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Vol. 64 No. 10

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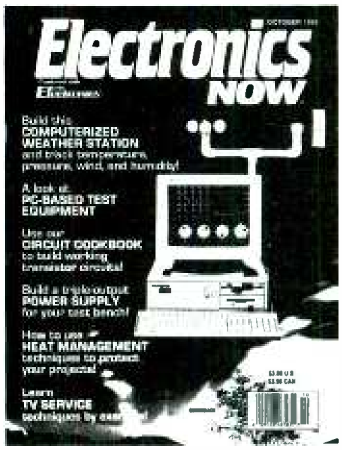
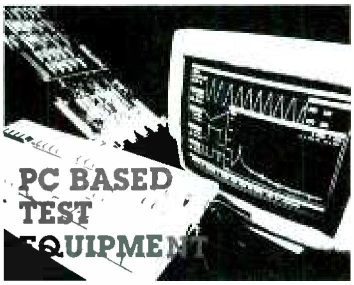


As we wrap up this issue, the Mississippi River continues to flood several midwestern states in a deluge that's already been recognized as the largest disaster ever to hit this country. While the thunderstorms barrage the middle of the country, here on the east coast we're sweating out a record-breaking heatwave and there's no rain in sight. Weather is a fascinating subject even under less extreme conditions. This month's cover story is a computerized meteorological station that uses the Experimenter, which appeared in the July and August issues, to link weather instruments to your computer. The station can be used to accurately measure and display weather conditions and, with a professional version of the software, to recall and graphically chart minute-by-minute information for future analyses and, we hope, accurate predictions. The story begins on page 31.



PC BASED TEST EQUIPMENT

Boards that plug into computers are attractive alternatives to conventional instruments for many test and measurement applications

T.J. BYERS

PAGE 39

HEAT Management Techniques

Proper heat management ensures that components have a long and healthy life.

PAGE 62

TV Service Case History

Learn about TV service from this step-by-step description of the repair of a faulty receiver.

PAGE 44

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WHAT'S NEWS

A review of the latest happenings in electronics.

Ultra-high-density disks

Scientists at IBM's Almaden Research Center in San Jose, CA have demonstrated a blue-laser optical recording system that can read and write data at a record-breaking density of 2.5 billion bits (gigabits) per square inch on a removable magneto-optical disk.

According to IBM, its technique depends on a blue-laser device and extensions of current technologies to achieve a density five times higher than that available in today's most sophisticated rewritable optical disk drives based on infrared lasers.

The blue laser has a higher frequency than infrared light, so it can be focused to a smaller spot, allowing more data bits to be written within the same area. At the new density, a standard 5¼-inch disk could hold 6.5 gigabytes of data—the equivalent of 6500 250-page printed books.

In the demonstration, IBM scientists wrote a pattern of data bits onto a rotating glass disk coated with a film of magneto-optic material optimized for use with blue light. The solid-state blue-laser device converts the infrared light output of an aluminum-gallium-arsenide (AlGaAs) diode laser into blue light by passing it through a frequency-doubler.

The scientists then read back the pattern at a rate of 2 million bits per second with the same accuracy, and the same relatively low power consumption of existing infrared lasers. High-density edge data-encoding and advanced sampled servo tracking positioned the laser's read/write head over the correct data tracks on the grooveless, low-noise disks.

The device demonstrated was about the size of a VHS videotape cassette. IBM says it will probably find its first application in optical-disk based database "jukeboxes" in banks, insurance companies, and hospitals for the storage of large amounts of data.

IBM SCIENTIST Dr. William J. Kozlovsky demonstrates a blue-laser that writes and reads data on a removable magneto-optical disk at a world-record density of 2.5 gigabits per square inch.

The IBM team plans to miniaturize the blue-laser device so it will fit inside a personal computer. It hopes to make high-data disks available within five years at a cost comparable to today's rewritable optical discs—between $50 and $100.

Quantum leap?

Bellcore (Red Bank, NJ) physicist Dr. Mark Johnson has invented and successfully tested a device that might lead to the production of circuits with 0.01-micron wide elements, compared with today's one-micron wide standard. According to Bellcore, the device could pack trillions of transistors onto a single, powerful computer chip.

Dr. Johnson's "spin transistor" device is based on a facet of quantum mechanics previously untapped by electronics researchers: electron spin. In normal electric current, electrons spin in a random mix of quantum states, called simply up and down. The spin transistor orders the movements of the electrons in a process similar to the polarization of light, into all up or all down states. That creates the "off" and "on" states that are fundamental to digital electronics.

Although only a prototype device has been constructed, even at this early stage it has demonstrated two properties that are particularly exciting: The smaller its size, the better it works, and it is made of from highly conductive metals. In theory, at least, metal spin transistors can be miniaturized to micron sizes and still produce strong signals.

The basic spin transistor device is a "sandwich" of thin gold film between two magnetic strips. An electric current causes polarized electrons to move from the first strip into the gold film. They exit through the second magnetic strip—turning the circuit "on" in the process.

The electron and the second magnetic strip must have the same polarity. Dr. Johnson says it is easy to change the polarity of the second strip by generating a weak magnetic field in it with a nearby wire. The condition for for conduction is that the electron spins must be either all "up" or all "down." Because the polarity of the second magnetic strip is "remembered" even after the current is turned off, the sandwich has a "memory."

Bellcore believes that devices made up of arrays of spin transistors could store information without electric power consumption. Moreover, it says future research could lead to logic processors made up of arrays of spin transistors.

Cryogenic conditions are needed for a superconducting magnet to create precise magnetic fields. The present operating temperatures are −298° and lower. Nevertheless, Dr. Johnson expects to create spin transistors that operate at room temperature. Ω

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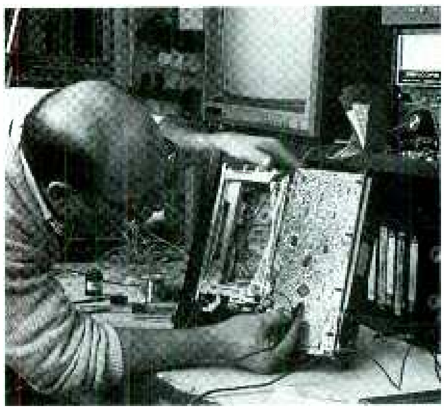

VCR Technician

VCR Repair

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If you have used a computer or are interested in how computers work you've probably got what it takes to become a computer repair specialist. This field continues to grow as personal computers are being used in almost every office and many homes.

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VIDEO NEWS

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

DAVID LACHENBRUCH

Digital VCR standards.

The next VCR you own might use ¼-inch tape and record and play back digitally—giving you an option of recording and playing back standard TV or virtually any digital high-definition system. A group of 10 major VCR manufacturers—eight Japanese companies and Philips and Thomson—has called a conference to consider consumer video-recording standards for the digital age.

Based on work already done by many manufacturers, the group defined some "basic specifications" as groundwork for the standards-defining effort. It envisions a system compatible with the existing NTSC, PAL, or SECAM standards and one that it hopes will accommodate any or all of the world's digital HDTV standards. The recording medium would be ¼-inch metal evaporated tape or equivalent in cassettes of two sizes. The smaller cassette, about half the size of an 8mm cassette, would record for one hour in NTSC or PAL and 30 minutes in HDTV, presumably for camcorders. The larger cassette—half the size of a VHS cassette—would record for 4½ hours in current formats and just half that in HDTV.

The system would use digital recording for video, with revolving heads similar to existing VCRs. Audio recording would use pulse-code modulation (PCM) for two- or four-channel sound. When there is agreement on the specifications, they will be submitted to the International Electrotechnical Commission (IEC) for designation as a worldwide standard.

The proposal assumes that any digital HDTV recording system will use magnetic tape, as does today's consumer system. However, with the development of magneto-optical disc recording for Mini Discs, there is bound to be increasing agitation to make the next consumer video-recording system a disc-based product.

"Video CD."

Another proposed standard—this one much closer to reality—has been endorsed by 10 companies, including Sony, Matsushita, Philips, and JVC. This is for full-motion video on standard compact discs. The "Video CD" format, developed by Philips and JVC, and already in use by JVC and Sony in Japan for karaoke, makes possible up to 73 minutes of digital video and audio on a single five-inch disc.

Discs made for the system are non-recordable and linear—that is, they are designed to play straight through, without interactivity. They would be compatible with such existing systems as Philips' CD-I and computers with CD-ROM drives and decoders for MPEG (Moving Picture Experts Group) compression protocol, as well as modified audio CD players and specially designed CD Video movie players.

Britain's Nimbus Engineering & Technology, which already has demonstrated a system it also calls "Video CD" that can be played back on a standard CD player connected to a TV set through a special adapter, protested that the new system would turn off consumers that are already suffering from "format fatigue."

Nimbus said that its own system would work with "tens of millions of CD players worldwide and a decoder which would cost under $200," as opposed to the new system, which it said would require expensive modification of audio CDs for compatibility. Nimbus said that the two "Video CD" systems were similar except for one major difference. Both discs are essentially CD-ROM data discs. All current data discs contain a digital flag in their table of contents to mute their output when played on a standard audio CD. The multi-company system retains this flag but requires a modification in audio CD players to tell them to ignore the flag.

IBM in video games.

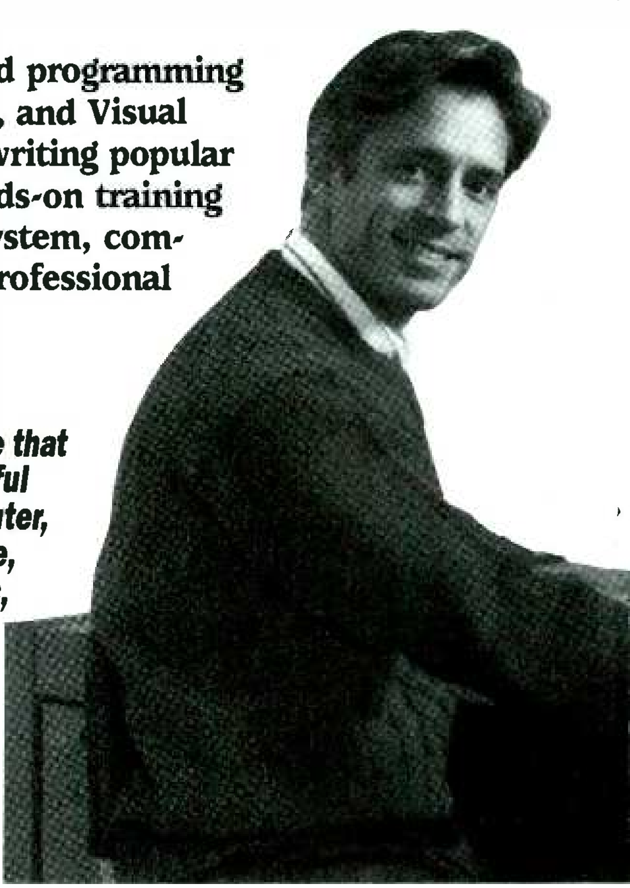
A new home video-game system designed to compete with Nintendo and Sega, as well as the sophisticated new 3DO standard, has been announced by game veteran Atari, which has signed a contract with IBM to manufacture it on a custom basis. The Atari Jaguar system—proudly announced as all American-made—uses a 64-bit RISC processor with 24-bit true-color graphics "manipulated in a real-time world," according to Atari. A 32-bit expansion port is to be designed for future connection to cable and telephone networks. It will also play audio CDs, CD Plus Graphics, and Photo CD discs. The game's audio will use 16-bit stereo to permit realistic sound effects as well as human voices. All this is promised for sale starting this fall or winter at a suggested list price of $200, as opposed to the $700 price tag on the first 3DO game consoles, made by Panasonic.

Apple's TV guide.

Add another entry to the burgeoning list of on-screen TV program guides for the 500-channel age: Apple Computer. As pointed out here last month, the field is already getting crowded with systems called StarSight, Trakker, Prevue Networks, Your Choice TV, and TV Guide On Screen.

Apple's system, called "eztv," is designed to be built into the converter supplied by cable systems and to use a special handheld remote control. The viewer would be able to scroll through program listings, which could be arranged by type of program and by various subcategories. The system would also permit previewing of pay-per-view programs, instant tele-shopping, and one-button VCR taping. In addition, it could eventually provide on-screen data on demand—such as baseball statistics during a live game. Ω

Learn computer programming computer system, Windows



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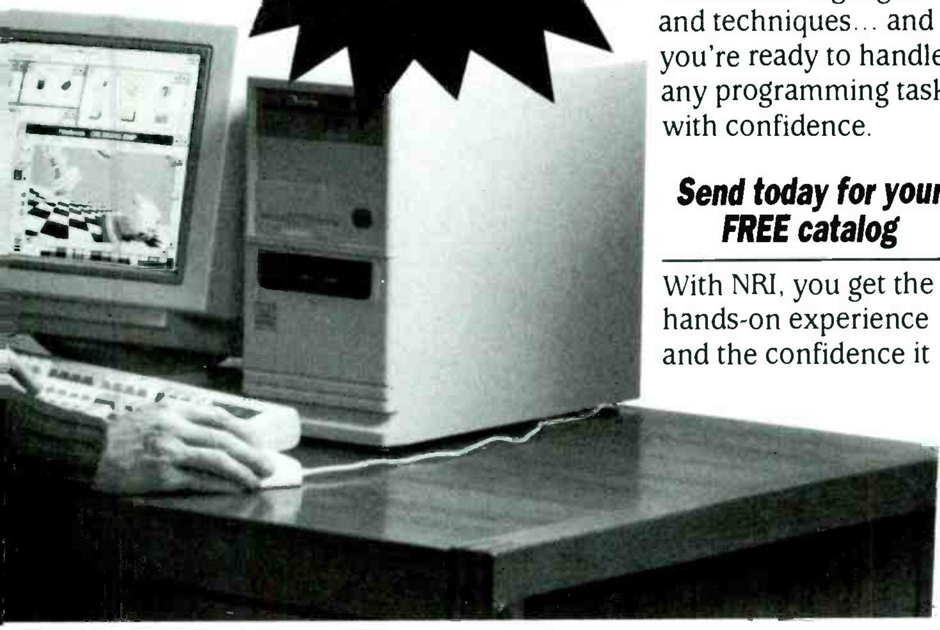

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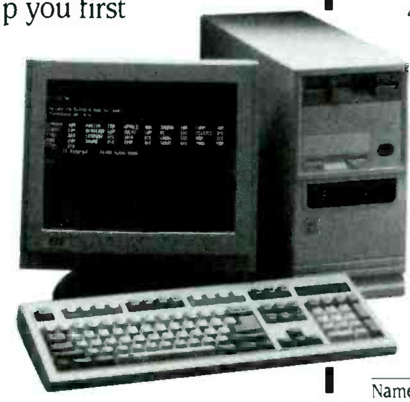

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Q & A

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MUTING CIRCUIT

I would like to build the Phone-Activated Audio Muting Circuit that was published in the January 1990 issues of *Radio Electronics*, page 43. I can't seem to contact the kit supplier for that project, and there's a discrepancy between the parts list and the schematic as to the correct part number for IC2. Can you help me out?—C.I. Mendes, Lakeland, FL

The beauty of a magazine like this one is that the projects can usually be built years after publication—unless, of course, printed mistakes prevent people from doing so. The correct part number for IC2, is an LM393, which is a dual voltage comparator made by National Semiconductor. Also note that the labels for pins 2 and 3 of IC2-a should be transposed in Fig. 1, and a connection dot should exist between R5, R6, and the line going to pin 8 of IC2-b (see Fig. 2). One last item; RY1 is a 12-volt relay, and not 5 volts as indicated in the parts list.

AUDIO MIXER

I'd like to be able to mix several audio signals together and have them at a single output. Because some of the inputs will be microphone-level and some will be line-level, I can't do the job with just a handful of resistors. Can you help me?—B. Weinberg, Mapleshade, NJ

What you're really trying to do is build an audio mixer. Those circuits have been around ever since the invention of the vacuum tube.

There's no end to the designs that will do the job you want done, but the circuit in Fig. 1 is one of the easiest to build and the most reliable. All you need is one IC and a handful of parts to mix a variety of audio signals. I've designed the circuit around an LM3900 quad op-amp, but there's no reason why you can't use a different chip—the basic circuit would still be the same. The LM3900 uses a single-sided power supply and it's inexpensive.

I've laid out the circuit to have two microphone and two line inputs, but you can change it around any way you want. The whole thing can be put together with wire wrap or you can design a printed circuit board.

The circuit is really handy to keep around so, if there's any chance that you'll ever want more than one of these things, I'd think it would be well worth the time to do a printed-circuit board.

