcade video game repairs. It also has a BBS at (404) 631-2928.

If you are at all interested in starting up your own technical venture, be certain to get a copy of my revised *Incredible Secret Money Machine II*. I've also get a new free catalog when you call or write.

My current Internet address is now Synergetics @genie.geis.com. You can send me messages, ask technical questions, or request catalogs over this email link. Any technical questions will be posted to Category 1, Topic 38 of my *GEnie* PSRT. Ω

NEED HELP?

Phone or write your **Hardware Hacker** questions to:

Don Lancaster
Synergetics
Box 809-EN
Thatcher, AZ 85552
(602) 428-4073

For fast **PSRT** access, modem (800) 638-8369, then an HHH. Then XTX99005,SCRIPT.

RELAYS

continued from page 82

arcing caused by contact opening eliminates the hazard of switching EM relays in the presence of explosive gas mixtures.

The term solid-state relay is usually a reference to a factory-made and tested product. However, identical functions can be performed by connecting discrete components on a circuit board. (Readers who want to build their own SSRs should refer to *Solid-State Relay* in the May 1992 *Radio-Electronics*.)

Some manufacturers build low-voltage SSRs on circuit boards in their electronic products, but most are likely to purchase factory-made relays for switching power circuits.

CMOS Bilateral switch

The CMOS *bilateral switch* shown schematically in Fig. 18-*a* acts like a low-power, voltage-activated SSR (or remote-operated SPST switch) with a near-infinite input impedance.

The output stage of the circuit consists of Q1, an N-channel, enhancement-mode MOSFET and Q2, a P-channel enhancement-mode MOSFET connected in inverse parallel (drain-to-source and source-to-drain). Their gates are driven in opposing phase with a pair of internal inverters.

The control input can be either a logic 0 or logic 1 signal. MOSFETs Q1 and Q2 are both fully cut off and an effective open circuit "switch" exists between the IN and OUT terminals when a logic 0 signal is applied to the CONTROL terminal. However, Q1 and Q2 are both driven fully on, and an effective "closed switch" exists between IN and OUT with a logic 1 control input.

When Q1 and Q2 are saturated, signal currents can flow in either direction between the IN and OUT terminals. However, the signal voltages must not exceed the V_{SS}-to-V_{DD} limits.

MOSFETs Q1 and Q2 have finite on-state resistance values (r_{on}) of about 125 ohms for 15-volt operation. Figure 18-*b* is a simplified bilateral switch equivalent circuit.

