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δ = Sigma or standard deviation

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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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June 1994, Electronics Now
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.

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 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-licensing 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"

Cablevision 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.
Get a sample of reality.

Looking for analog confidence in a digital oscilloscope? Tektronix’ TDS 350 sets the standard with Digital Real Time. Its incredible one gigasample/second sampling delivers real-life capture like never before—both for single shot or repetitive events. Select peak detect for slow events, or push the scope to its full 200 MHz bandwidth—with no aliasing. And, like the entire TDS 300 family, the TDS 350 sets a new standard in price/performance: under $4000.

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The TDS 300 family is simple and intuitive; just like your trusty analog scope. Even the digital interface is simplified with on-screen icons. You may never have to crack open the instruction manual!

High-end digital features. Each model features over 20 automatic measurements. Continuous update for hands-free operation. Four acquisition modes and video trigger—perfect for tailoring the display. And a communication option for hardcopy to most printers, or to send/receive waveforms and setups.

Get real. For more real-time benefits of the TDS 300 family, call your authorized Tektronix distributor today. Or call Tektronix at (800) 426-2200, ext. 212.

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CIRCLE 92 ON FREE INFORMATION CARD
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 Kmart 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 Post 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 analogue 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.

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.

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.
• **Videogame battles continue.** The hottest fight ticket in town is the battle between Sega and Nintendo. The upset Sega has thrown the erstwhile champ Nintendo off balance with a big win 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.

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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 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.

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 re-solder 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 near future. 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. 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.
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June 1994 Electronics Now
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 the input of the op-amp.

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...
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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 IC1 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 super-hets by amplifying the difference frequency produced in an IF circuit. Those were usually called autodyne circuits.

S. BIAŁKOWSKI
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 detergents” 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
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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 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 relia-

ble, 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 Mart- ty 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)
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 we were 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 01845, 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 its 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.
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.
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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, respectively. The manufacturer guarantees maximum DC specifications such as 1-millivolt input offset voltage, ±50 nanoampere offset current, and 600 nanoampere bias current.

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digital codes (DCS), and

16 Touch Tone (DTMF) 

characters.
The decoder monitors

the demodulated audio

output from a communica-
tions receiver, service

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The decoder monitors

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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 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
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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.

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 a 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.

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/VEISA-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.
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

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**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.

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

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- Low Output noise rating less than 0.3mV.
- Line/load regulation rated at low 0.01% + 1mV.
- Transient response time of 50μ Sec.
- Overload protection.
- Output enable/disable
- Coarse and fine voltage/current adjustment.
- Auto series/parallel operations for triple output supplies.
- 3 year full warranty—not 1 or 2 years.

**AMREL LPS-300 Series—Offer Features And Prices That The Competition Can’t Beat!**
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- User friendly keypad data entry.
- Low output noise rating less than 1mV.
- Line/load regulation rated less than 2mV.
- Output enable/disable and Power—off memory.
- 2 year warranty.
- Optional RS-232 interface capability.

**Model**

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**AMERICAN RELIANCE INC.**
11801 Goldring Road, Arcadia, CA 91006
Fax: 818-358-3838

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

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**Centronic Inc.**
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Anchor Business Park
Newbury Park, CA 91320
Phone: 805-499-5902
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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.

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.

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.


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.

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.

1994 Equipment, Tools & Supplies Catalog; Print Products International, 8931 Brookville Road, Silver Spring, MD 20910; Phone: 800-638-2020; Fax: 800-545-0058; free.

This 84-page catalog includes descriptions and illustrations of test and
The first benchtop bridge you can hold in your hand.

Introducing B+K Precision's dual display LCR meter.

The new Model 878 is the only LCR meter that delivers the performance of a benchtop bridge at the price of a handheld model.

At the press of a button, you can sort parts to 1%, 5%, or 10% tolerances; record minimum, maximum and average values; and make relative measurements. Capacitance and dissipation factor (DF) or inductance and quality factor (Q) are displayed simultaneously. Components are tested at accuracies comparable to benchtop bridges, at selectable 120Hz or 1kHz test frequencies. Values are displayed on a large 4-digit, 10,000 count display. Best of all, the price makes it easy for every station or technician on your staff to have a bench bridge.

So whether you need a bridge for engineering, QC or production, get your hands on the new B+K Precision Model 878.