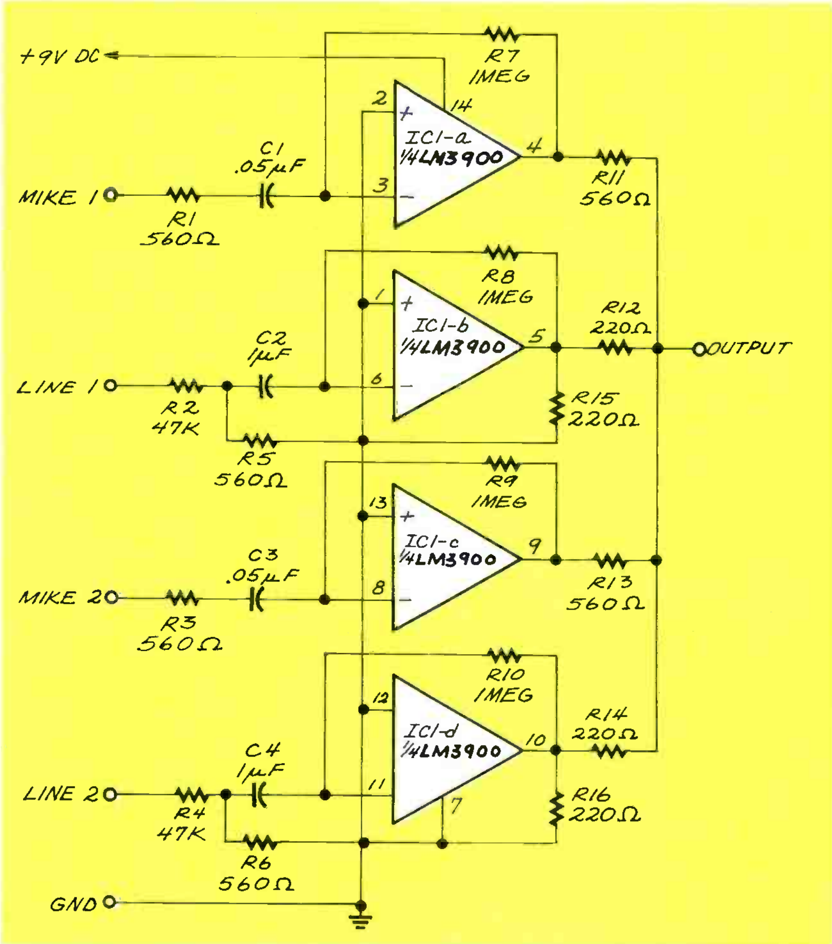

FIG. 1—THIS AUDIO MIXER is designed around an LM3900 quad op-amp.

SKIPPING CD PLAYER

I have a CD player that skips regardless of how well I clean the discs. I suspect that the problem is caused by interference that is generated by my computer, which is on the same AC line. Can you suggest a filter that would help?—G. Elder, Panama City, FL

It's unlikely that the skipping or mistracking problem is a result of RF interference from your computer. The leading cause of CD mistracking is dirty discs. But apparently you've ruled out that possibility. A dirty lens in the laser receiver can also cause tracking problems. Laser lens cleaners for CD players are available from hi-fi shops and some music stores. Since a cleaner is not expensive (under $20), trying one is a logical next step.

If a dirty lens is not causing the mistracking, solving the problem is going to be more complex and more expensive. Before you can stop the mistracking, you must understand how a correctly functioning CD player maintains tracking.

A single laser beam is split into three beams by a diffraction grating or beam splitter. The middle beam reads the data from the transition between the pits and flats on the disc. The two outside beams follow the blank areas between the data track being read and the two adjacent tracks. If an outside beam hits some pits, a photodiode array detects the strike, and a tracking-error signal is generated by a differential amplifier. The error signal is then fed to tracking actuator coils, which move the head in one direction or the other to restore proper tracking of the disc.

A tracking problem can also be caused by a weak laser—a solid-state CD laser does not have an unlimited lifespan—or a malfunctioning photodiode in the sensor array. Actuator coils can also cause mistracking if they burn out.

Another common cause of tracking problems is the spindle motor that turns the disc. A little dirt can cause the bearings to wear prematurely. That causes the disc to wobble as it spins. The actuator coils can't keep up with the wobble, and the disc skips. Unfortunately, replacing the motor is time-consuming and expensive. If you do not have experience servicing CD players, don't attempt any repair other than cleaning. Even before doing that, however, it is recommended that you obtain instructions on how to service your CD player from its manufacturer.

MONITOR REPLACEMENT

I use a computerized engraving machine that has a monochrome composite-video monitor. The monitor has bitten the dust, and I'd like to convert the system so I can use a TTL monitor. Is there any converter on the market that will accept NTSC video at the input and give me TTL video at the output?—E. Wandasiewicz, Wilkes-Barre, PA

The answer to your question is probably yes, but I don't think it makes a lot of sense economically. You can buy a replacement NTSC monitor for about fifty bucks from many of the suppliers who advertise in this magazine. They're still used for some computers such as the current Apple II series. (Apple monitors are expensive, but there are lots of other models around as well.) A bit of library research on your part will give you the names of companies that have NTSC monitors in stock.

As an alternative, you can probably feed any video input with the output from your engraver. That includes the video inputs on the back of TV's and VCR's. And while we're talking about the consumer market, I'll bet that you can get a small black-and-white TV for next to nothing—certainly less than what a converter will cost. Ω

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

EVOLVING JOB REQUIREMENTS

In his *Computer Connections* column about a bit meter in every basement (**Electronics Now**, July 1993), Jeff Holtzman said that many jobs will be eliminated by automation, and that most new future jobs will be related to computer programming or software.

Unfortunately, my own experience seems to bear out Holtzman's dire prediction. Trained as a hardware-oriented electronics technician, I find my future in electronics clouded by the trend toward disposable circuits and the increasing emphasis on a working knowledge of computers and programming—skills that I lack.

After obtaining a two-year Associate's Certificate in electronics in 1974, I found work as a technician for a U.S. Department of Energy research laboratory. My duties included building, testing, and maintaining electronics at the circuit-board level. I earned a good reputation there, and learned a lot that helped me in my career.

However, I was laid off in 1985 due to Federal budget cutbacks. The best job I could get near home (the south suburbs of Chicago) was in a two-way radio repair shop. Here at work, I see products becoming more microprocessor- and software-dependent. Moreover, modern fabrication methods such as surface-mount technology make it almost impossible to repair many faulty circuits economically. Typically they become disposable modules that are just thrown away.

My employer is finding ways to cut the technical staff. He is putting increasing emphasis on reducing the time spent making repairs, and is making employees account for that time. Those circuit boards that can be economically repaired will probably soon be sent to a central depot.

The DOE lab where I worked obtained more funds, and its activity has picked up, so I sought re-employment. However, my former group leaders told me that the work I did is no longer being done. Although I have written several small assembly-language programs, this experience is not enough to qualify me as a full-time programmer. I have been told that most of those jobs require a master's degree, or at least a bachelor's degree.

No doubt that qualification requirement is due, in part, to an oversupply of skilled persons even in that field. Apparently those with the highest level of computer training are being hired first. However, the last data I saw indicated that less than 30% of the adult U.S. population has any college degree—and most of those degrees were not in technology.

As I see it, the prosperity of the United States has been built upon opportunity and the availability of jobs. In the past, nearly everyone willing to work could earn a comfortable standard of living. I can understand that technological change will alter the available jobs and the qualifications necessary to hold them, but the trend is out of control.

In my view, that accelerating rate of change should be slowed somehow to permit displaced personnel to be retrained. In that way the economy can reabsorb them in meaningful jobs. Government, business, labor unions, and the general public must be willing to forsake immediate economic gains to assure long-term economic stability for all of the people.

At the present time, too many educated and trained people willing to work are just being cast off as excess labor or forced into early retirement. If that trend continues, the U.S. will become another third-world country where an elitist class will own and run almost everything.

I fear that the majority of the population will be relegated to jobs that cannot be turned over to computers (such as driving taxis or mowing lawns), or will just become burdens on the government. If this trend is allowed to continue, there will be rebellion by those who have been pushed aside by technological change. They will become desperate and fight to regain what they once had.

MICHAEL KILEY
Crestwood, IL

PARITY-CHECKING PRIMER

The answer to H. Bansh's question about parity checking (*Q&A*, **Electronics Now**, July 1993) caused my blood to boil. Rarely have I seen a better example of misinformation used to cover up an author's ignorance of a subject.

Let me start with the comment "... and the BIOS decides that everything you've been doing for the last couple of hours should be lost." For the *Q&A* columnist's information (obviously needed), parity check is done at *every* memory-read cycle, and processing stops *instantly* with the parity message (provided by BIOS) on the screen. Thus there can be no "couple of hours" lost work!

Allow me to enlighten the *Q&A* author on the benefits of parity checking:

First, to give credit where due, some form of parity checking has been incorporated in IBM equipment since it introduced punched-card acounting machines years ago. IBM's equipment at that time was almost fanatically over-designed to prevent undetected digital errors.

IBM knew it was not possible to prevent errors, so it designed parity circuits that would stop the equipment *instantly* if a digital error were detected. That instant stop prevented an error from being compounded. The reason was obvious. Any industry or business engaged in large-scale "number crunching" involving billions of dollars or a threat to public safety can't afford the consequences of incorrect data. The consequences range from law suits to bankruptcy!

Bank failure or the financial ruin of thousands of customers is one thing; the failure of a bridge or the crash of an aircraft causing death and injury that is due to faulty design is another. Arithmetic errors, unchecked, can lead to disaster.

I'm appalled by the sentence, "All it takes is one error to make the entire computer lock up." Isn't it obvious to *Q&A* that if you're running data for any critical numerical application, that's *exactly* what you want? There's no way to distinguish between one-time glitches and either unreliable or previously reliable "bit-cell" failure.

Q&A's response made it seem as if one error is trivial, and nothing that trivial should be allowed to interfere with ongoing computer operation. If your computer is generating memory bit errors—even one—you ought to be aware of it!

Continued on page 25

Micro Scope V5.0 Diagnostic Software

A helping hand for PC service technicians

CIRCLE 14 ON FREE INFORMATION CARD

Anyone who is responsible for maintaining or repairing IBM-standard personal computers will want to have the latest release of Micro Scope PC diagnostic software from Micro 2000, Inc. (1100 East Broadway, Suite 301, Glendale, CA 91205; 818-547-0397).

Unlike most diagnostic software, Micro Scope works independently of the PC's operating system; the disk on which the diagnostic software is distributed contains its own operating system, called Microdos.

There are some important advantages to Micro Scope's DOS-independence. For example, its memory-test routine can access more base memory than would be possible with a disgnostic program running under MS-DOS. Another advantage is Micro Scope's ability to access the boot sector on a hard disk drive, which is also unavailable under MS-DOS. That makes it possible to restore a disk that has been made unbootable by a computer virus. (It won't guarantee success but, because 90% of viruses hide in the boot loader program, the chances of recovery are pretty good.) Partition tables, which tell the operating system how a disk drive is segmented, can also be restored with the help of Micro Scope.

The Micro Scope program is supplied with two serial loopback plugs (one 9-pin and one 25-pin) and one parallel loopback plug that are required for some tests. An informative 178-page technical manual is also provided. The program is supplied on both 5¼ and 3½-inch floppy disks.

Micro Scope can be run under MS-DOS, and there are some instances where that is desirable. (Troubleshooting a floppy drive with boot-up problems, for example.) For full functionality, however, the program should be loaded from the self-booting disk. Once the Microdos operating system has been loaded, a menu provides two options: load base memory tests or load diagnostics

The base memory tests take up only two kilobytes of base memory, allowing all other base memory to be tested. (Because virtually any error in the first 2 kilobytes of base memory would make a PC unbootable, the test, in effect, verifies that all of the base memory is functioning.) Choosing to load the full diagnostic program brings up the program's main menu, which presents five options: System Information, Batch Menu, Diagnostics, Utilities, and Quit or reboot.

System information

The System Information menu calls up a five-entry submenu that provides access to information about the motherboard, plug-in adapters, interrupt (IRQ) assignments, network adapters, and more. The computer system's configuration is determined from information gathered by Micro Scope from the computer's CMOS memory, power-on self test (POST), and proprietary routines. The information presented on-screen includes the computer's system type (e.g., AT, XT), the revision date of the BIOS (basic input/output system), CPU type, detected hardware (floppy and hard drives, video adapters, I/O ports, base memory, extended memory, video memory, and more), and the CMOS memory settings. Any conflicts between the contents of the CMOS memory and what Micro Scope detects are flagged with an asterisk.

Micro Scope can also search for adapter cards that contain an active ROM BIOS. (Many plug-in cards, including network adapters and video cards, contain programs that serve as extensions to the computer's main BIOS.) Micro Scope can identify the starting and ending addresses of the BIOS extensions so that addressing conflicts—one common frustration encountered when new cards are installed—can be identified.

The status (disabled, enabled, or active) of IRQ or interrupt assignments can be displayed, along with their associated I/O ports, devices, and interrupt vectors. Interrupt conflicts, which can be diagnosed with the help of Micro Scope, are another common problem encountered when new hardware and software is installed in a system.

The physical-partition table of the computer's hard-disk can be studied. The partition table and volume-boot sector can also be edited—or corrected to restore a virus-infected or damaged disk. By studying the partition table, the properties of the drive installed in the computer can be identified; the number of heads,

Continued on page 94

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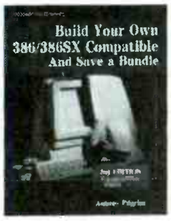

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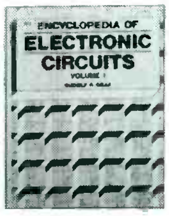

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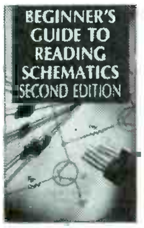

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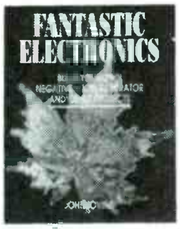

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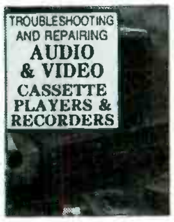

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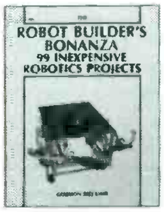

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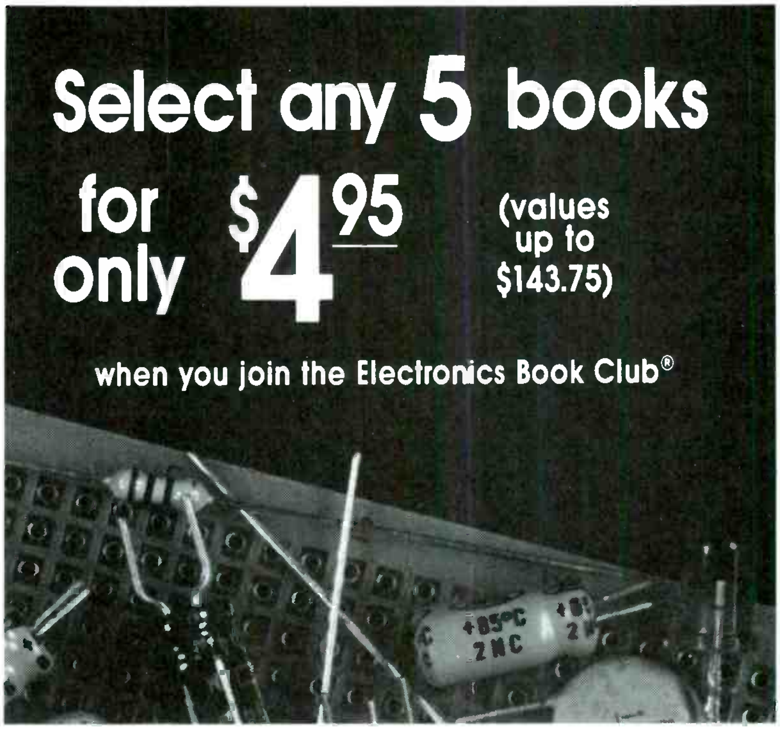

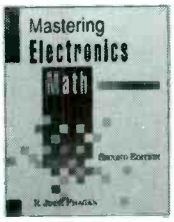

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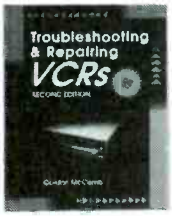

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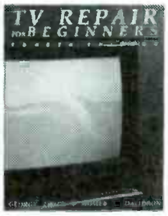

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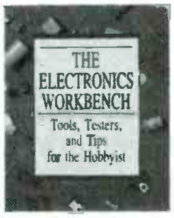

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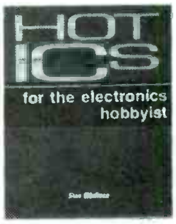

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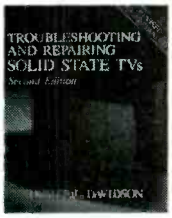

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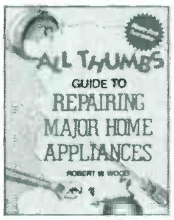

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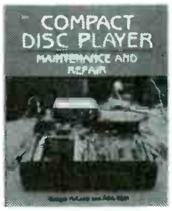

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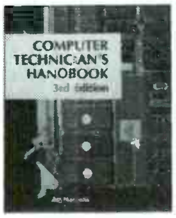

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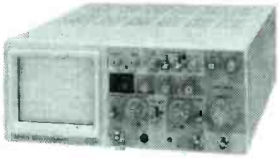

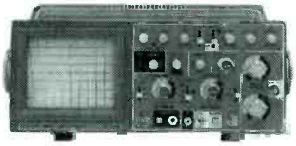

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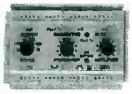

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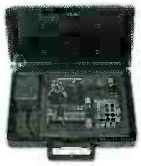

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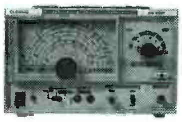

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MULTISTANDARD TV SIGNAL GENERATOR. The *Fluke* and *Philips*, *PM 5418 Video Pattern Generator* is said to be able to produce all the signals needed for testing TV sets, VCRs and computer monitors. These include more than 100 test patterns that meet the NTSC, PAL, and SECAM video standards

The signal generator offers both caption and text modes in either of two operating channels. The closed-caption information is present in line 21 of the NTSC video signal.