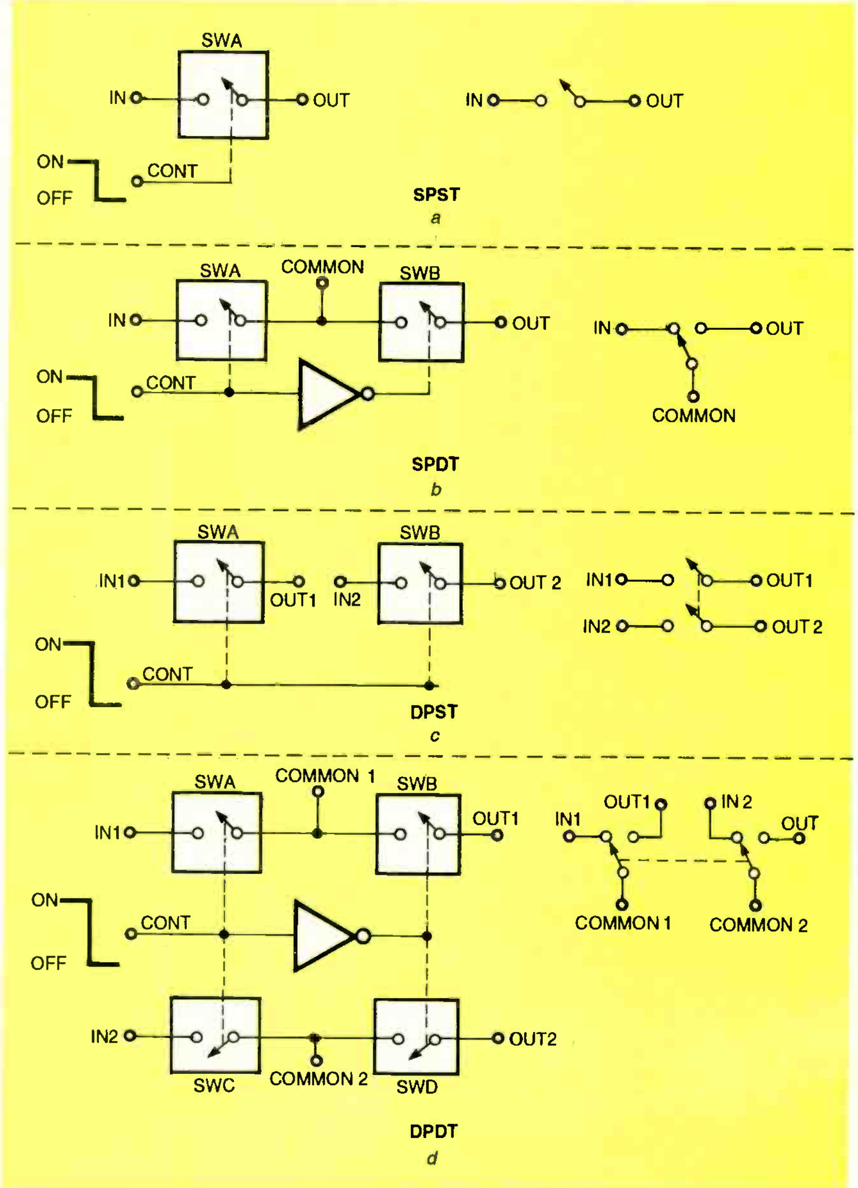

FIG. 22—FOUR BASIC SWITCHING functions organized on a CD4066: SPST (*a*), SPDT(*a*), DPST(*a*), and DPDT(*a*).

The bilateral switch is useful in analog-to-digital and digital-to-analog conversion and the digital control of frequency, impedance, phase and analog signal gain. Four of these switches have been integrated on the CD4066B as shown in Fig. 19.

Figure 20 shows a simplified equivalent circuit for the power supply and control connections for switching digital and analog signals. When working with the CD4066B, be sure that all unused sections are disabled either by connecting its control terminal to V_{DD} and one of its switch terminals, connecting V_{DD} to the control terminal or connecting V_{SS} to the control terminal, as shown in Fig. 21.

Figure 22 shows how the CD4066B can perform the four basic SPST, SPDT, DPST and DPDT switching functions. The SPST function is shown in Fig. 22-*a*. The SPDT function, shown in Fig. 22-*b*, is formed by connecting an inverter stage between the SWA and SWB control terminals. The DPST switch in Fig. 22-*c* is just two SPST switches sharing a common control terminal. The DPDT switch in Fig. 22-*d*, is two SPDT switches sharing an inverter stage in the control line. Ω

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CABLE TV converters/descramblers. 2 year warranties on Jerrold, Zenith, Tocom, Scientific Atlanta. We service most converters. Money back guarantee. **NATIONAL CABLE SERVICES,** (219) 935-4128.

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CONVERTER — descramblers: Examples, Zenith Ztac $225.00, Scientific Atlanta 85XX $195.00, 8600 $335.00, Tocom 5503A $210.00, Oak RTC56 $99.00, M35B $45.00. **All Pioneer test generator** $160.00. Most makes in stock, COD ok. **MOUNT HOOD ELECTRONICS,** (206) 260-0107.

CABLE test-chips as low as $9.95, for testing cable boxes in **full service** mode. Jerrold: Starcom VI & VII, Jerrold cubes; Pioneer, clears E2 thru E5; Pioneer cubes: BA-5000 thru BA-6700; Tocom 5503/5507; Scientific Atlanta: 8500 thru 8600; Zenith: all but PZ1; remotes $10.00. **N.E. ENGINEERING,** 1 (800) 926-4030, fax (617) 770-2305.