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Only $275.00

Parameter | Range | Resolution | Accuracy
--- | --- | --- | ---
Inductance (L) | 0.1μH-9999H | 0.1μH | 0.7% Typ.
Capacitance (C) | 0.1pF-9999nF | 0.1pF Max | 0.7% Typ.
Resistance (R) | 0.001Ω-9.999MΩ | 0.001Ω Max | 0.5% Typ.

I have also included 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 using flyback transformers. An expanded cross-reference indexes flyback transformer replacements by manufacturer's part number and brand name.

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.


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.

Troubleshooting and Repairing Audio Equipment, 2nd Edition
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.
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CIRCLE 187 ON FREE INFORMATION CARD

WORLD’S SMALLEST FM TRANSMITTERS! New Surface Mount Technology (SMT) makes all others obsolete! XST500 Transmitter—powerful 3 transistor audio amplifier, transmits whispers up to 1 mile. XSP250 Telephone Transmitter-line powered, transmits conversations up to 1/4 mile. Both tune 88-108 MHz. Easy to assemble E-Z KITS (SMT components pre-assembled to circuit board)! XST500—$44.95, XSP250—$34.95, VISA/MC. COD add $6.

XANDI ELECTRONICS, 201 E. Southern Ave., Suite 111, Tempe, AZ 85282. 1-800-336-7389.

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FAX: 516-293-3115

CIRCLE 127 ON FREE INFORMATION CARD

LETTERS

continued from page 16

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
Tucson, AZ

"Patent Office, please."
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 bubble gum 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 X).

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
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 counter-claim 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 applications, 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
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.

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 first approach is a kind of linear system 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...
which of those two methods of information transfer is expected to be faster, the more erratic the input will be. If you make too many mistakes in your input, the more likely the output will be too short or too long. The PLL will become unstable if the input is too short, and if the PLL becomes too long, then the PLL will still be too short. These are two possible values for the PLL operation.

n the case of a ladder filter, the expected range of the PLL will vary by at least ten to one (say, 500K to 500K rpm). If the PLL is tuned to a different range of values that will work, the PLL will work, no matter what range of values is used.

Computer Connections

Across the finish line

On the other hand, Microsoft has made mistakes. Its early commitment to the MS-DOS and WordPerfect standards was a failure. Microsoft has been forced to rework its products to make them compatible with existing systems. The latest version of Windows has improved significantly, and it is now a viable alternative to the Macintosh.

Q & A

incremental improvement makes it hard for Lotus to keep up with Windows. Then one day Lotus realized that WordPerfect was more than just a word processor. It was a complete productivity suite, and it was more expensive than the Macintosh. WordPerfect had no products for that environment. Two years later, Lotus was briefly caught up with Microsoft, but then realized that they had no products for the Internet environment. Two years later, Lotus was again caught up with Microsoft, and then realized that they had no products for the Internet environment. Two years later, Lotus was again caught up with Microsoft, and then realized that they had no products for the Internet environment. Two years later, Lotus was again caught up with Microsoft, and then realized that they had no products for the Internet environment.
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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 caracter 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
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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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 x ⅛ 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 x 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.

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.

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

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.

FIG. 4—COMPLETED PC BOARD and tube assembly.

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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
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 1/2. 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 1/4-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 milliamperes 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 (9305p) $22.50
  • Complete kit of parts and PC board, less case, for 2-channel TubeHead (9305x) $78.25
  • Punched, formed, and anodized case with 2-color legend 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 x 5 x 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 x 3/4-inch ventilation 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
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 “squeashing” 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.

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.

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.

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AM POWER LOOP ANTENNA

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.

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

ALLEN A. GAULT
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.
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.

At least a 17-volt output is needed to tune the loop 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 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.

![FOIL PATTERN FOR REMOTE TUNING CONTROL PC BOARD.](image)

**Packaging the electronics**

**Tuner-amplifier.** The tuner-amplifier case is a stock project case with an aluminum cover that measures 2 1/8 x 1 1/8 x 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 x 3/4-inch panhead machine screw as shown in Fig. 6, and assemble a washer before inserting it in the hole and fastening it with a 1/4-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 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 2¼ 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 2½ × 1½ × 1½ inches. Drill a hole in the aluminum cover to admit the lens of the miniature red LED.1 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.

Loading coil. The plastic case for the loading coil measures 4¼ × 2½ × 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 10½ 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 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
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 ¼ 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 the second adapter "B."