The *PM 5418* generates high-precision signals for geometry alignment, 16:9 and 4:3 aspect ratio patterns, and special patterns for VCR and 100-Hz improved definition TV (IDTV) testing. Mono, stereo, and NICAM sound test signal are also available.

CIRCLE 16 ON FREE INFORMATION CARD

In addition, the instrument contains test configurations for Teletext TOP/FLOF, VPT and Antiope test signals, programmable PDC (program delivery control), VPS and closed-caption test signals. The *IEEE-488 programmable PM 5418* offers full radio-frequency coverage from 32 to 900 MHz with internal/external modulation, RGB, Y/C (S-VHS/Hi-8), CVBS and audio outputs.

Prices for the *PM 5410* family of TV signal generators begin at $2200.

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MEMORY-EXPANDABLE GRAPHIC CALCULATOR. *Hewlett-Packard* has introduced two new graphics calculators, the *HP 48GX* and the *HP 84G*.

The *HP 48G* offers expandable memory, graphics, calculation, and computer programming capabilities. It can perform 3-D plotting, a feature HP says has never before been available in any handheld calculator.

CIRCLE 18 ON FREE INFORMATION CARD

The *HP 48GX* includes 128 kilobytes of RAM, and it accepts plug-in cards that contain extra memory or programs to extend its basic functions. The calculator includes a serial interface for connecting it to IBM-compatible or Macintosh personal computers with two-way infrared links. Its graphics are integrated with calculus functions, symbolic-math functions, and built-in libraries of engineering equations and engineering constants.

Two expansion slots permit the addition of up to 4 megabytes of programs or memory. Enhanced graphics include a form-driven user-interface, shading, 3-

HANDHELD TEST BENCH METERS. *B+K Precision* is offering two new digital multimeters: the *Models 390* and *391*.

The *Model 390* is a 4000-count, 3¾-digit DMM offering 0.01% DC voltage accuracy. It has a 42-segment analog bargraph display. Up to 40-ampere AC and DC current and resistance up to 40 megohms can be measured. Five capacitance ranges extend to 40 microfarads. The DMM can count frequency to 500 kHz, and it can measure temperature from −50°C to +1300°C, ±2°C. The *Model 390* offers relative mode, data-hold memory, min/max average, and auto or manual ranging.

The *Model 391* has a full 4½-digit, 20,000-count liquid-crystal display. Up to 20-ampere DC and AC current can be measured. It can count frequencies to 200 KHz. This DMM can indicate logic state (1 or 0) in TTL voltage-level digital circuits. It also has data-hold and a duty-cycle measurement capability.

CIRCLE 17 ON FREE INFORMATION CARD

Both models can test diodes and have audible continuity beepers. Both DMMs are overload protected and fused on both the microampere/milliampere and 20-ampere current ranges. The DMMs are covered by three-year warranties and are enclosed in drop-resistant cases with impact-absorbing rubber boots. *Model 390* is priced at $159 and *Model 391* is $179.

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Phone: 312-889-1448
Fax: 312-794-9740

D plots, trace, and simultaneous plots. Optional fill-in-the-blanks input forms guide the user through applications. Dialog boxes provide access to calculator functions, and a stack-based interface is available.

The *HP 48G* has 32 kilobytes of RAM and all the features of the *HP 48GX* except the expansion capability for those who don't require it.

The price of the *HP 48GX* is $350 and the price of the *HP 48G* is $164.

Hewlett-Packard Company
Inquiries Manager
1000 N.E. Circle Boulevard
Corvallis, OR 97330
Phone: 503-752-7736
(between 8 AM and 3 PM Pacific Daylight Time)

PC-BASED DEVELOPMENT SYSTEM. The *Micro Controller Tool (MCT)* PC-based development system from Electronic Product Design is IBM-compatible for designing the Signetics 87C751 and 87C752 single-chip microcontrollers into products.

The integrated, menu-driven *MCT* package includes a project manager, text editor, assembler, and programmer. The *MCT* software allows users to develop and produce products that include the 87C751 and 87C752. Program development is simplified with the included sample start-up programs.

An expandable library that includes 32-bit mathematics and serial communications routines is also included. A project-oriented main menu simplifies the design process.

The *MCT* development system is sold with a microcontroller handbook, operator's manual, software, and serial programming modules. Also included are an AC adaptor and RJ-11 to

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DB-25 connectors. The package price is $399. Optional accessories available from Electronic Product Design include prototyping kits, microcontrollers, and an ultraviolet EPROM eraser module.

Electronic Product Design Inc.
6963 Bluebelle Way
Springfield, OR 97478
Phone: 503-741-0778

PHOTODIODE AMPLIFIER. *Centronic's CA-100* photodiode amplifier, an alternative to a pico ammeter, amplifies low-level input signals to make them more distinguishable and readable by instruments.

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The amplifier converts the signal from Centronic detectors into a voltage that can directly drive oscilloscope deflection plates or other voltage-sensing instruments. It generates ±2 volts from eight gain settings ranging from 10^3 to 10^{10} volts per ampere with high-gain accuracy and low noise. The input can vary from 200 picoamperes full scale to 2 milliamperes in eight ranges.

In its normal current-meter mode, the *CA-100* displays the photocurrent directly on its front-panel display. The amplifier can also function in the optical-power mode. A calibration adjust knob sets the amplifier to a known optical power, and the liquid-crystal display presents the optical power reading directly.

The *CA-100* photodiode amplifier is priced at $675.

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

BENCH-TOP POWER SUPPLIES. *Kepco* is offering a line of 360-watt benchtop power supplies with communications capabilities. A serial two-wire communications port that complies with IEEE-1118 is provided for long-distance (300 meter) communication, and an optional built-in, single-board computer (SBC) provides a choice of IEEE-488-2 short-range parallel communications or RS-232C control.

The *MBT Series* of digital power supplies is available in eight output combinations. They range from 0 to 6 volts at 32 amperes for the *MBT 6-32MG* to 0 to 150 volts at 2.4 amps for the *MBT 150-2.4MG*

The stand-alone power supplies offer direct-entry keyboard control of voltage, current, and protective settings with slew up/down buttons for convenient incrementing. A pair of knobs controls optical encoders. A two-line, 16-character panel display shows menu selections, control settings, and output readings. These functions can be read back on any of the supply's external communications buses.

The *MBT Series* power supplies with the single-

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board computer are priced at $2499, and the supplies without the computer board are priced at $1899.

Kepco, Inc.
131-38 Sanford Avenue
Flushing, NY 11352
Phone: 718-461-7000
Fax: 718-767-1102

LED TESTER. The *LED-Tester Box* from *Lumex Opto/Components* is a compact, handheld instrument for testing, evaluating, and checking the quality of discrete light-emitting diodes.

The tester has individual sockets with fixed current levels of 2, 5, 20, and 30 milliamperes, and seven sockets rated for 10 milliamperes so that comparable LEDs can be compared for color and brightness. A single 9-volt transistor battery powers the pocket-sized, 3-ounce unit.

The *LED-Tester Box* is priced at $38, with a battery included.

Lumex Opto/Components Inc.
292 East Hellen Road
Palatine, IL 60067
Phone: 708-359-2790
Fax: 708-359-8904

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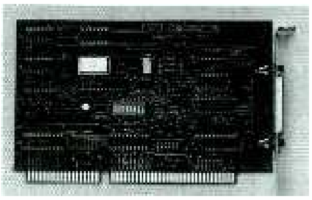
DATA ACQUISITION BOARD. *BSOFT Software* is offering a new *ANA201* eight-channel, 12-bit, programmable-gain data acquisition board. An on-board 8- or 16-bit data-mode jumper block permits the *ANA201* to plug into any half or full slot of an IBM PC/XT/AT or compatible computer.

Channel conversion speed is either 10 microseconds for the *ANA201* or 3 microseconds for the alternative *ANA201/A* version. It is intended for for digital signal processing, audio instrumentation, and telecommunications.



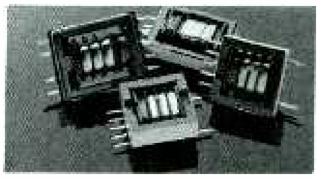
CIRCLE 23 ON FREE INFORMATION CARD

The *ANA201*, complete with a user's manual and a demonstration disk of programming examples, is priced at $129.

BSOFT Software, Inc.
444 Colton Road
Columbus, OH 43207
Phone: 614-491-0832
Fax: 614-497-9971

SURFACE-MOUNT TRANSFORMERS. *Associated Components Technology* is offering two new lightweight surface-mount transformers. The *CCFL16* and *EL16* transformers, in 28.55 × 17.5 × 8.5-mm packages, offer current-handling capabilities comparable to those of conventional board-mounted transformers.

The *CCFL16* has a rated output of 500 to 1500 volts peak-to peak with an input voltage of 3 to 20 volts. Its maximum power dissipation is 5 watts at 25 kHz. The transformer can operate at 20 to 40 kHz.



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The *EL16* has a rated output of 50 volts rms, with an input voltage of 3 to 20 volts. Its maximum power dissipation is 2.5 watts at 25 kHz, and its normal operating frequency is 1.5 kHz. It can be a component in DC-to-AC inverters for halogen lamp drivers.

Both transformers are said to be 85% efficient, 25 to 35% more efficient than conventional transformers.

In 5000 quantities, the *CCFL16* and *EL16* are priced at $3.15 each.

Associated Components Technology
11576 Trask Avenue
Garden Grove, CA 92643
Phone: 714-636-2645
Fax: 714-636-8276

CIRCLE 25 ON FREE INFORMATION CARD

DIGITAL AC LINE MONITOR. If you need a simple way to monitor AC line voltages, then consider the *Datel DMS-20PC-1-LM Digital AC Line Monitor.* The $45 device plugs into any AC outlet and can display from 85 to 264 VAC at 47–63 Hz on a 3-digit LED display.

DATEL, Inc.
11 Cabot Boulevard
Mansfield, MA 02048
508-339-3000 Ω

LETTERS

continued from page 15

What happens to "crude" parity errors? When data are stored in the memory bit-cells and/or in a memory that is read into a data register, only two abnormal things can happen: The data can "drop" a bit or it can "pick up" a bit. In other words, a zero can become a one (pickup), or a one can become a zero (drop).

First, set out the bits with values associated with the positions of each bit:

8 4 2 1
X X X X

Thus, a bit in a specific position as shown above gives the string of bits a value. For example, 4 is represented by binary as 0100 (the one bit is in the 4 position, the other bits are zero), 6 is binary 0110 (add another one bit in the 2 position), etc.

With this bit-value representation in mind, it can easily be seen that "dropping" or "picking up" bits can alter numbers.

In computers, parity checking is performed when the binary data is written *to* memory. The eight data bits are examined for either an *odd* or *even* number of one bits, and the parity bit is added to make the total nine bits *odd* or *even*.

In the *odd* scheme, for example, note how the check bit status (0/1) is determined. The numbers 0–9 are represented in hexadecimal as 30H – 39H. All numbers are represented by eight bits—twc groups of four bits each. The first group is always 3 (binary 0011); the second group can be from 0 to 9 in bits (binary 0000 to 1001), so a 7 is represented as binary 0011 0111, while a 2 is binary 0011 0010. Each eight-bit group is examined for its number of one bits.

In the *odd* scheme, there must be an odd number sum for the nine bits. Because 7 (binary 0011 0111) and a 2 (binary 0011 0010) already have an *odd* number of one bits, the parity bit is set to zero; thus the *total* remains odd. A 6 (0011 0110) or a 5 (0011 0101), however, have an even number of one bits, so the parity bit is set to one to yield an *odd* total.

Nine-bit parity checking does not catch *even* multiple-bit failures that occur simultaneously, but it does catch *odd*, multiple-bit failures.

By analyzing its large failure database, IBM discovered that about 99% of all bit failures (from either mechanical or electronic causes) were single-bit failures. The data showed that multiple-bit failures are more common in magnetic-memory storage.

In examining the data on the very small percentage of multiple-bit failures, IBM found the odds to be 50-50 that they would be either *odd* or *even*. Thus, about half of those could be caught with a nine-bit parity scheme.

Clearly, no prudent engineer or anyone else engaged in large-scale "number crunching" would be without parity checking—particularly if those calculations involve large sums of money or public safety.

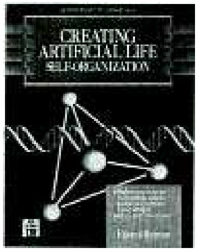
JAMES W. BIGGER
San Diego, CA Ω

NEW LIT

Use The Free Information Card for fast response.

Creating Artificial Life: Self-Organization; by Edward Rietman. Windcrest/ McGraw-Hill, Blue Ridge Summit, PA 17294-0850; Phone: 1-800-233-1128; Fax: 717-794-2103; $29.95.

This book explores several different possible explanations for the intriguing question—when does a system become a *living* system? After exploring several definitions of life, the author explains the mathematical techniques that scientists use to simulate many different complex, dynamic systems.



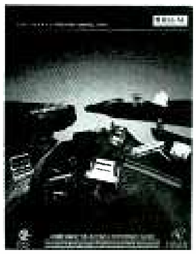
CIRCLE 40 ON FREE INFORMATION CARD

Mr. Rietman's book, based on actual, ongoing research into artificial life, tells you how you can "create" your own artificial life forms on a personal computer with programs written in BASIC, C, and Pascal. You will learn how to model everything from genetic codes and computer viruses to cellular automata, self-organizing systems, and mathematical bioforms on your personal computer.

The book includes a disk that contains source code for all of the programs listed. Many tables, drawings, and photographs will help you to gain a better understanding and appreciation of this exciting new branch of science.

Custom and Standard Connectors Selector and Reference Guide; Regal Electronics Inc., 471 Gianni Street, Santa Clara, CA 95054; Phone: 800-882-8086; Fax: 408-988-2797.

Regal's 24-page guide illustrates and lists the company's complete line of more than 260 standard and custom connectors. These include IDC, BNC, D-subminiature, DIN, SCSI-II, and filter connectors. A complete line of pin headers, sockets, noise filters, and hardware is also included.The guide contains a full-page custom-cable design guide.



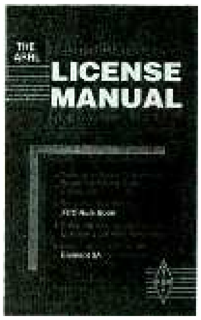
CIRCLE 39 ON FREE INFORMATION CARD

New products from Regal include surface-mount connector products and backshells with grommets. Intended as a guide for product designers, the catalog and guide provides a picture and brief description of each product. It also discusses Regal's custom manufacturing. You are invited to call the company's toll-free number to request detailed drawings and specifications.

The ARRL Technician Class License Manual For Novice Class Licensees; edited by Larry D. Wolfgang, WR1B, Joel P. Kleinman, N1BKE, and Jim Kearman, KR1S. The American Radio Relay League, 225 Main Street, Newington, CT 06111; Phone: 203-666-1541; Fax: 203-665-7531; $6.00.

Radio amateurs with Novice Class licenses who are ready to upgrade to Technician Class will find this American Radio Relay League's (ARRL) manual a helpful study guide. Upgrading will reward the novice with additional operating privileges—you can roam the complete spectrum allocated to the Amateur Service above 30 MHz. Moreover, it is no longer necessary to master the Morse Code.

This manual, one of ARRL's License Manual Series, offers a brief description of the Amateur Radio Service focusing on the Technician Class license. Subsequent chapters cover operating procedures, radio-wave propagation, amateur radio practice, electrical principles, circuit components, signals and emissions, and antennas and feed lines.



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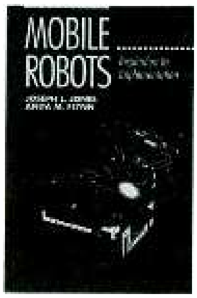
The manual also includes sample tests consisting of questions drawn from the question pool that is used for actual exams. Answer keys and page references are also provided. They permit the reader to locate the appropriate text that explain the correct answers to the test questions included.

Mobile Robots: Inspiration to Implementation; by Joseph L. Jones and Anita M. Flynn. A. K. Peters, Ltd., 289 Linden Street, Wellesley, MA 02181; 617-235-2210; Fax: 617-235-2404; $39.95.

Mobile Robots offers step-by-step procedures for building two inexpensive but fully functional robots that have a wide range of abilities. The projects are intended to serve as stepping stones to the book's main goal—to expand the readers' background in electronics and artificial intelligence, and provide them with the basic skills and knowledge of tools needed to enter and be successful in the field of robotics.



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The authors' enthusiasm for their subject is infec-

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WAE02

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Virginia Beach, VA 23455-2500

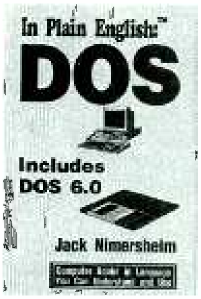
tious. The book and its projects will appeal to readers at all levels of home project construction expertise. For the inexperienced, chapters on the fundamentals of building an electronic/electromechanical project are included. A list of basic tools needed to get started is also included in the book.

The TuteBot (for Tutorial Robot) is a simple, obstacle-avoiding robot. It is easy to build, and can serve as a "warm-up exercise" for the more challenging Rug Warrior. The software-controlled Rug Warrior has many sensors and actuators that give it the ability to chase people, hide in the dark, avoid obstacles, play music, and move toward noise sources.