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Buffalo, NY. 14216. Voice/Fax (716) 874-2088
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Part No.	Watts	+5VDC (Amp)	+12 VDC (Amp)	-5 VDC (Amp)	-12 VDC (Amp)	1-9	10-24
103173	9	.6	0.25	-----	0.25	$19.95	$17.95
101362	17.2	2	0.3	-----	0.3	39.95	35.95
105769	19.6	2	0.4	-----	0.4	12.95	11.49
77981	28	2	1.5	-----	-----	12.95	11.49
98685	28	4.3	0.5	0.1	-----	17.95	15.95
109461	40.2	3	2.1	-----	-----	14.95	13.49
28898	41	4.8	1.1	0.1	0.34	19.95	17.95
66131	43	2.5	2	-----	0.5	24.95	22.49
103544	42.6	3	2	-----	0.3	19.95	17.95
101354	41	3	2	0.3	0.3	49.95	44.95
88401	45	3	2	-----	0.5	39.95	35.95
28871	50	6	0.5	0.5	1	19.95	17.95
96680	51	8	0.5	0.4	0.4	19.95	17.95
65912	53	7	1	-----	0.5	9.95	8.95
17056	54	5	1	1	1	49.95	44.95
101397	61	4	3	0.1	0.1	54.95	49.49
28943	59	6	2	0.3	0.3	19.95	17.95
101944	65	7.5	1.5/0.42	0.2	0.3	24.95	22.49
101371	66	5.5	2.5	0.5	0.5	59.95	53.95
101813	73	10	1.5	0.3	0.3	22.95	19.95
98706	77	10	0.2	5	-----	24.95	22.49
101389	85	8	3	0.5	0.5	74.95	67.49
66940	100	20	-----	-----	-----	16.95	14.95
103501	137	15	4.5	0.5	0.5	29.95	26.95
65795	192	28	4	-----	0.35	17.95	15.95
93315	194	28	4	-----	0.5	19.95	17.95

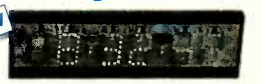
Jameco Analog Display Soldering Station

- Temperature control from 200° to 878° F • Weight: 4 lbs.
- Power consumption: 60 watts
- Includes one 1/16" chisel tip
- Size: 4.25"W x 6"D x 3.38"H

Part No.	Description	Price
35086	Soldering Station	$79.95

2.5" 6-Digit Clock Kit

NEW



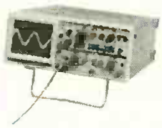
- 2.5" High Red Displays • 6-Digit Display

Kit includes: PC board, components, wall transformer and complete instructions (183 pieces)

Digital clock features: • Bright red LED displays • Size: 2.5"H • Six digits display for hours, minutes and seconds • Allows you to select either standard (12 hr) or military (24 hr) time • Ideal for use in home, office and military settings • Red lens/case not included

Part No.	Description	Price
105507	Digital clock kit	$69.95
109241	Black case & lens	29.95

GoldStar 20 Mhz Dual Trace with 1 MHz Function Generator



- Frequency range: 0.1Hz to 1Mhz (7 ranges) • Output voltage: $14V_{P-P}$
- Output waveform: sine, triangle, TTL pulse • Output impedance: 50 OHM
- Two-year warranty

Part No.	Description	Price
94650	Scope/generator	$499.95

GoldStar 2 MHz Sweep Function Generator & Frequency Counter

- Counter: Frequency range: 2Hz to 2MHz (Ext. 4MHz)
- Output impedance: 50 Ohm or 600 Ohm
- Frequency range: .02 Hz to 2 MHz
- Maximum input voltage: 150 VRMS at 1KHz
- Two-year warranty

Part No.	Description	Price
94676	Generator/counter	$299.95

Linear Series Devices

51262

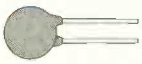
Part No.	Product No.	Price
23051	LH0002CN	$7.95
33216	TL074CN	.89
24811	MAX232CPE	2.75
23683	LM324N	.49
23771	LM336Z	1.09
23835	LM338K	4.39
23851	LM339N	.49
23966	LM358N	.49
27422	NE555V	.45
24539	LM741CN	.39
23157	LM1488N	.49
23181	LM1489N	.49
23237	LM1871N	4.95
23253	LM1872N	4.95
34278	ULN2003A	.95
34972	XR2206	3.75
34315	ULN2803A	.99
23376	LM2941T	2.95
51262	7805T	.59
51334	7812T	.59
50964	75176	1.95

Microprocessors

Part No.	Product No.	Price
26147	MM54104N	$24.95
26227	MM58274N	7.49
43158	6402	4.95
43166	65C02	5.95
43254	6522	3.75
43596	6821	1.95
51844	8031	3.59
51676	80C31	6.95
52003	8052AH	6.95
52142	8088	3.95
52652	8251A	2.95
52724	8255	2.75
52732	8255A-5	2.95
52417	82C55A	3.95
53022	8748	8.75
53057	8749H	9.75
53081	8751H	24.49
52978	87C51	32.95

Capacitors

Monolithic, Silver Mica, Radial and Axial Electrolytic Capacitors also available.