Insert a No. 6-32 x 1½-inch flat head machine screw in the adapter marked "A" and a No. 6-32 x 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 onto 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 direction) 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 x 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
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 13\(\frac{3}{8}\) 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 5\(\frac{1}{2}\) inches. Record that measurement.

Obtain a 3-foot length of \(\frac{5}{8}\)-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 \(\frac{1}{8}\)-inch holes close to both ends of the channel to accommodate No. 6-32 machine screws. Cut 90° vee-cuts 5\(\frac{1}{2}\) 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.

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

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 I 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 of the ten input and output ports. This article presents complete construction diagrams, including the PCB 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 (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 on 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 16 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 10–16 outputs of IC2 provide the base address of each block. Jumper JUI allows you to configure the base address so that conflicts are avoided in your system. This article and the
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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: INTR (usually used by serial port COM2, if present), IRQ1 (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...
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 $\frac{1}{2}$-ampere fuse in the 5-volt supply line and a $\frac{1}{4}$-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 $7.0 \times 4.5 \times 1.25$ 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.

\[ N = \text{INP} \text{(PORT)} \]

The second writes N to the specified port.

\[ \text{OUT} \text{PORT, N} \]

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:

\[ N = \text{INP}(256) \]

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

\[ \text{OUT} 256, N \]

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-
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 INW 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

<table>
<thead>
<tr>
<th>Port</th>
<th>Hexadecimal Address</th>
<th>Decimal Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>100</td>
<td>256</td>
</tr>
<tr>
<td>1</td>
<td>101</td>
<td>257</td>
</tr>
<tr>
<td>2</td>
<td>102</td>
<td>258</td>
</tr>
<tr>
<td>3</td>
<td>103</td>
<td>259</td>
</tr>
<tr>
<td>4</td>
<td>104</td>
<td>260</td>
</tr>
<tr>
<td>5</td>
<td>105</td>
<td>261</td>
</tr>
<tr>
<td>6</td>
<td>106</td>
<td>262</td>
</tr>
<tr>
<td>7</td>
<td>107</td>
<td>263</td>
</tr>
<tr>
<td>8</td>
<td>108</td>
<td>264</td>
</tr>
<tr>
<td>9</td>
<td>109</td>
<td>265</td>
</tr>
<tr>
<td>A</td>
<td>10A</td>
<td>266</td>
</tr>
<tr>
<td>B</td>
<td>10B</td>
<td>267</td>
</tr>
<tr>
<td>C</td>
<td>10C</td>
<td>268</td>
</tr>
<tr>
<td>D</td>
<td>10D</td>
<td>269</td>
</tr>
<tr>
<td>E</td>
<td>10E</td>
<td>270</td>
</tr>
<tr>
<td>F</td>
<td>10F</td>
<td>271</td>
</tr>
</tbody>
</table>

LISTING 1—FIPOUT.BAS

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

AO–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 AO–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—CYCOLOUT.BAS

100 REM * for ST-1 Purpose: to display an input port on screen.
110 REM * Hardware: Switch to set input, resistors.
120 REM *
130 REM * I/O address input port, T counter, A5 any key, N input byte
140 REM *
150 REM * NP bit position during printing
160 REM *
170 REM *
180 REM * Program checking
190 REM *
200 REM * 1 and 2 are bit stuck high, 3 and 4 bit stuck low
210 REM *
220 REM *
230 REM *
240 REM *
250 REM *
260 REM *
270 REM *
280 REM *
290 REM *
300 REM *
310 REM *
320 REM *

LISTING 3—INP2CRT.BAS

100 REM * for ST-1 Purpose: to display an input port on screen.
110 REM * Hardware: Switch to set input, resistors.
120 REM *
130 REM * I/O address input port, T counter, A5 any key, N input byte
140 REM *
150 REM * NP bit position during printing
160 REM *
170 REM *
180 REM * Program checking
190 REM *
200 REM *
210 REM *
220 REM *
230 REM *
240 REM *
250 REM *
260 REM *
270 REM *
280 REM *
290 REM *
300 REM *

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 *
130 REM *
140 REM *
150 REM *
160 REM *
170 REM *
180 REM *
190 REM *
200 REM *
210 REM *
220 REM *
230 REM *
240 REM *
250 REM *
260 REM *
270 REM *
280 REM *
290 REM *
300 REM *
310 REM *
320 REM *
330 REM *
340 REM *
350 REM *
360 REM *
370 REM *
380 REM *
390 REM *
400 REM *
410 REM *
420 REM *
430 REM *
440 REM *
450 REM *
460 REM *
470 REM *
480 REM *
490 REM *
500 REM *
510 REM *
520 REM *
530 REM *
540 REM *
550 REM *
560 REM *
570 REM *

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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.
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 craftsman's bench. Later it came to mean a surveyor's mark made on a permanent land-mark 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 test 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.