This book by Jones and Flynn includes all of the necessary schematics and parts lists to build the robots. It also includes the Rug Warrior software program. A directory of commercial sources for the materials and components needed to build the robots is given. For those who wish to inquire more deeply into the subject, there is a bibliography of books and robotic publications.

In Plain English: DOS; by Jack Nimersheim. World-Comm, 65 Macedonia Road, Alexander, NC 28701; Phone: 704-252-9515; Fax: 704-255-8719; $9.95 (U.S.), $12.95 (Canada).

Here is another self-help book on the DOS operating system. Mr. Nimersheim says that personal computers don't have to be bewildering, and neither does the popular MS-DOS operating system. By minimizing the computer jargon, he helps readers master DOS, including version 6.0.



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His book explains the basics—what DOS is, what it does, how it works, and how to install it. It also outlines the differences between the older versions of DOS, that required precise commands to be typed on the prompt line, and the relatively new graphics-based DOS shell.

Included is information that describes how the PC user can function in both DOS environments. It covers the preparation and management of disks, the use of organizing files and directories, and the customizing of DOS to meet specific needs. As advertised, Mr. Nimersheim's book is written in plain English; glossaries at the end of each chapter help the reader become computer-literate.

Project Studio Blueprint: A Guide to Design, Installation, and Management; by Greg Galluccio. Howard W. Sams & Company, 11711 North College, Carmel, IN 46032; Tel: 800-428-5331; Fax: 800-448-3804.

Galluccio's book explains everything you'll need to organize and build an audio studio. It is intended to help readers put their own studio design ideas on paper. Topics covered include how to budget the costs of building and maintaining a studio, how to do the best sound proofing to obtain the best acoustics, how to install audio connections and patch bays properly, and how to troubleshoot equipment and connections.

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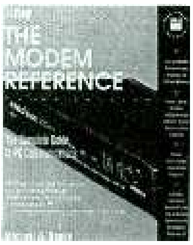
This book is for those who are willing to spend about the same amount of money building a studio that would be needed to buy a new car. The latest audio technologies are explored. Included are explanations of multimedia capabilities for your studio. Practical tips, checklists, proven business strategies, and a sample business plan show how to turn a profit from your recording studio.

The Modem Reference: Third Edition; by Michael A. Banks. Brady Publishing, 11711 N. College Avenue, Suite 140, Carmel, IN 46032; Phone: 800-428-5331.

This complete guide to personal computer communications shows you how to connect your computer to a vast on-line world of information. Text and illustrations explain how to get the most from modern communications.

Beginners in computer communications will find hundreds of tips, hints, and ideas to get them up and running. Banks covers everything from selection, installation, and basic operation to advanced data transmission and troubleshooting techniques. The book includes a shopper's guide for on-line services, communications hardware, and software.



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An included disk contains DON.MAC, a script that "talks" with other computer users on CompuServe and ZABTOOLS, which helps "unpack" programs and other files downloaded from BBS or on-line services. Quick-Select Batch File will assist the user in configuring his system.

Relays and Accessories Cross Reference and Technical Guide (RC-003). NTE Electronics, Inc., 44 Farrand Street, Bloomfield, NJ 07003; Phone: 800-631-1250 (including Canada) or 201-748-5089; Fax: 201-748-6224.

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This 136-page catalog from NTE describes its expanded line of UL- and CSA-approved electromechanical and solid-state AC and DC relays, input-output modules, sockets, and accessories. More than 16,000 industry part numbers from 166 manufacturers are cross-referenced to the NTE line. They include all manner of relays: general purpose, power, latching, circuit-board mount, reed, automotive, and solid-state. Ω

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The professional discussions seen on the TV screen in your home reveals how to detect and disable wiretaps, midget radio-frequency transmitters, and other bugs, plus when to use disinformation to confuse the unwanted listener, and the technique of voice scrambling telephone communications. In fact, do you know how to look for a bug, where to look for a bug, and what to do when you find it?

Bugs of a very small size are easy to build and they can be placed quickly in a matter of seconds, in any object or room. Today you may have used a telephone handset that was bugged. It probably contained three bugs. One was a phony bug to fool you into believing you found a bug and secured the telephone. The second bug placates the investigator when he finds the real thing! And the third bug is found only by the professional, who continued to search just in case there were more bugs.

The professional is not without his tools. Special equipment has been designed so that the professional can sweep a room so that he can detect voice-activated (VOX) and remote-activated bugs. Some of this equipment can be operated by novices, others require a trained countersurveillance professional.

The professionals viewed on your television screen reveal information on the latest technological advances like laser-beam snoopers that are installed hundreds of feet away from the room they snoop on. The professionals disclose that computers yield information too easily.

This advertisement was not written by a countersurveillance professional, but by a beginner whose only experience came from viewing the video tape in the privacy of his home. After you review the video carefully and understand its contents, you have taken the first important step in either acquiring professional help with your surveillance problems, or you may very well consider a career as a countersurveillance professional.

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To obtain the information contained in the video VHS cassette, you would attend a professional seminar costing $350-750 and possibly pay hundreds of dollars more if you had to travel to a distant city to attend. Now, for only $49.95 (plus $4.00 P&H) you can view ***Countersurveillance Techniques*** at home and take refresher views often. To obtain your copy, complete the coupon or call.

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RONALD M. JACKSON

THE BAROMETRIC PRESSURE IS falling rapidly, dropping by almost an inch of mercury in 12 hours. A big storm is on the way. Relative humidity begins a slow rise as cloud cover increases. The wind rapidly picks up speed. Gusts peak at over fifty miles an hour. The relative humidity increases sharply and air temperature drops. Steady heavy rains begin, sending the relative humidity over 96%. The downpour lasts an hour. Over one inch of rain falls in that time. The wind direction changes from southwest to northwest as the storm front passes. Front passage is confirmed as the barometric pressure begins a slow rise. As the cold air scours out the warm, the temperature drops ten degrees. With the weather station presented in this article, your computer can monitor every facet of the storm.

A weather monitor

The weather affects everyone. But instead of just being a source of rained-out picnics, the weather can be a source of endless fascination. Driven by the forces of heat from the sun and the rotation of the earth, modified by both continental and local topology, the weather is a constantly changing panoply of winds, heat, moisture, and pressure. This month's project is a professional caliber instrument that will to help you unlock the secrets of the weather.

This computerized meteorological station uses the Experimenter (presented in the July and August issues of **Electronics Now**) to link weather instruments to your computer. Any PC-compatible computer with CGA, EGA or VGA graphics can be used. A Macintosh software version is in development, and may be available by the time you read this. Because of the extensive measurement capabilities built into the Experimenter, the electronics for this project are relatively simple.

With the standard software package, this project can measure and display a wide range of weather conditions with great accuracy. However, a professional version of the software can be purchased. It permits measurements to be stored on disk so that they can be recalled and displayed graphically on the screen or printed on laser or dot-matrix printers. Minute-by-minute information can be recorded for 24-hour periods to aid in weather forecasting. Hourly data and daily minimum/maximums are stored for historical analysis.

By using the alarm capabilities in the software, along with the relay and eight driver outputs on the Experimenter, you can program the station to take actions based on weather conditions. Perhaps you would like to automate a greenhouse so that when the temperature drops too low or rises too high, an exhaust fan or heater will be activated; if the relative humidity dropped too low, a mist system or lawn sprinklers could be triggered.

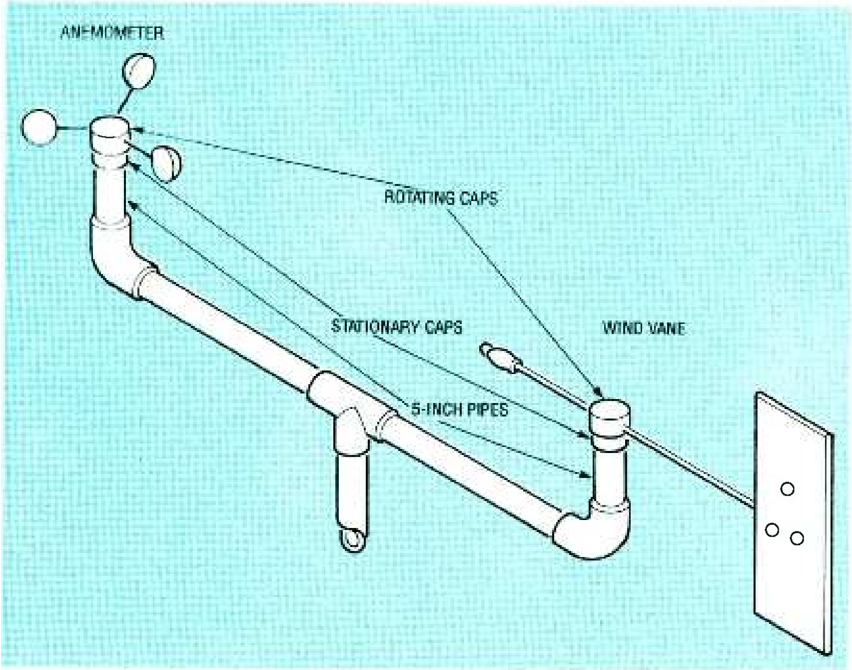

FIG. 1—THE ANEMOMETER AND WIND VANE mount on a single PVC pipe assembly.

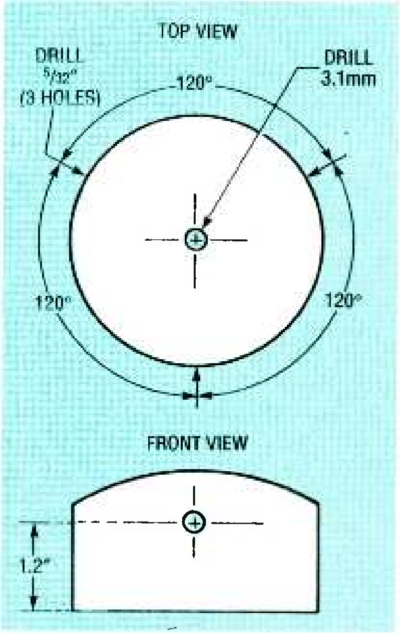

FIG. 2—ANEMOMETER ROTATING CAP. Drill three 5⁄32-inch holes, evenly spaced, in a 2-inch PVC end cap, 1.2 inches up from the open end. Drill one 3.1 mm hole in the exact center of the top of the cap.

Because we've already covered the electronics in the Experimenter, most of this article is mechanically oriented. Let's get right down to building the mechanical elements of the weather station.

Construction

You might want to build only part of the weather station because the software can be easily configured for the particular sensors you choose to include. You can have a system working with as little as one instrument.

Instruments can be purchased completely assembled and tested, or you can build them yourself. Complete kits of pre-drilled, ready-to-assemble parts are also available for quick and easy construction. For those with a well-equipped shop, kits with only the hard-to-find parts are also available.

All instruments can be calibrated to professional levels of accuracy. Calibration procedures that do not require special equipment are included for each instrument.

The electronics are simple enough to be added in the wiring-grid area on the Experimenter. For those who dislike point-to-point wiring, or want the most reliable system possible, a circuit board can be made from the foil patterns that will be provided next month, or one can be purchased from the kit supplier.

Wind and rain

Which way is the wind blowing? Is it a gale or a zephyr? How much rain fell last night, and how much fell in that last downpour? The wind vane, anemometer, and rain gauge are easy to assemble. If you choose to assemble those instruments from the kits of already drilled parts, you can skip the sections on preparing materials. But, if you have a well equipped shop and know your way around a hardware store, you can use the hard-to-find parts kit and buy the other components locally. The wind vane and anemometer are mounted on a single assembly composed mostly of PVC pipes and fittings, as shown in Fig. 1.

Building the anemometer

The anemometer consists of a rotating assembly (including wind cups and a rotating cap), and a stationary base. The rotating cap turns a stainless steel shaft which is supported vertically on a sharp pin, and horizontally by a sintered bronze bushing. Rotation is detected by a magnetic switch. If you are using the complete kit you can skip this section on preparing materials and go right to the section on assembly.

The rotating and stationary caps are made from schedule 40 PVC end caps, available at most plumbing supply stores. Be sure to use only schedule 40 PVC pipe and fittings; lighter grades might not hold up well in cold or rough weather.

Figure 2 shows the construction of the rotating cap. Drill three 5⁄32-inch holes evenly spaced around a 2-inch PVC end cap, 1.2 inches from the open end of the cap. Drill a 3.1-millimeter hole through the exact center of the top of the cap. Be sure that the holes are perpendicular to the cap. If they are not, the anemometer's accuracy will be degraded.

The stationary cap is shown in Fig. 3. Some PVC caps have molding bumps on their outside diameters. If the 1½-inch stationary cap has any that could rub on the inside of the rotating cap, they must be sanded or filed off. The stationary cap requires two holes: In the exact center of the cap drill a ¼-inch hole for the sintered bronze bearing. At 9⁄16-inch from the center, drill a 5⁄16-inch hole for the magnetic sensor.

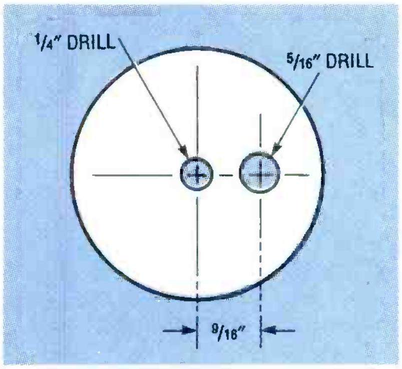

FIG. 3—ANEMOMETER STATIONARY cap. Drill a ¼-inch hole in the exact center of the top of a 1½-inch PVC end cap. Drill a 5⁄16-inch hole offset 9⁄16-inch from the center of the top.

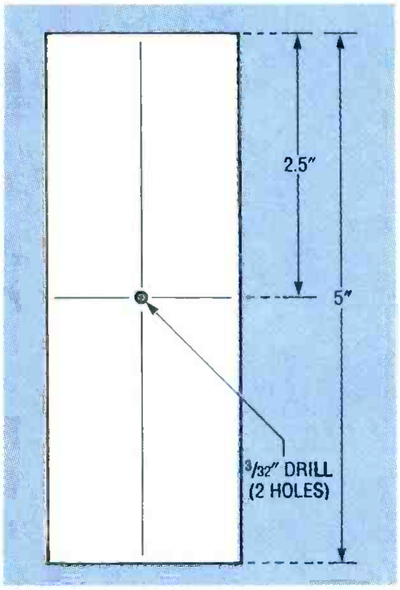

FIG. 4—ANEMOMETER VERTICAL pipe. Cut a 5-inch long piece of 1½-inch PVC pipe. Drill two 3⁄32-inch holes on opposite sides of the piece, 2½ inches from each end.

The stationery cap mounts on a 5-inch piece of 1½-inch diameter schedule 40 PVC pipe. Drill two 3⁄32-inch holes on opposite sides of the PVC pipe, 2.5 inches from each end. See Fig. 4. The wind cups are hemispheres of tough, pliable plastic (actually non-perforated Wiffel balls cut in half), with holes on opposite sides made near the cut edge. The pieces of the anemometer are now ready for assembly.

For best appearance and longest life, use only stainless-steel hardware on the anemometer. The wind cups are fastened to the rotating cap with 4-inch 8-32 machine screws. See Fig. 5. Slip a lock washer and a flat washer on a 4-inch screw, th... push the screw through o... the holes into a wind c... on another lock wa... thread two nuts a... on the screw. Slip... lock washer, then... screw through the o... and out of the wind cu... another lock washer o... screw and thread another... on the screw. Move and tight... the nuts to clamp the wind cu... in place. Adjust the nuts so that the wind cup is round. Repeat for the other two wind cups.

Now attach the wind cups to the rotating cap. Thread a nut about ½-inch on the screw, then slide on a lock washer. Thread the screw into one of the holes in the side of the rotating cap. On the inside of the cap, slip on a lock washer and then thread a nut onto the screw. Adjust the inside nut so it is flush with the

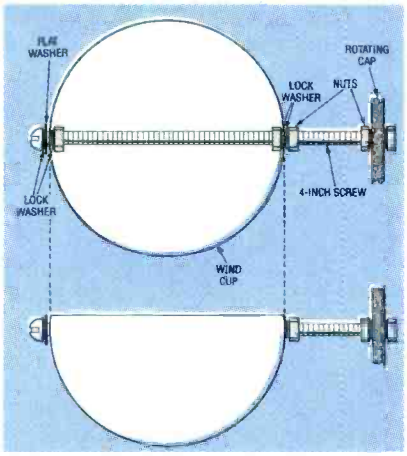

FIG. 5—ATTACHING THE WIND CUPS. The wind cups secure to the rotating cap with 4-inch long machine screws.

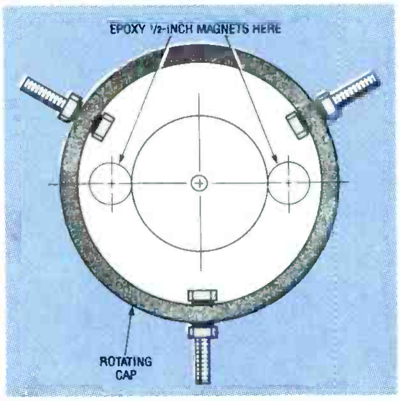

FIG. 6—ANEMOMETER MAGNETS. Two ½-inch diameter magnets must be epoxied under the top of the rotating cap.