Ceramic Disc (± 20%)

Part No.	Capacitance	Voltage	1-9
15405	22pf	50v	$.10
15341	100pf	50v	.10
15190	.001µf	50v	.10
15229	.01µf	50v	.10
15253	.047µf	50v	.12
15270	.1µ	50v	.15

Mylar (± 10%)

Part No.	Capacitance	Voltage	1-9
26884	.01µf	100v	$.11
26921	.033µf	100v	.15
26956	.1µf	100v	.19
26972	.22µf	100v	.27
26999	.47µf	100v	.35
27001	1µf	100v	.59

Dipped Tantalum (± 10%)

Part No.	Capacitance	Voltage	1-9
33486	.1µf	35v	$.19
33662	1µf	35v	.23
33734	2.2µf	35v	.27
33806	4.7µf	35v	.39
33689	10µf	35v	.65
33822	47µf	25v	2.49

Jameco ABS Speedy Boxes

Will not crack or split when drilled or punched. PCB mounting slots on all four sides and the lid has a lip for precision fit (adds 0.4" H). Complete with four screws and lid. Color: black

Part No.	Size (L x W x H)	Price
18921	3.125" x 2.0" x 0.875"	$2.25
18913	4.875" x 2.5" x 1.5"	2.49
18892	6.0" x 3.5" x 1.875"	2.95
18905	7.5" x 4.25" x 2.25"	3.49

Jameco Prototype Builder Boards:

The Jameco Prototype Boards are designed to fit into ABS Speedy Boxes. These pre-cut boards will allow the builder an immediate start on prototyping circuits. Each board has 2 or 4 mounting holes. Drilled holes: .040" dia. on .080" square pad on .10 x .10 spacing. Solder mask.

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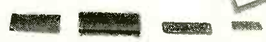

Part No.	Size (L x W)	Fits	Price
105099	2.70" x 1.60"	18921	$3.95
105128	4.40" x 2.00"	18913	5.95
105152	5.50" x 3.10"	18892	6.95
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106551	Ckt. Brd.Hdwe. (4 sets)		1.19

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Part No.	Product No.	Ohms	1-9
42964	63P1K	1K	$.85
43078	63P5K	5K	.85
43001	63P10K	10K	.85
43051	63P20K	20K	.85
43027	63P100K	100K	.85
42981	63P1MEG	1MEG	.85

3/4" Rectangular 15-Turn Cermet

Part No.	Product No.	Ohms	1-9
41785	43P1K	1K	$.99
41890	43P5K	5K	.99
41822	43P10K	10K	.99
41873	43P20K	20K	.99
41911	43P50K	50K	.99
41849	43P100K	100K	.99
41806	43P1MEG	1MEG	.99

Microprocessor Crystals (HC49/U)

Part No.	Product No.	Freq.(MHz)	1-9
102613	CY1.843	1.8432	$2.75
14533	CY3.57	3.579545	1.09
14592	CY4	4.0	1.09
14681	CY6	6.0	1.09
14699	CY6.14	6.144	1.09
14710	CY7.37	7.3728	1.09
14728	CY8	8.0	1.09
14402	CY12	12.0	1.09
14584	CY32.76	32.768KH	.89

TTL Crystal Clock Oscillators (Full Can)

Part No.	Product No.	Freq.(MHz)	1-9
27861	OSC1	1.0	$3.29
27924	OSC2	2.0	3.29
27967	OSC4	4.0	3.29
27991	OSC8	8.0	3.29
27887	OSC10	10.0	3.29

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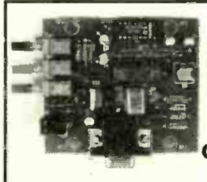

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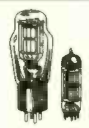

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Output Pwr. +dBm	1.5	4.5	10.0	12.5	2.0	5.5	12.5	17.5
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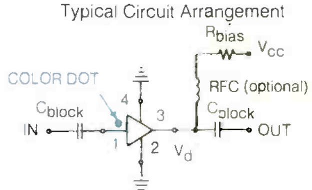

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