**COMPUTER BENCHMARKS**

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

**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 sev-
eral 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 (Dhrys/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.

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

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**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 TI-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+1+3
240 ' PRINT PRIME;
250 K=1+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"
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, although they both might have the same average access time.

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

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

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### LISTING 2

**HARD DISK DATA THROUGHPUT**

```
10 CLS : KEY OFF
100 BS = "12345678"
110 CS = BS + BS + BS + BS + BS
120 AS = CS + CS + CS + CS
130 PRINT "WRITING 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 TI = TIMER
200 FOR I = 1 TO 5000
210 PRINT #1, BS
220 PRINT #2, BS
230 PRINT #3, BS
240 PRINT #4, BS
250 PRINT #5, BS
260 NEXT I
270 T2 = TIMER
280 CLOSE
290 TI = (T2 - TI) / 5
300 BPSW = 650000: / T3
310 CS = BS + BS + BS + BS
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 RE1S = INPUTS(1280, 1)
430 RE2S = INPUTS(1280, 2)
440 RE3S = INPUTS(1280, 3)
450 RE4S = INPUTS(1280, 4)
460 RE5S = INPUTS(1280, 5)
470 NEXT I
480 T5 = TIMER
490 CLOSE
500 T6 = (T5 - T4) / 5
510 BPSW = 650000: / T6
520 PRINT
530 PRINT "READ SPEED IS"; INT(BPSW); "BYTES PER SECOND"
540 BPSWTHRU = (650000 * 10) / (T5 - T1)
550 PRINT
560 PRINT "THROUGHPUT SPEED IS"; INT(BPSWTHRU); "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 acceptable performance.

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-

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**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 decompress 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 decompression 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
- VGAZIP.ZIP
- VIDSPED.EXE
- WINBENCH.ZIP
- WINTACH.ZIP
- ELECTRONICS NOW BENCHMARKS
  - DISK.BAS
  - SIEVE.BAS
  - VIDEO.BAS

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**LISTING 3**

```basic
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 "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.

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
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-
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 non-latching 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
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).

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 II. 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.

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:

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 microswitches 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

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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.
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 ex-
ists 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

![Diagram of reed switch capsule recessed in a door or window frame, triggered by a permanent magnet recessed in the door or window edge. Together they function as an input switch in an intrusion detection system.](image)

**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.

![Block diagram of intrusion detection alarm circuit, energized by closing switch S1, can be triggered by opening any of the normally closed reed switches S2 to S4.](image)

**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.

![Solid-state relay block diagram. The optocoupler isolates the input circuit (coil) from the triac (contacts). The zero-voltage circuit protects the triac.](image)

**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.
When protect the alarm and its second set latches with RY1 an inverting CMOS quad age switches to S4 closed. Connected switch "standby" current when quiescent miniature, relays.ature introduced relay the talent FIG. 12. When The circuit in Fig. 17 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

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.

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.

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Surge currents result from switching loads such as incandescent lamps or capacitors.

The triac, once triggered, will...
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 DIGILYZER, 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 signals—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 memory location on a bus.

To use the Digilyzer you start by connecting the test inputs to the addresses 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 Digilyzer 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 Digilyzer can be used by investigators, and 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 is used as a data 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 is used to 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
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 (OEN) used by the data buffer. (The clock line generated by the match-signal processor should not 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 out-