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Gently tap the bronze bea... into the center hole of the st... tionary cap, from the inside o... the cap outward. The flange on the bearing should be pressed flush against the inside surface of the cap. The fit should be tight enough that the bearing is held solidly. Using the plastic nuts provided, secure the magnetic switch in the second hole so that it extends ⅜-inch above the top of the stationary cap. See Fig. 7.

Cut a 1½-inch long piece from a one-by-two cedar board (which actually measures about ¾- by 1½-inch). This will form part of the support for the rotating assembly. Sand or file the corners of the wood block as necessary so that it fits snugly into the pipe. Slip the wood block into the pipe, and slip the stationary cap lightly in place. Slip the stainless steel shaft through the brass bearing and press it lightly into the wood to make a small indentation. Remove the rotating assembly, stationary cap, and the wood block. Install a No. 10 ½-inch

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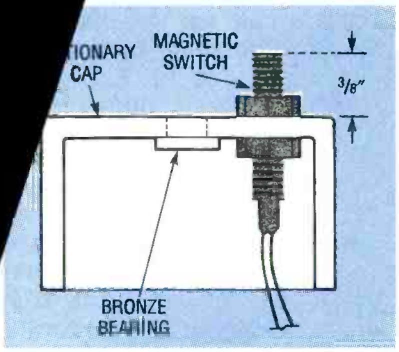


FIG. 7—THE BEARING AND MAGNETIC switch install in the stationary cap as shown here.

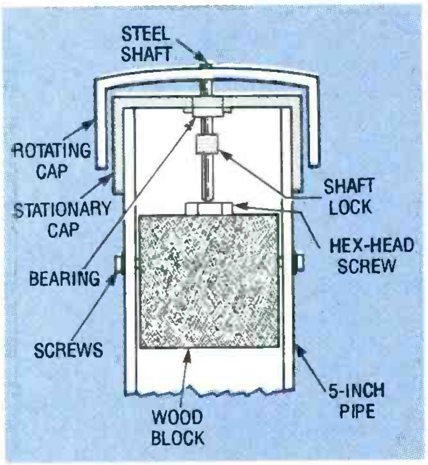


FIG. 8—THE ANEMOMETER SECTIONS go together as shown here.

nated with oil, this will help to reduce friction further.

Push the wood block back into the tube. Align the ¾-inch sides of the block with the 3/32-inch holes in the side of the 5-inch pipe. The stationary cap will mount on the end of the tube nearest the hex-head screw on the wood block. Slip the magnetic switch wires out through the tube through the large space along the side of the wood block. Grasping the sides of the stationary cap only (do not press down on the rotating cap), force the stationary cap solidly onto the tube.

By reaching through the open end of the tube, adjust the vertical position of the wood block so that the point of the shaft supports the rotating assembly. Rotate the assembly to verify that the magnets do not hit the magnetic switch, and that the nuts do not drag on the stationary cap. The anemometer should turn easily when you blow on the cups. If not, determine the cause of the drag. Rotate the assembly while using an ohmmeter to verify that the magnetic switch opens and closes. Secure the wood block in position with two No. 4 ½-inch sheet-metal screws, threaded through the 3/32-inch holes in the tube. The anemometer is now finished.

Building the wind vane

Like the anemometer, the wind vane consists of a rotating assembly (including the tail, counter balance, and rotating cap), and a stationary base. Wind direction is translated into two voltages by a dual-wiper potentiometer. The rotating assembly is fastened to a ball bearing unit, press fit into the stationary cap. A length of flexible tubing links the rotating assembly to the potentiometer shaft.

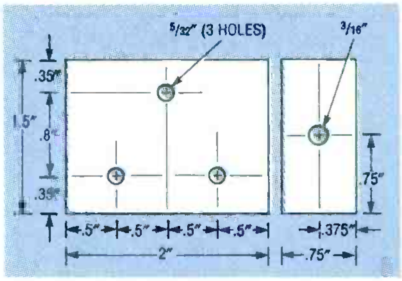


FIG. 10—TAIL MOUNTING BLOCK. The wind vane tail mounts on a wood block.

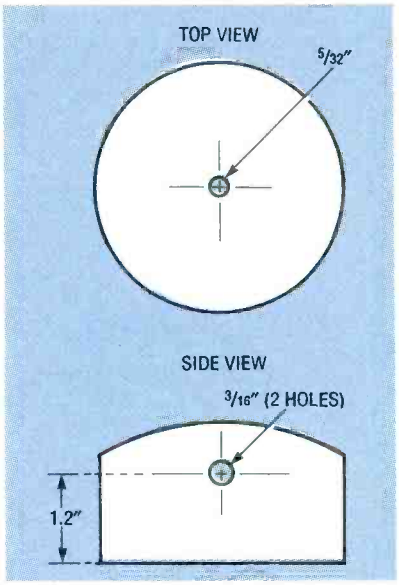


FIG. 11—WIND VANE ROTATING CAP. Make the wind vane rotating cap from a 2-inch PVC end cap.

If you purchase a complete kit, you can skip this section on preparing materials and go right to the assembly. To prepare the tail, cut a 3- by 17.6-inch piece of thin-gauge aluminum. Aluminum flashing, available at many hardware stores, has the right thickness. Punch nine 5/32-inch holes in the aluminum as shown in Fig. 9. Fold it along the lines indicated in the figure, both toward the same side. The tail in the kit is anodized for improved corrosion resistance; if you are making your own, and you live in a wet climate, you might want to paint it. Painting the aluminum will increase the tail's weight, so you might need to use a larger counterweight.

The tail mounts on a wood block with the measurements shown in Fig. 10. Use a durable, moisture-resistant wood such

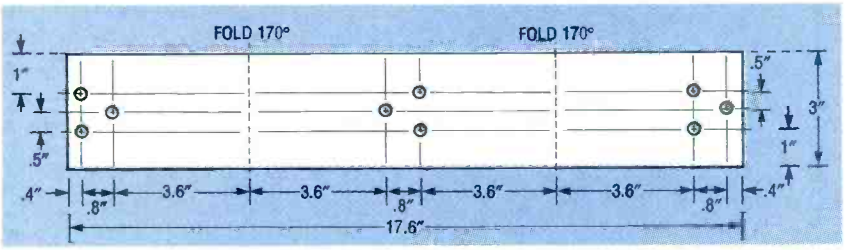


FIG. 9—WIND VANE TAIL. This can be made from aluminum flashing, available at hardware stores.

as Cedar. Drill three 5/32-inch diameter holes in the face of the block, and one 3/16-inch diameter hole down the length of the block as shown in the figure.

Make the counterweight for the wind vane from a 1½-ounce, egg-shaped fishing weight. Drill a 3/16-inch diameter hole through the weight lengthwise so that it will slide onto a No. 10 screw. Since lead is a soft metal with a low melting point, use a fresh drill bit, a low drill speed, and a dab of oil to avoid melting the lead.

As with the anemometer, the parts for the wind vane are made from schedule-40 PVC. Make the rotating cap from a 2-inch PVC end cap as shown in Fig. 11. Drill a 5/32-inch diameter hole in the exact center of the top of the cap. Drill two 3/16-inch diameter holes on exactly opposite sides of the cap, 1.2-inches up from the open end of the cap. Be sure that these holes are perpendicular to the cap.

Make the stationary cap from a 1½-inch PVC end cap. Sand or file off any molding bumps that might rub on the inside of the rotating cap. Drill a 39/64-inch hole in the exact center of the cap. A 5/8-inch outside diameter, ¼-inch inside diameter flanged ball bearing unit installs in this hole. Using a reaming bit, enlarge the hole to a few thousandths under 5/8-inch to permit press-fitting of the ball bearing unit.

Cut a 5-inch length of 1½-inch PVC pipe. Drill two 5/32-inch holes on opposite sides of the pipe, 2.5 inches from one end; the potentiometer mounting bracket will bolt inside through these holes. The holes are drilled in the same positions as in the anemometer tube, but the drill bit is larger.

Construct the potentiometer mounting bracket from a 0.8-inch by 2.8-inch piece of 0.032-inch thick aluminum. Punch one 3/8-inch diameter hole, two 3/16-inch diameter holes, and one 1/8-inch diameter hole as shown in Fig. 12. Then make two 90° folds in the bracket in the indicated positions. It is essential that the folds be made at exactly the same distance from the 3/8-inch potentiometer mounting hole. If the distances are wrong, the potentiometer will be off center, which will degrade the sensitivity of the wind vane. The pieces of the wind vane are now ready to be assembled. Be sure to use only stainless-steel machine screws and other hardware on the wind vane.

Use Fig. 13 as a visual aid for the following procedures. Slip a lock washer and a flat washer on a 6-inch long No. 10-24 screw, then slide the screw through the 3/16-inch diameter hole running the length of the wood block. Slip another flat washer and lock washer on the screw, and secure with a hex nut.

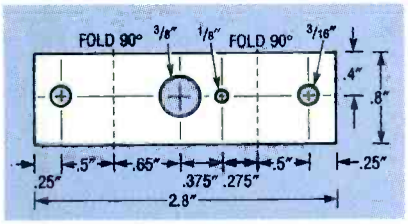


FIG. 12—POTENTIOMETER MOUNTING bracket. Make the potentiometer mounting bracket from a 0.8- by 2.8-inch piece of 0.032-inch thick aluminum.

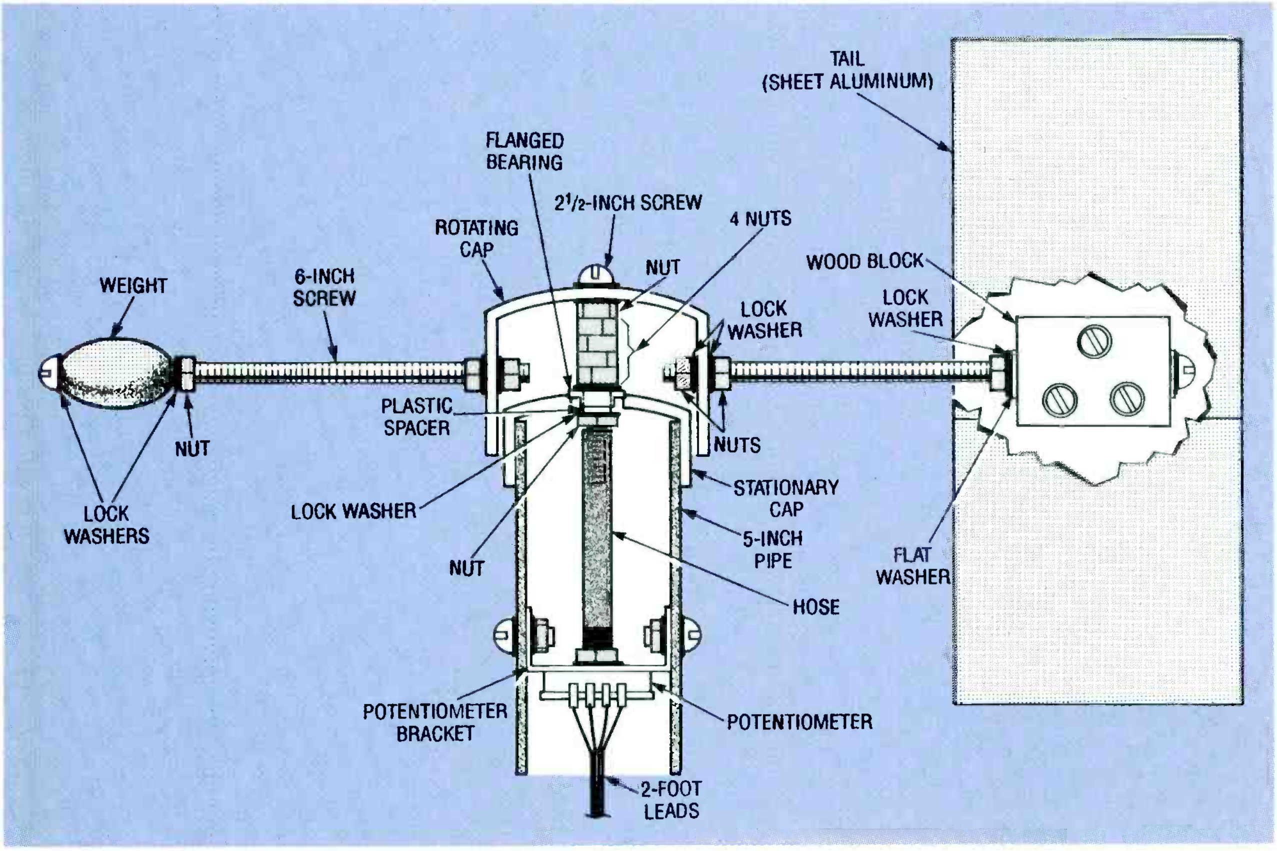


FIG. 13—THE WIND VANE SECTIONS go together as shown here.

Thread a hex nut about ½-inch on the screw, slip on a lock washer, then run the screw into one of the 3⁄16-inch holes in the side of the rotating cap. Slip a lock washer and thread on a hex nut so that it is flush with the end of the machine screw. Rotate the screw so that the wood block is vertical with the two holes below and the single hole above, then securely tighten the hex nut against the outside of the rotating cap.

Slip a lock washer down the length of the other 6-inch screw. Slide the lead weight on next, followed by another lock washer. Thread a hex screw down to the lead weight and tighten it. Thread another hex nut about 1-inch on the screw, slip on a lock washer, and run the screw into the 3⁄16-inch hole opposite the tail. Slip on a lock washer then thread on a hex nut. The hex nuts will be adjusted later on so that the lead weight exactly balances the tail.

Use a vise to press the ball bearing unit into the stationary cap from the top side. Place blocks of wood on either side of the center hub so that the jaws of the vise press only on the flange and do not put pressure on the ball bearings. Press in the flange flush with the outside of the cap.

Slip a lock washer on a 2½-inch No. 8-32 machine screw, and thread the screw down the 5⁄32-inch hole in the top of the rotating cap. Slip another lock washer on the screw, thread on a hex nut, and tighten it securely. Thread another four hex nuts on the screw and tighten. Slip a lock washer on the screw, then push the plastic spacer on. Slide the stationary cap with the bearing in it over the screw and onto the plastic spacer. Slip on a lock washer, thread on a hex nut, and tighten it. Verify that the rotating assembly turns freely, without rubbing on the stationary cap.

Now slip the tail section over the wood block and align the three holes. Secure it in place with three 1-inch No. 6-32 machine screws. Be sure to use lock washers under the screw heads and hex nuts.

Turn the wind-vane assembly sideways, and run the counter weight screw in or out as necessary to precisely balance the weight of the tail. When balanced, remove the stationary cap from the rotating assembly and tighten the hex nuts on the counter-weight screw to secure it in position.

PARTS AND KITS

The following kits are available from Fascinating Electronics, PO Box 126, Beaverton OR 97075-0126. You can call 1-800-683-KITS with VISA and Mastercard orders, catalog requests, and technical questions 24 hours a day, 7 days a week. Please include $3.40 for US shipping and handling with any order. Canadian shipping and handling is $5.00, with payment in US dollars. Foreign orders, please inquire for prices and availability. NOTE: The following kit descriptions are also to be used as parts lists. If you are gathering the parts together on your own, you'll need all parts listed under the "Complete Kit" headings to build each unit.

ANEMOMETER

• **Complete kit—$37.50**
(3) 3-inch diameter plastic hemispheres, punched
(1) oil-impregnated bronze bearing, 0.126- × 0.252- × ⅜-inch, flanged
(1) stainless-steel shaft, 0.1247- × 3-inch, pointed on one end
(1) shaft lock, ⅛-inch
(1) magnetic switch, 1.5- × 5⁄16-inch, with hex nuts
(2) disk magnets, ½-inch diameter
(1) 2-inch schedule-40 PVC cap, precision drilled
(1) 1½-inch schedule-40 PVC cap, precision drilled
(1) 1½-inch schedule 40 PVC pipe, 5 inches long, drilled
(1) wood block, ¾- × 1½- × 1½-inches
(2) No. 4 stainless-steel sheet-metal screws, ½-inch long
(3) 8-32 stainless-steel machine screws, 4 inches long
(15) 8-32 stainless-steel hex nuts
(3) No. 8 stainless-steel flat washers
(18) No. 8 stainless-steel lock washers, internal tooth
(1) No. 10 stainless-steel hex-head sheet-metal screw, ½-inch

Hard-to-find parts kit—$17.50
(3) 3-inch diameter plastic hemispheres, punched
(1) oil-impregnated bronze bearing, 0.126- × 0.252- × ⅜-inch, flanged
(1) stainless-steel shaft, 0.1247- × 3-inch, pointed on one end
(1) shaft lock, ⅛-inch
(1) magnetic switch, 1.5- × 5⁄16-inch, with hex nuts

WIND VANE

• **Complete kit—$39.90**
(1) dual-wiper potentiometer
(1) ball bearing, ¼-inch ID, ⅝-inch OD, flanged
(1) plastic spacer, ⅛-inch ID, ¼-inch OD
(1) tail fin, anodized aluminum, punched and folded
(1) potentiometer mounting bracket, punched and folded
(1) 1½-oz. lead egg-shaped fishing weight, drilled
(1) 2-inch schedule-40 PVC cap, precision drilled
(1) 1½-inch schedule-40 PVC cap, precision drilled
(1) 1½-inch schedule-40 PVC pipe, 5 inches long, drilled
(1) wood block, ¾- × 1½- × 2-inches, drilled
(1) hose, 1½ inches long, ⅛-inch ID
(3) 6-32 stainless-steel machine screws, 1-inch long
(3) 6-32 stainless-steel hex nuts with lock washers
(6) No. 6 stainless-steel flat washers
(3) No. 6 stainless-steel lock washers
(1) 8-32 stainless-steel machine screw, 2½ inches long
(2) 8-32 stainless-steel machine screws, ½ inch long
(6) 8-32 stainless-steel hex nuts
(2) 8-32 stainless-steel hex nuts with lock washer
(6) No. 8 stainless-steel lock washers
(2) 10-24 stainless-steel machine screws, 6 inches long
(7) 10-24 stainless-steel hex nuts
(2) No. 10 stainless-steel flat washers
(8) No. 10 stainless-steel lock washers

• **Hard-to-find parts kit—$15.50**
(1) dual-wiper potentiometer
(1) ball bearing, ¼-inch ID, ⅝-inch OD, flanged

• **Assembled and tested anemometer & wind vane on "T" mount with 100 foot cable and modular connector—$159.90**

Attach 2-foot wires to the four terminals on the dual-wiper potentiometer. Label the wires 1 through 4 from left to right. Fasten the potentiometer to its bracket with its ⅜-inch hex nut and lock washer. The potentiometer shaft should point in the direction opposite that of the bracket flanges.

Run a 1½-inch long piece of ⅛-inch inside-diameter hose about 0.5-inch onto the No. 8 screw in the rotating assembly. Push the other end of the hose down the length of the potentiometer shaft. Grasping the assembly carefully, press the stationary cap onto the 5-inch pipe while watching for the holes in the potentiometer

RAIN GAUGE

- **Complete kit—$29.90**

(1) magnetic switch, 1.5- × 5⁄16-inch with hex nuts (Hamlin Mfg)
(1) disk magnet, ½-inch diameter
(1) downspout adapter, 2- × 3- × 3-inches, drilled
(1) measuring spoon, Rubbermaid #2235 ½ TBSP, drilled
(1) plastic funnel, 8-inch diameter (spout smaller than ½-inch in diameter)
(1) 3-inch diameter schedule-40 PVC pipe, 3 inches long, drilled
(1) brass rod, 1⁄32-inch diameter, 2.75 inches long
(2) No. 6 stainless-steel sheet-metal screws, ½-inch long
(2) cocktail straw sections, ¾-inch long

- **Hard-to-find parts kit—$5.90**

(1) magnetic switch, 1.5- × 5⁄16-inch with hex nuts (Hamlin Mfg)

- **Assembled and tested rain gauge with 50-foot cable and modular plug—$59.90**

SENSORS

- **Temperature sensor kit—$15.90**

(5) LM334Z current sources (National Semiconductor)
(5) 2.26-kilohm, 1% resistors
(5) 0.01 µF capacitors
(1) dual-wall heat-shrink tube, 3⁄16-inch diameter, 6 inches long
(1) DB25M connector, with shell

- **Humidity sensor kit—$29.90**

(2) humidity sensors (Philips 2322 691 9001)
(2) 555 timer ICs
(2) 0.1 µF disk capacitors
(4) 1-megohm, 1% resistors
(1) dual-wall heat-shrink tube, ½-inch diameter, 3 inches long

- **Assembled and tested temperature and humidity sensors—$99.90**

Includes:
One humidity sensor and one temperature sensor on a 50-foot cable with a modular plug
Four temperature sensors and one humidity sensor connected to a DB25 connector with shell
One humidity sensor and one temperature sensor on a 10-foot cable
One temperature sensor on a 50-foot cable
Two temperature sensors on 30-foot cables
(Custom cable lengths are available, inquire for pricing.)

bracket to line up with the holes in the side of the pipe. It might be necessary to remove the assembly and adjust the position of the hose on the screw and potentiometer shaft to get the bracket holes to line up when the assembly is pushed fully in place. Install two ½-inch No. 8-32 machine screws, with lock

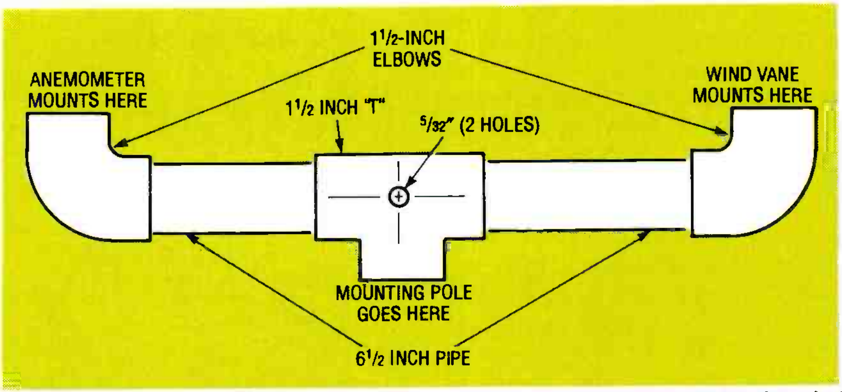


FIG. 14—WIND INSTRUMENT MOUNTING. A simple, yet sturdy mount for the wind instruments can be made from PVC pipe.

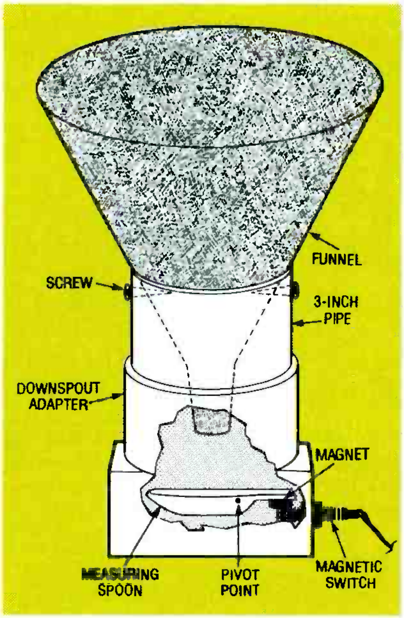


FIG. 15—THE RAIN GAUGE is configured as shown here.

washers, through the holes. Use hex nuts with captive lock washers inside the tube to secure the bracket to the screws. The wind vane is now finished.

Mounting

A simple yet sturdy mount for the wind instruments can be built from two 6½-inch sections of 1½-inch schedule-40 PVC pipe, two 1½-inch 90° elbow fittings, and one 1½-inch "T" fitting (see Fig. 14). Use cement formulated specifically for PVC (available where the pipe is sold) to bond the pieces together. Directions for using the cement are provided on the label; you won't use much, so buy the smallest amount available.

Drill a 5⁄32-inch diameter hole in the center of both sides of the "T" fitting. Cement the two 6½-

CONDITIONING BOARD AND BAROMETER

- **Signal conditioning board and barometer kit—$49.90**

(1) signal conditioning board
(2) TLC2274 op-amps (National Semiconductor)
(1) 74HC393 dual counter (Harris)
(1) AD621 instrumentation amplifier (Analog Devices)
(1) SCC15A pressure sensor (Sensym)
(1) 20-kilohm multiturn potentiometer
(16) 0.1 µF disk capacitors
(2) 1-megohm, 5%, ¼-watt resistors
(2) 10-kilohm, 5%, ¼-watt resistors
(5) 499-kilohm, 1%, ¼-watt resistors
(7) 100-kilohm, 1%, ¼-watt resistors
(1) 28.0-kilohm, 1%, ¼-watt resistor
(1) 13.7-kilohm, 1%, ¼-watt resistor
(1) 12.7-kilohm, 1%, ¼-watt resistor
(1) 10.0-kilohm, 1%, ¼-watt resistor
(1) 2.87-kilohm, 1%, ¼-watt resistor
(1) 1-kilohm, 1%, ¼-watt resistor
(1) DB25M connector
(3) 6-contact modular jacks

- **Bare signal-conditioning PC board only—$19.90**
- **Assembled and tested signal-conditioning board and barometer—$99.90**

Includes:
Signal conditioning circuitry for all sensors
Both DB25 and modular connectors installed
Barometer that requires calibration to your location

SOFTWARE

- **Professional version software for PC—$39.90**
- **Professional version software for MAC—$49.90**

THE EXPERIMENTER

- **Experimenter kit—$149.90**
- **Optional analog supply—$4.90**
- **Assembled and tested Experimenter with analog option—$199.90**

For more information on the Experimenter, see the July and August 1993 issues.

inch pipe sections in the arms of the "T." Cement the elbows on the pipe sections, setting the assembly on a table top to make all the connections line up properly. Run a 2½-inch long No. 8-32 machine screw through the hole, and secure it with a hex nut and lock washer. Slip the wind instruments into the two elbows. Run their wires through the pipes and out through the "T." Tie the connecting cable to the No. 8-32 screw, then connect the wires to the wind instruments. An appropriate length of pipe can be fitted to the bottom of the "T" to support the assembly. Run the cable down the inside of the supporting pole, and cement the pole to the "T."

Telephone wire is suitable for the cable, and is available in six-conductor cables. Be sure to record which signal connects to which color wire! If you use a flat cable, connect the magnetic switch to the first two conductors, then the four numbered potentiometer wires, in sequence, to the next four conductors.

Building the rain gauge

The rain gauge, shown in Fig. 15, is built around a 2-inch by 3-inch downspout adapter. A 3-inch diameter PVC pipe connects the downspout adapter to a large funnel. The funnel collects rain water and channels it into a small measuring spoon, which acts as a tipping bucket. The measuring spoon is hinged and balanced so that when sufficient water collects, the spoon tips, dumping the water. A small magnet mounted on the spoon triggers a magnetic switch each time the spoon tips. With the components specified, the rain gauge has a resolution greater than one hundredth of an inch. If you purchase the complete kit you can skip this section on preparing materials and go right to the section on assembly.

Drill the downspout adapter as shown in Fig. 16. Drill a ⁵⁄₁₆-inch diameter hole for the magnetic switch in the middle of the 2-inch wide face of the downspout adapter, 1 inch up from the bottom. Drill a ¹⁄₁₆-inch diameter hole on each of the 3-inch wide faces, 1.63 inches from the face with the magnetic switch hole, and 1.44-inches up from the bottom.

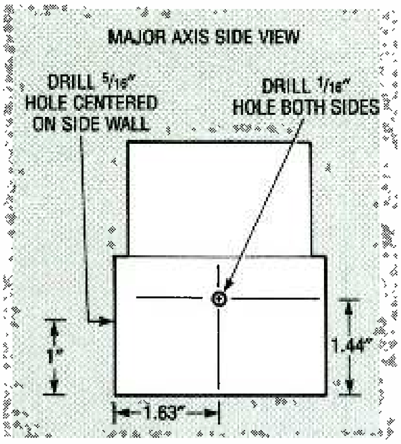


FIG. 16—RAIN GAUGE DOWNSPOUT adapter. A 2-inch by 3-inch downspout adapter forms the base of the rain gauge.

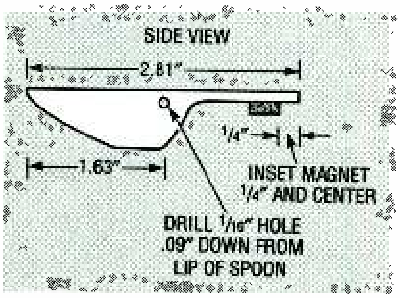


FIG. 17—RAIN GAUGE MEASURING spoon. The measuring mechanism in the rain gauge uses a ½-tablespoon measuring spoon.

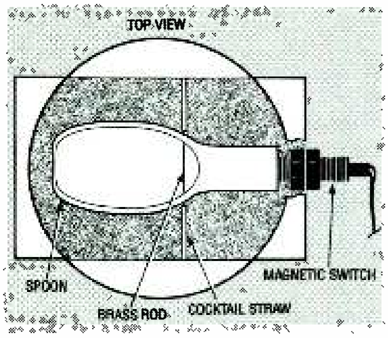


FIG. 18—MEASURING SPOON installation. The top view of the downspout adapter is shown.

Cut the excess length off of the measuring-spoon handle as shown in Fig. 17, reducing the overall length to 2.81 inches. Drill ¹⁄₁₆-inch diameter holes on each side of the spoon's bowl, 1.63 inches from the front edge and 0.09-inch down from the top. Glue the ½-inch diameter magnet to the handle of the spoon, ¼-inch from the end of the handle.

Referring to Fig. 18, cut a 2¾-inch long section of ¹⁄₃₂-inch diameter brass rod, and cut two ¾-inch long sections from a cocktail straw. Cut a 3-inch long section of 3-inch diameter schedule-40 PVC pipe, and drill two ⅛-inch diameter holes on opposite sides of the pipe 0.375 inch from one end.

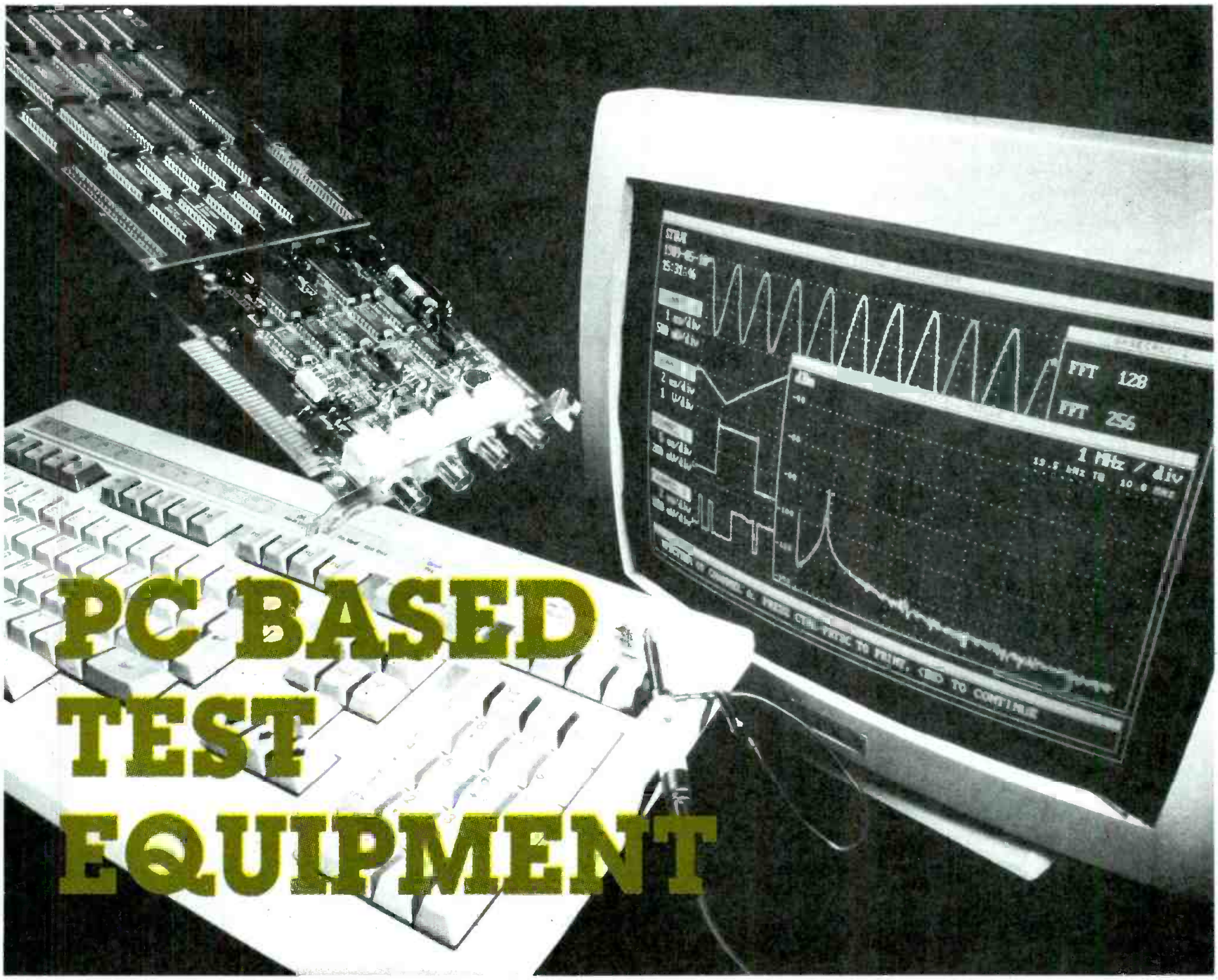
Using the plastic nuts provided, install the magnetic switch in the ⁵⁄₁₆-inch diameter hole in the downspout adapter with the switch's wire leading outside the adapter. Adjust the nuts so that the other end of the switch extends ¾-inch inside the adapter.

Insert the 2¾-inch long brass rod through one of the ¹⁄₁₆-inch diameter holes into the downspout adapter. Slip a ¾-inch long section of plastic cocktail straw on the brass rod. Then slip the rod through the two holes in the measuring spoon, through the other ¾-inch long piece of cocktail straw, and into the other ¹⁄₁₆-inch diameter hole in the downspout adapter. The handle on the spoon should rest on the magnetic switch. Seal the holes with the tip of a soldering iron to prevent the brass rod from slipping out.

Insert a 3-inch section of 3-inch diameter schedule-40 PVC pipe into the downspout adapter. Place an 8-inch plastic funnel on top of the PVC pipe. Make sure that the spout on the funnel is centered over the spoon bowl and is perpendicular to the adapter. If the separation from the funnel spout and the bowl of the spoon is too great, trim the 3-inch PVC pipe shorter. Secure the funnel to the pipe with two No. 6 sheet-metal screws through the ⅛-inch diameter holes in the pipe.