---

**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.
put-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 IC's only when the output-enable (OE) 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 diode in each LED is a connection 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 OE 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 OE 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 Digilzyzers 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 processor is composed of only 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 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, 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 OE 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 (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 OE 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>
<thead>
<tr>
<th>TABLE 1—LATCH OPERATION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input</strong></td>
</tr>
<tr>
<td><strong>Activity</strong></td>
</tr>
<tr>
<td>Depressing S11</td>
</tr>
<tr>
<td>Releasing S11</td>
</tr>
<tr>
<td>Data Match</td>
</tr>
<tr>
<td>Data Mismatch</td>
</tr>
</tbody>
</table>
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 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 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 AUTS=INPUT$(1)
40 INPUT "How many test values are there";N
50 DIM TEST(N-1)
60 FOR I=0 TO N-1
70 PRINT "What's the #";I+1:" value?"
80 INPUT TEST(I)
90 NEXT I
100 PRINT "Downloading dummy value. Press the reset button on the Digilyzer"
110 PRINT "to begin test procedure."
120 LPRINT CHR$(0)
130 FOR I=0 TO N-1
140 LPRINT CHR$(TEST(I))
150 NEXT I
160 IF AUTS="Y" OR AUTS="y" GOTO 100
170 PRINT "The procedure has ended. To repeat the procedure press Y:"
180 ANSS=INPUT$(1)
190 IF ANSS="Y" OR ANSS="y" GOTO 100
200 END
```
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.
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.
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 x 3½ inches with 0.42-inch holes in a 0.1 x 0.1-inch grid. The dimensions of the circuit board were determined by the inside dimensions of the construction case: 4¾ x 2½ x 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 Vcc 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.
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 T1 1/4 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 yellow 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.

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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

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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.
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 tangentially across the nylon pawl rotates the hollow shaft at extremely high speeds.](image)

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 communications 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 (S2) 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 headend 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-non-sense FM-SSL-75 antenna with 12 decibels of gain. Considering that

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**NEW FROM DON LANCASTER**

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<td>PostScript Show &amp; Tell</td>
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<td>22.50</td>
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<tr>
<td>Undst FS Prgmm (Holtgang)</td>
<td>29.50</td>
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<td>The Whole Works (all PostScript)</td>
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**SYNERGETICS**

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

![Diagram of supply system with diagrams of accumulator, 60 PSI main regulator, flow restrictor set to 30 PSI or to your desired no-load speed, working pressure gauge, compressor, and handpiece or air turbine.](https://www.americanradiohistory.com)
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 re-manufacture. Serious inquiries only, please. Your BMW will be required as a deposit.

The **IC Master** is a complete di-
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 homebrew 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 lavishly 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

---

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

---

**OBSELETE 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) 544-4539

- **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 Unobtainium**
  - 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
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

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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.

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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.

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.

![FIG. 22—FOUR BASIC SWITCHING functions organized on a CD4066: SPST (a), SPDT (b), DPST (a), and DPDT (a).](image-url)
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<tr>
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<th>Capacitance Voltage</th>
<th>Price</th>
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<td>22pf 50V</td>
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<tr>
<td>15341</td>
<td>100pf 50V</td>
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</tr>
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<td>15190</td>
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Ceramic Disc (± 20%) Part No. Capacitance Voltage Price

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<td>26895</td>
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<td>26999</td>
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<tr>
<td>27001</td>
<td>1uf 1000V</td>
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Dipped Tantalum (± 10%) Part No. Capacitance Voltage Price

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<tr>
<td>33889</td>