Next month

That's all we have room for this month. Next month we'll make the electrical connections to the mechanical devices that you should have finished by then. Ω



PC BASED TEST EQUIPMENT

Boards that plug into computers are attractive alternatives to conventional instruments for many test and measurement applications

TJ BYERS

IT IS DIFFICULT TO FIND ANY HUMAN activity today that hasn't been drastically changed by the personal computer. The PC has had a dramatic impact on the industrial test and measurement field, where PC-controlled automated test equipment and instrument clusters are now reported to outnumber stand-alone instruments.

PC-based instruments are fundamentally plug-in circuit boards supported by appropriate applications software that permit the computer to take on the functions that were formerly those of stand-alone electronic test measurement instruments. Most PC instrument circuit boards plug into ISA-bus (Industry Standard Architecture) slots in IBM-PC/AT computers or compatibles, generally, but not exclusively, desktop models.

Early sales of PC-based test instruments never reached expectations because they were mistakenly targeted as direct replacements for benchtop, stand-alone instruments. Because PC-based instruments operate in the digital domain and require that analog input signals be first converted to digital signals, they can't respond in real time as rapidly as, for example, a permanent-magnet, moving-coil meter movement.

It takes a finite amount of time to digitize and process the data, which puts PC-based instruments at a disadvantage in performing and displaying real-time measurements. Add to that the cost of analog-to-digital conversion electronics. This reason alone ruled out the possibility that PC-based instruments would ever be direct replacements for most standard test instruments.

However, PC instrument advocates, typically software and hardware vendors, finally convinced the industry that PC-based test equipment's real strength is in its versatility and flexibility—it can respond rapidly to changing test situations. Because it is PC-based, its characteristics can be readily changed with software.

In addition, several PC-based instruments can be linked together to form an instrument console or automated test equipment (ATE) station. A single computer enclosure can hold more test instruments in the form of plug-in boards than a workbench full of conventional instruments. This feature saves space and improves test and measurement productivity. Moreover, PC-based instruments, unlike the conventional instruments, can log data automatically and store it for delayed processing.

Surveying the market

Personal computer plug-in boards fall into two categories: controller/interface (mostly those conforming to the IEEE-488 standard), and analog/digital signal processing.

The IEEE-488 bus, widely known as the General Purpose Interface Bus (GPIB), is a digital system that permits up to 15 instruments or devices to communicate with each other. It's primary purpose is to integrate conventional dedicated instruments from the same or different vendors. For example, an oscilloscope from Hewlett-Packard can be integrated with a signal generator from Tektronix into an instrument cluster. Unfortunately, the data transfer rate between connected and properly interfaced instruments is quite slow, usually less than 20 kilobytes per second.

Plug-in signal processing boards have the speed and power to meet many of the latest demands for high-speed automated testing. In the time it takes a GPIB-interfaced device to acknowledge a request to send, a PC-based digital sampling oscilloscope can log 1000 measurements. These boards are sold as either general-purpose data converters for analog-to-digital or digital-to-analog conversion, or as instrument-specific boards that emulate such functions as an oscilloscope or frequency counter.

A BACKPLANE ENCLOSURE THAT ACCEPTS MANY PC-BASED INSTRUMENT and overcomes noise and interference problems inherent in desktop computers. Rapid Systems' PCXI includes 7 to 13 ISA or EISA slots and a 200-watt power supply.

The only difference between the two kinds of boards is that instrument-specific boards are sold with software that automatically makes the adapter card look and act like a conventional benchtop instrument.

Some plug-in boards perform functions that cannot be performed by conventional instruments, yet others offer superior performance at lower cost. A prime example is Guide Technology's GT650 time interval analyzer. It costs less than half the price of a comparable time-interval analyzer from Hewlett-Packard, yet provides 2000 times the memory and 50 times the throughput. However, this particular specification might not take into account all of the differences in performance or features that would govern a specific purchase.

General-purpose digital signal processing boards offer high performance, but the user must write his own program or buy it from a software vendor such as Hyperception. There is a lot to be said for creating your own PC-based instruments because certain qualities can be emphasized. This is especially true if the user is constrained by specific price or performance goals.

For example, when a Spectrum Signal Processing analog-to-digital converter board with 16-bit resolution and a sampling rate of 153 kilosamples per second is paired with Hyperception's AMPS Windows software program, the combination can emulate four different instruments:

- High-speed digital storage oscilloscope
- Fast Fourier Transform (FFT) spectrum analyzer
- Programmable digital filter
- Digital chart recorder

Alternatively, you can elect to save money and buy Keithley MetraByte's DAS-1200 ADC board with QuickBASIC support. It can create a 16-trace digital storage oscilloscope or digital chart recorder for only $449. The company says its product is suitable for multimedia applications.

PC-based instruments can be expensive when compared with their conventional counterparts. They could cost nearly three times as much as the stand-alone instrument. But when you cluster a number of instrument boards in a single computer enclosure, or configure one data converter board for multiple functions, pricing can favor the PC-based setup. As with any buying decision, you must shop wisely. The following is an overview of a selection of available PC-based test instruments with a commentary on what to look for when buying each one.

Digital sampling oscilloscope

The most popular PC-based test instrument is the digital sampling oscilloscope because it has the widest range of applications, and it takes advantage of the computer monitor's large display screen. These instruments are available from most PC instrument vendors, and they range in price from $595 to over $7000.

The core of the PC-based oscilloscope is the analog-to-digital converter (ADC). The resolution of the sampled input is determined by the number of ADC bits, which typically range from 8 to 16. On-board random-access memory (RAM) initially captures the sampled waveform. As the on-board RAM is used, the computer moves the data from the on-board RAM to its system memory, where it is processed by the video circuitry for display on the monitor.

The amount of RAM determines the length of the waveform that can be captured. At high sampling rates, the memory is used very quickly. So make sure that the system you specify will not only sample as fast as required (see the sidebar—Analog-To-Digital, and Back Again), but also for as long as required. To avoid loosing data from memory overflow, captured waveforms can be stored on hard disk with special software programs called *streamers*.

Most PC-based multichannel oscilloscopes consist of a single-channel, analog-to-digital converter (ADC) and an input multiplexer, as shown in Fig. 1. The multiplexer time shares the input signals by allowing each of them to be sampled independently. To find the maximum sample rate per channel, the sampling rate of the ADC must be divided by the number of channels sampled. For example, if an eight-channel board has a performance specification of 1 megasample per second, each of the eight channels would have a sample rate of only 125 kilosamples per second.

The maximum sample rate might be specified with all channels set at the same gain. Changing the gain from channel to channel can slow the overall sampling rate.

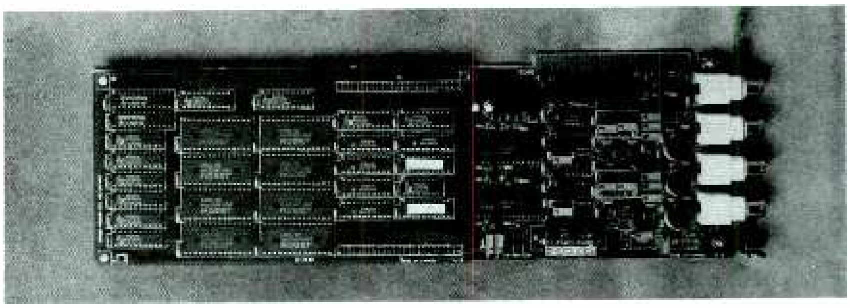
One of the fastest PC-based digital oscilloscope boards available is Signatec's DA500. It has a sample rate of 500 megasamples per second, a 350-MHz bandwidth, and is sold with 256 kilobits of RAM that can be expanded to 32 megabits.

At $595, the CompuScope LITE from Gage Applied Sciences seems to be the lowest cost digital oscilloscope board available. It offers a 40 megasample per second rate, a 7-MHz bandwidth, and is sold with 16 kilobits of RAM that is expandable to 64 kilobits.

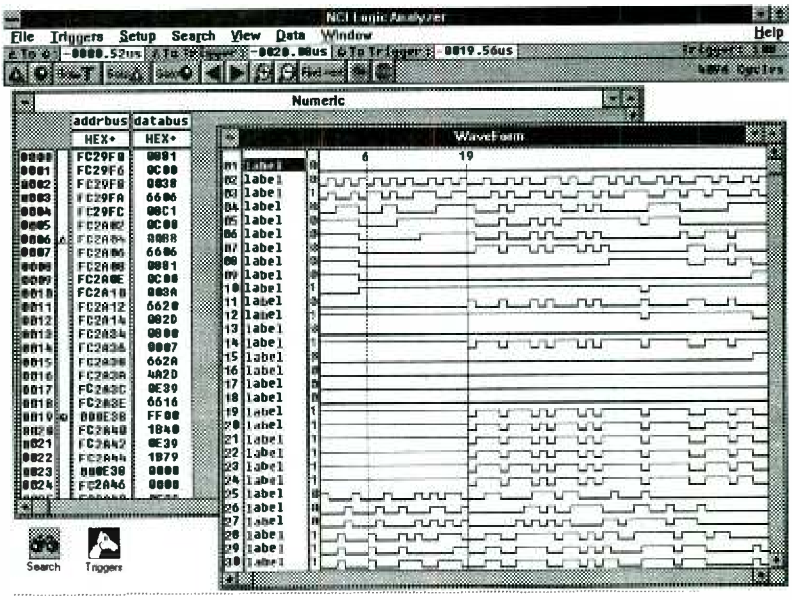
Spectrum analyzer

Another common PC-based instrument is a spectrum analyzer that examines the frequency domain of the acquired input data. The PC-based version makes frequency domain measurements with the fast Fourier transform (FFT) technique. It digitally processes a signal over a specific period of time to provide frequency, amplitude, and phase information. It can analyze periodic and non-periodic signals.

Unlike the most common common swept-spectrum or superheterodyne spectrum analyzer architecture, the FFT architecture can display the data in a large number of formats. These include rectangular, triangular, exponential, and extended cosine bell—plus the classical Kaiser-Bessel



PC-BASED TEST INSTRUMENT BOARDS such as CompuScope's 220 plug into any ISA or EISA PC expansion slot.



PC-BASED INSTRUMENTS USE Windows 3.1. An example is NCI's PA485 logic analyzer. Its operating screen is shown here.

ANALOG-TO-DIGITAL AND RETURN

The heart of all PC-based test instruments is either an analog-to-digital or digital-to-analog converter—ADC or DAC. Some products have both of those functions on the same board, or built within the same function.

Central to the operation of an ADC is a clock that generates pulses to drive the conversion electronics. The time taken to perform one complete conversion cycle in an ADC is called the sampling rate, and it is usually specified in kilosamples per second or megasamples per second.

General samplling theory—commonly referred to as the Nyquist theorem—states that the minimum sampling rate must be at least twice as fast as the highest frequency component in the input or output signal being sampled. To sample a 2-MHz sinewave, for example, the sampling rate must be at least 4 megasamples.

The maximum sample rate for a board depends on its ADC. There are three principal circuit architectures for converting analog signals to the digital output that the computer needs to process the data: dual-slope, successive approximation, and flash conversion. Of these, only successive approximation and flash converters can perform the conversions fast enough for instrumentation emulation.

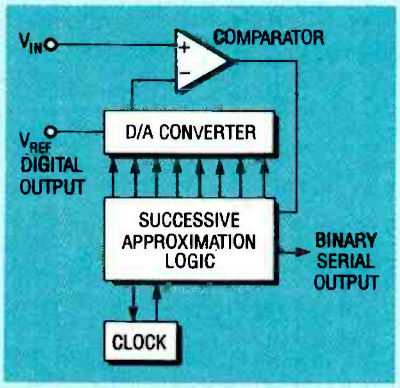


FIG. 2—SUCCESSIVE APPROXIMATION analog-to-digital converter block diagram.

A successive approximation (SA) converter consists or a comparator, a DAC, and successive approximation counter and logic as shown in Fig. 2. The analog input signal is first buffered and conditioned by the comparator. The converter compares an unknown analog voltage against a group of weighted references in a process that is analogous to the weighing of an unknown quantity on a precision balance.

In that process a set of weights in descending order of value is tried, starting with the largest. Any weight that tips the scale is removed. At the end of the process when balance is achieved, the sum of the weights remaining on the scale represents the unknown value.

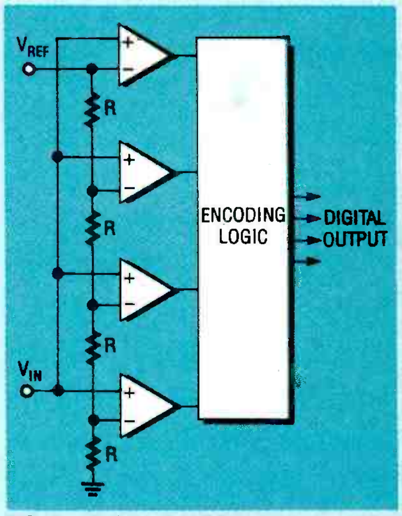


FIG. 3—BLOCK DIAGRAM OF A FLASH analog-to-digital converter.

Similarly, after successive stepping, the successive approximation DAC's digital output equals the unknown input voltage. A ten-bit SA converter, for example, can make 10-bit conversions of an unknown voltage in less than 20 microseconds.

A flash converter is an ADC for high-speed, high-resolution conversion. As shown in the simplified block diagram Fig. 3, it consists of a parallel array of voltage comparators, a weighted resistor network, and encoding logic. It performs analog-to-digital conversion with one comparator for each possible level, and it feeds the input signal to all comparators. The digital output is taken from the encoding logic. Flash converters require $2_n - 1$ comparators for an n-bit binary word.

The SA DAC take more time to settle on a digital output value than the flash converter. However, an SA DAC in integrated circuit form costs less than a flash converter DAC IC, so now it is the DAC most widely used in the present generation of PC-based instruments.

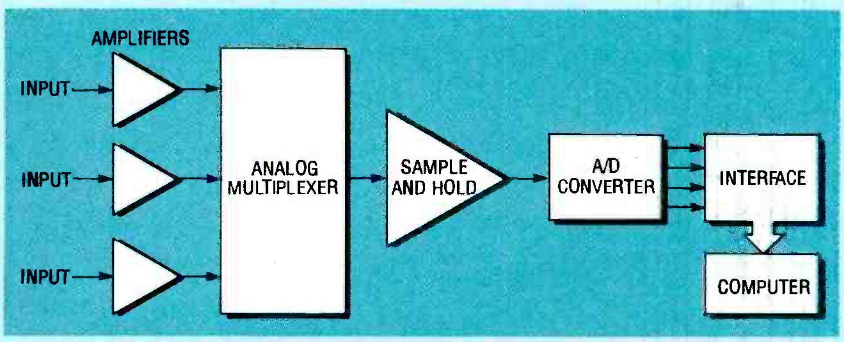


FIG. 1—MULTI-CHANNEL PC-BASED instruments include a single A/D converter and an input multiplexer that switches each channel.

and Hamming formats.

Most PC-based FFT spectrum analyzers process the data collected by a digital sampling oscilloscope through an FFT software program. The price of the FFT software varies according to manufacturer and display options, but can cover the rather wide range of $100 to $1000. While each program is dedicated to the PC board for which it is written, one can purchase software packages from vendors such as Geotest and Hyperception that support a variety of boards from different vendors.

The FFT calculations are done by the PC's CPU, so the faster the processor, the faster the data throughput. In some cases, installing a math coprocessor chip, such as an Intel 287 or 387, can improve throughput up to 10 fold. However, Intel's 486 processor with its built-in math coprocessor dramatically reduces calculation time.

Nevertheless, there are test situations in which even a 486-based PC with an FFT board isn't fast enough. This can occur when more than one channel of data is being processed.

However, adding a digital signal processor (DSP) integrated circuit to the ADC board can improve FFT throughput. By moving the FFT calculations from the computer to the DSP device,

WHERE TO BUY

Gage Applied Sciences, Inc.
5465 Vanden Abeele
Montreal, Quebec
Canada H4S 1S1
(514) 337-6893
CIRCLE 360 ON FREE INFORMATION CARD

Geotest
18242 West McDurmott St.
Suite A
Irvine, CA 92714
(714) 263-2222
CIRCLE 361 ON FREE INFORMATION CARD

Guide Technology Inc.
920 Saratoga Ave.
Suite 215
San Jose, CA 95129
(408) 246-9905
CIRCLE 362 ON FREE INFORMATION CARD

Hypercecption
9550 Skillman LB 125
Dallas, TX 75243
(214) 343-8525
CIRCLE 363 ON FREE INFORMATION CARD

Keithley Metrabyte Corp.
440 Myles Standish Blvd.
Taunton, MA 02780
(508) 880-3000
CIRCLE 364 ON FREE INFORMATION CARD

NCI
6438 University Dr.
Huntsville, AL 35806
(205) 837-6667
CIRCLE 365 ON FREE INFORMATION CARD

Optoelectronics Inc.
5821 NE 14th Ave.
Fort Lauderdale, FL 33334
(800) 327-5912
CIRCLE 366 ON FREE INFORMATION CARD

Quatech, Inc.
662 Wolf Ledges Pkwy.
Akron, OH 44311
(216) 434-3154
CIRCLE 367 ON FREE INFORMATION CARD

R.C. Electronics Inc.
6464 Hollister Ave.
Goleta, CA 93117
(805) 685-7770
CIRCLE 368 ON FREE INFORMATION CARD

Rapid Systems Inc.
4307 Leary Way NW
Seattle, WA 98107
(206) 784-4311
CIRCLE 369 ON FREE INFORMATION CARD

Signatec, Inc.
357 Sheridan St. No. 119
Corona, CA 91720
(714) 734-3001
CIRCLE 370 ON FREE INFORMATION CARD

Spectrum Signal Processing Inc.
100 Production Ct.
8525 Baxter Pl.
Burnaby, BC V5A 4V7
(604) 421-5422
CIRCLE 371 ON FREE INFORMATION CARD

the CPU is relieved of a heavy burden, giving it more time for other tasks.