<td>10uf 35V</td>
<td>$5.19</td>
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<th>Ohms</th>
<th>Price</th>
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<tr>
<td>42964</td>
<td>63K</td>
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<td>43086</td>
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4/4 Rectangular 15-Turn Cermet

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<th>Part No.</th>
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Microprocessor Crystals (HC49U)

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TTL Crystal Clock Oscillators (5415H)

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<td>27991</td>
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</tr>
<tr>
<td>27807</td>
<td>1.0H</td>
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<td>Single 5V/3A</td>
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10 HUB DRIVE, MELVILLE, NY 11747
RE-ENGINEERED & DESIGNED FOR 1994

150 LE - Student  200 LE - Technician  400 LE - Engineer

Standard Features - AC/DC Voltmeters, DC Current, Resistance, Continuity Test, Diode Test, Capacitance Test, Transistor Test, DC Temperature Test, Kelvin Probe, LCD 10M ohm Input Test

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$29.95

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$49.95

Designed to meet IEC-345 & UL-1244 safety specifications

2 Year Warranty  (Parts & Labor)

"Not only does the Kelvin 94 boast allot of features ... the features go the extra distance."

"If we had to run into a burning building to do some emergency trouble-shooting and could carry in only one piece of equipment, the Kelvin 94 would be it!"

Popular Electronics Reviewed - May 1993

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LCR Hz dbm True RMS Logic Probe

The only meter with 0.1% Accuracy on DC Voltages, built-in True RMS, Freq Counter to 20MHz Res. 10 kHz, LCR-Inductance Test Res: 10 µH, DC/AC Voltages Meter Res: 0.1 ohms

TRUE RMS PLUS

Model 94  $199.95
Model 95  $990.11

$199.95  *See Standard Features Listed below

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Model 95  #990122

$199.95  A Must For Auto Mechanics

- Standard Features - Models 94 & 95
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- DC/AC CURRENT
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- DATA HOLD
- RELATIVE MODE
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- DIODE TEST
- MAXIMUM AVERAGE MEMORY RECORD
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Established 1945
M/C & VISA  *20 Minimum Order
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Laptop Digital Trainer comes with 100 page instruction manual, power supply, built-in digital tracemaker display, two independent channels, user adjustable freq & duty cycles, 4 data bit switches and 4 LEDs displays. Assembled by No. 860460

BINARY QUARTZ CLOCK

Digital & Alarm

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Dual Trace 2-Yr Warranty Parts & Labor
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40 MHz SCOPE
2 Yr. Warranty
Stock No. 740066  $655

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SCOPE PROBES
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1.5V DC 5.55 ea 250 ea

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BREADBOARDS

TRIGGER COIL

60 Last Order

INFRARED LED

Photo Cell

MINIATURE MOMENTARY SWITCH

CIRCLE 178 ON FREE INFORMATION CARD
DC-2000 MHz

AMPLIFIERS

In plastic and ceramic packages, for low-cost solutions to dozens of application requirements, select Mini-Circuits' flatpack or surface-mount monolithic amplifiers. For example, cascade three MAR-2 monolithic amplifiers and end up with a 25dB gain, 0.3 to 2000MHz amplifier for less than $4.50. Design values and circuit board layout available on request.

It's just as easy to create an amplifier that meets other specific needs, whether it be low noise, high gain, or medium power. Select from Mini-Circuits' wide assortment of models (see Chart), sketch a simple interconnect layout, and the design is done. Each model is characterized with S parameter data included in our 740-page RF/IF Designers' Handbook.

All Mini-Circuits' amplifiers feature tight unit-to-unit repeatability, high reliability, a one-year guarantee, tape and reel packaging, off-the-shelf availability, with prices starting at 99 cents.

Mini-Circuits' monolithic amplifiers...for innovative do-it-yourself problem solvers.

---

**Notes:**
- Frequency range DC-1500MHz
- Gain 1/2 dB less than shown

**Typical Circuit Arrangement:**
depending on supplies.

---

**Designers' kit, KH-1 available only $59.95 Includes:**
- 40 AMPLIFIERS* 10 MAR-1, 10 MAR-3, 10 MAR-4, 10 MAR-8
- 150 CAPACITORS* 50 1.00pf, 50 1.00ppf, 50 10.00ppf

**740 page RF/IF DESIGNERS HANDBOOK**
- MIXERS, POWER SPLITTERS, COMBINERS, AMPLIFIERS, ELECTRONIC ATTENUATORS
- IQ/DPSK MODULATORS, ATTENUATORS, TERMINATIONS, DIRECTIONAL COUPLERS
- RF TRANSFORMERS, DIGITAL ATTENUATORS, PHASE DETECTORS, SWITCHES/DRIVERS
- FILTERS, LIMITERS, FREQUENCY DOUBLERS

*values or models may be substituted without notice, depending on supplies.

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**99¢** Unit price ($25 qty)

<table>
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<th>Type</th>
<th>MAR-1</th>
<th>MAR-2</th>
<th>MAR-3</th>
<th>MAR-4</th>
<th>MAR-6</th>
<th>MAR-7</th>
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<td>1.34</td>
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<td><strong>VAM-7</strong></td>
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</tbody>
</table>

**PLASTIC SURFACE-MOUNT**
- Suffix SM to model no. (ex. MAR-1SM)
- Ceramic surface-mount
- Plastic flat-pack

**Output Pwr. +dBm**
- 1.45
- 1.29
- 1.75
- MAV-1
- MAV-2
- MAV-3
- MAV-4
- MAV-5
- MAV-6
- MAV-7
- MAV-8

**Gain, dB**
- 18.5
- 12.5
- MAV-1
- MAV-2
- MAV-3
- MAV-4
- MAV-5
- MAV-6
- MAV-7
- MAV-8

**NF, dB**
- 1.5
- MAV-1
- MAV-2
- MAV-3
- MAV-4
- MAV-5
- MAV-6
- MAV-7
- MAV-8

**Unit price**
- $ (25 qty)