Here again, Gage Applied Sciences seems to be offering the lowest-priced plug-in FFT spectrum analyzer. It costs only $100 more to add 1024-point FFT capabilities to the company's $595 CompuScope LITE digital oscilloscope board.

The most impressive FFT software program is VIEWDAC, distributed by Keithley MetraByte. This 32-bit Windows-based program is compatible with a large number of different PC boards from several vendors. It can execute a 25,000-point FFT in less than 25 seconds, and run through an FFT of 1024 points in just 57.7 milliseconds.

PC-BASED TEST INSTRUMENTS GO PORTABLE

Not all PC-based test instruments are anchored to the electronic workbench. They are just as much at home in the field as their conventional counterparts—and a lot more versatile. Many PC-based boards, such as Optoelectronics' PC10 Universal Frequency Counter, are sized to fit the current crop of laptop personal computers.

The 9-inch PC10 card easily fits in many PC/XT half-length slots, weighs under 6 ounces, and consumes just 2 watts of power. Moreover, this $335 board outperforms many handheld counters that cost ten times as much. It measures frequencies from sub-audio to 2.4 GHz with 10-millivolt sensitivity and 10-digit resolution. It also does something no portable counter can—it can save the data to disk for later study and analysis.

Signal generator

It would be hard to find a test lab or ATE setup that does not have a reliable, accurate signal generator. That instrument provides the test signals needed to "shake down" new designs or do quality assurance testing on parts in production.

Signal generators are based on three architectures: function, arbitrary, and pulse. The simplest is the function generator that can deliver sine, square, triangular, or pulse waveforms over a wide range of frequencies. An arbitrary generator allows the waveshape to be defined by plotting it on a grid, dot by dot, so it can be repeated as many times as desired. A pulse generator provides transistor-transistor logic (TTL)-compatible signals of varying widths and repetition rates.

All PC-based signal generators have a core of a digital-to-analog converter (DAC). Regardless of the shape of the waveform, each point is defined by a binary quantity that the DAC converts to an analog voltage. Normally, the waveform is stored in on-board RAM. The amount of RAM needed increases directly with the complexity of the waveform and the number of resolution bits.

Arbitrary waveform generators are versatile because some can fill all three requirements, but they cost no more than a comparable function or pulse generator. They carry an average price of bout $1300. However, good arbitrary waveform generators are available for less than $1000.

Frequency Counter

The universal frequency counter is reported to be losing sales to the versatile digital sampling oscilloscope, which can also display frequency and time measurements as well as waveforms. But recent advances in counter technology have resulted in new class of instruments called *time-interval analyzers*. Like a sampling oscilloscope, a time interval analyzer samples a small "window" of information and stores it for display or analysis. However, the counter characterizes the dynamic variation of time intervals or frequency, rather than the dynamic variation of the voltage.

A typical time-interval analyzer application is in the demodulation of an FM signal in near-real time. A significant advantage of this technique is attributable to its extraordinary dynamic range of more than 1000:1—while maintaining a high 1 part per million (ppm) resolution.

As with any sampling mea-

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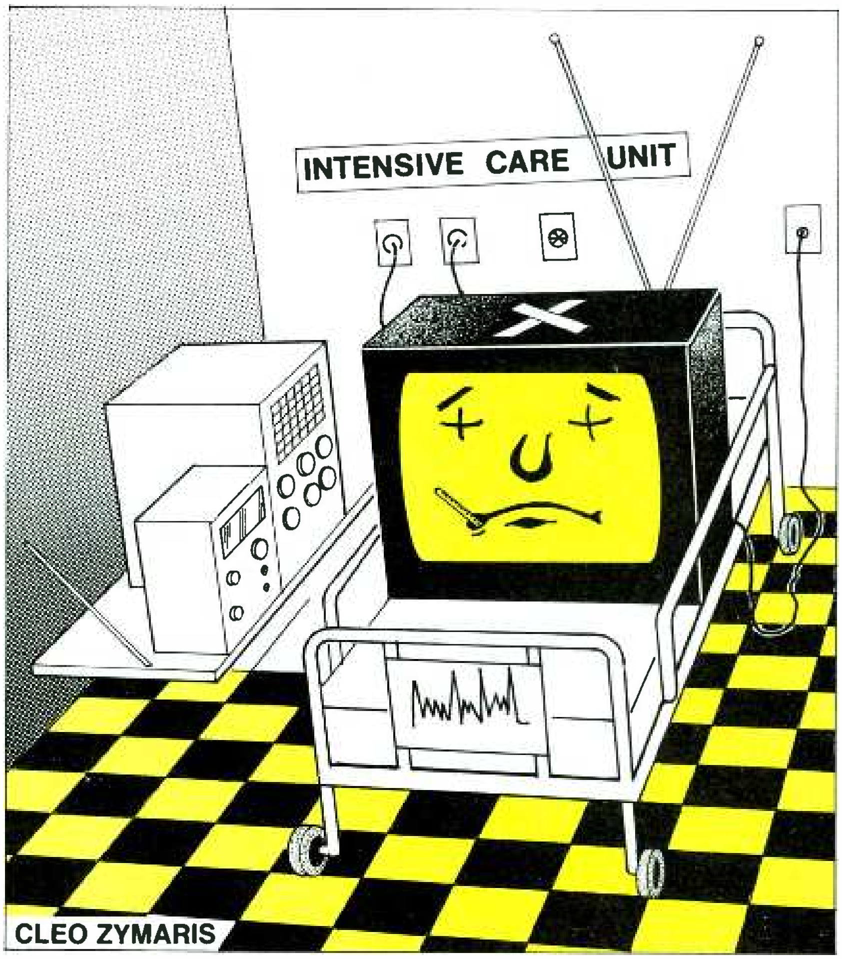


TV Service Case History

Learn about TV service from this step-by-step description of the repair of a faulty receiver.

BUSINESS STUDENTS LEARN MANagement techniques by studying business histories, and medical students learn to treat patients by studying medical case histories. Now you can learn how to repair a common problem in TV receivers by studying a service case history. The procedure is broken down into three steps: fault analysis, diagnosis, and repair.

The TV set discussed here is typical of many now in service around the world, and the fault is a common one and widely encountered, particularly after the set has been trouble-free for several years.

Case of the mute TV

The "patient" was a Sylvania CX-1161W 19-inch color TV receiver. It was brought in for repair because the owner reported that after turning it on, there was no picture, no sound, and no raster. These symptoms immediately suggested trouble in the power supply. Figure 1 is a pictorial of the main circuit board that contains the components which were tested to determine the location of the fault in the circuit.

Two schematic diagrams, Figs. 2 and 3, are simplified copies of applicable sections of the manufacturer's schematics with the manufacturer's component designations included; they do not follow **Electronics Now** drawing standards.

The hand tools needed to perform this repair were those that are basic for all TV service, and include screwdrivers, needlenose pliers, and a 40-watt soldering pencil. The test equipment used included a general-purpose oscilloscope, a digital multimeter with continuity checker, a plug-in isolation transformer, a variable transformer, and a laboratory, benchtop DC power supply with a built-in voltmeter and an ammeter.

The first step in the repair was the removal of the back cover from the set, giving access to the main circuit board. The principal components involved in this TV service case history are shown in Fig. 1, a drawing of part of the circuit board. Two fuses (FS500 and FS501) were mounted on the board. Figure 2 is a simplified schematic for the SCR-regulated power supply.

Because the power supply was suspected, the fuses were tested while the set was disconnected from the power line. Fuse FS501 was found to be blown. Figure 3, a simplified schematic of the horizontal deflection circuit, shows that FS501 is in the B+ line of that circuitry.

An ohmmeter check was made between the load side of fuse FS501 and ground and it showed a short circuit. The screws holding horizontal output transistor Q402 (in a TO-204 metal case) to the heatsink were removed, and the transistor was removed from its socket. Another ohmmeter check showed a collector-to-emitter short. The ohmmeter also confirmed that with Q402 out of the circuit, the short between FS501 and ground was cleared.

This TV set had an SCR-regulated, low-voltage power supply with a full-wave bridge rectifier connected directly across the 120-volt AC power line. An isolation transformer (it has separate primary and secondary windings to isolate it from the power line) was inserted between the AC outlet and the line plug of the TV set to insulate the TV set from earth ground. This transformer reduces the risk of electrical shock from the "hot" chassis, and permits grounded electronic test equipment to be used for servicing.

In Fig. 2, it can be seen that the raw DC output of the bridge rectifier is regulated by SCR513, which, in turn, is triggered by horizontal-output sweep pulses modified by the pulse-width regulator (SCR-gating circuit). All other voltages, including those for the cathode-ray tube heater, are generated by windings on horizontal output transformer T402 shown in Fig. 3.

When the TV set power switch S1 is turned on, approximately 158 volts of unregulated DC flows from the bridge rectifier through resistor R512, zener diode SC512, and diode SC518 to the gate of SCR513, dropping to a value of about 82 volts, which is sufficient to initiate TV set turn-on. (This 82-volt gate bias will not control SCR513 once it is on and +112 volts DC appears at its cathode.)

SCR513 conducts for the required duration of the horizontal sweep interval during each raster line under the control of the pulse-width regulator (SCR-gating circuit) to maintain the +112-volts DC output of SCR513. Notice that the winding between pins 22 and 24 of horizontal output transformer T402 is in series with the anode of SCR512. A negative spike from T402 turns off the SCR at the end of each conducting cycle interval in preparation for

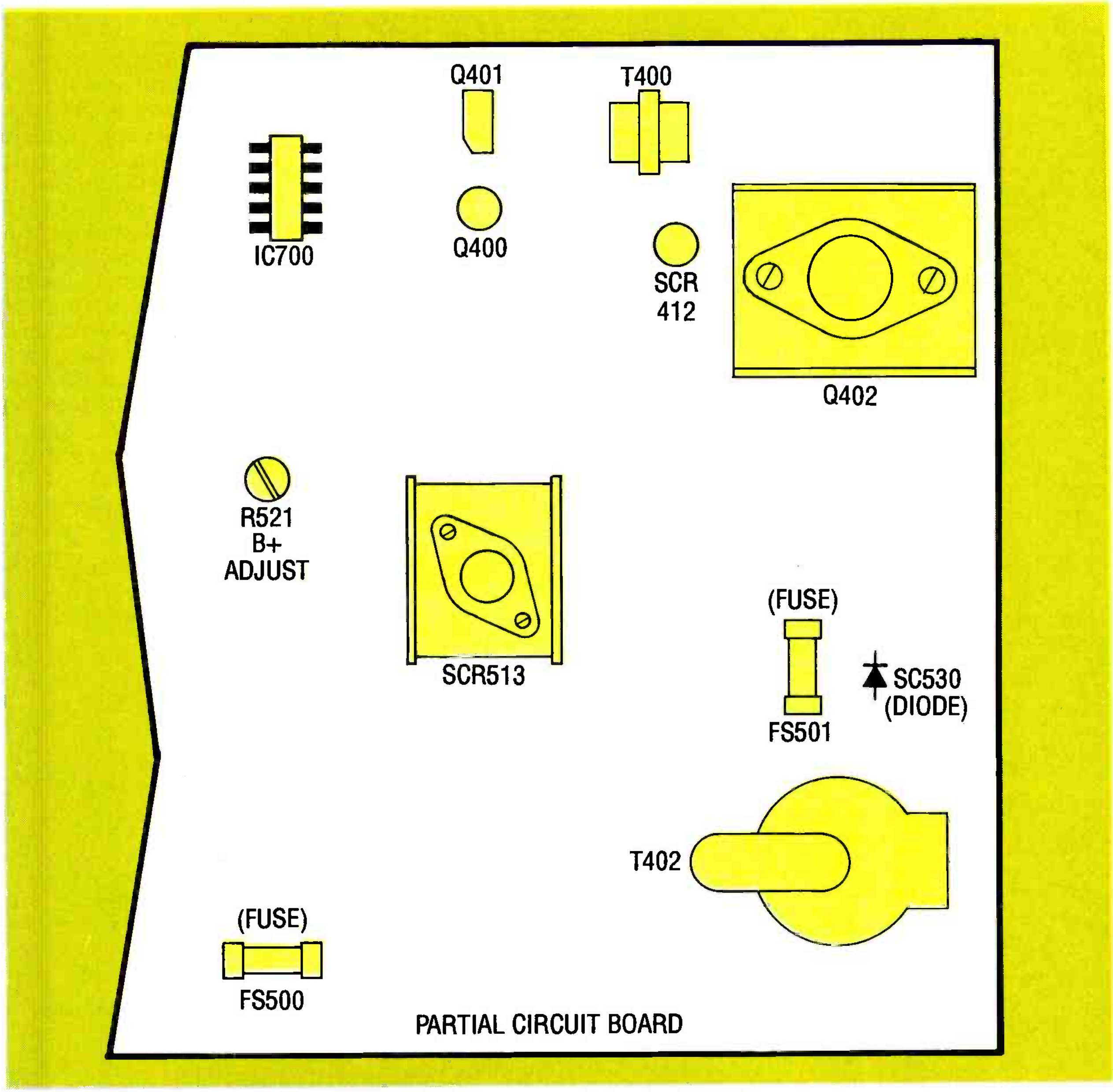


Fig. 1—LOCATION OF THE PRINCIPAL COMPONENTS on one end of a circuit board discussed in this case study of a TV repair.

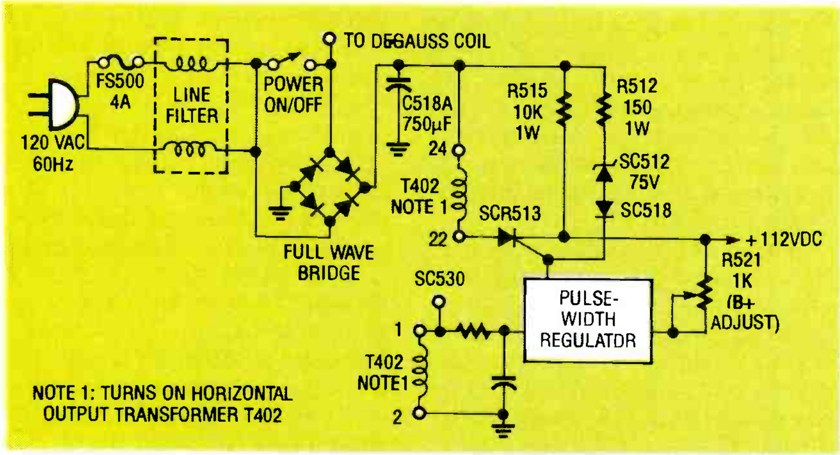


FIG. 2—SCHEMATIC OF THE SCR-REGULATED POWER SUPPLY for the color TV receiver discussed in this case history.

the next gate actuation. Also notice that the winding between points 1 and 2 of T402 is the source for the waveform that is controlled by the pulse-width regulator.

Immediately after the +112-volt line has been energized, current will flow through resistor R421 (see Fig. 3) to forward bias startup transistor Q400. Collector current flows through resistor R460. The resulting voltage at Q400's emitter is clamped to about 8.2 volts by diode SC404 and zener diode SC403. This voltage appears at pin 9 of the horizontal oscillator vertical countdown IC700, starting the oscillator.

Once the oscillator is started, rectifier SC530 rectifies the pulse voltage across pins 1 and 2 of T402 to develop +25 volts. That voltage is applied to diode SC706 and dropped by resistor R726 to appear at pin 9 as 8.6 volts at pin 9 of IC700 as 8.6 volts due to IC700's internal shunt zener regulator.

Horizontal deflection and, as a consequence the high voltage, can increase if a fault in the low-voltage regulator allows the voltage on the +112-volt line to increase beyond safe limits. It could result in a possible X-ray emission hazard. If this excessive voltage occurs, SCR412 turns on. With SCR412 conducting, the voltage at pin 9 of IC700 is grounded through diode SC404.

The gate of SCR412 senses the +112-volt and +220-volt lines. If either of these voltages is sufficient to cause the breakdown of zener diode SC409 (by sensing +112 volts) or SC409 and SC406 (by sensing +220 volts), SCR412 is turned on.

Repairing the TV

The proper operation of the horizontal deflection circuit was checked simply by substituting the proper voltage from an external power source. It was then possible to determine if the proper drive was being applied to the base of the horizontal output transistor Q402.

To make that test, a +25-volt supply was connected to the cathode of diode SC530 (the +25-volt source) and returned to chassis ground. Surprisingly, the 8.6-volt line at pin 9 of IC700 did not rise to its proper value. Was this due to a circuit fault or a sneak path?

Schematic Fig. 3 shows that current can flow from the +25-volt source (cathode of diode SC530) through the series string of diode SC706, 560-ohm resistor R726, and diode SC404 to the base of Q400 and on through its collector (which is only reverse biased when +112 volts is present). The path then

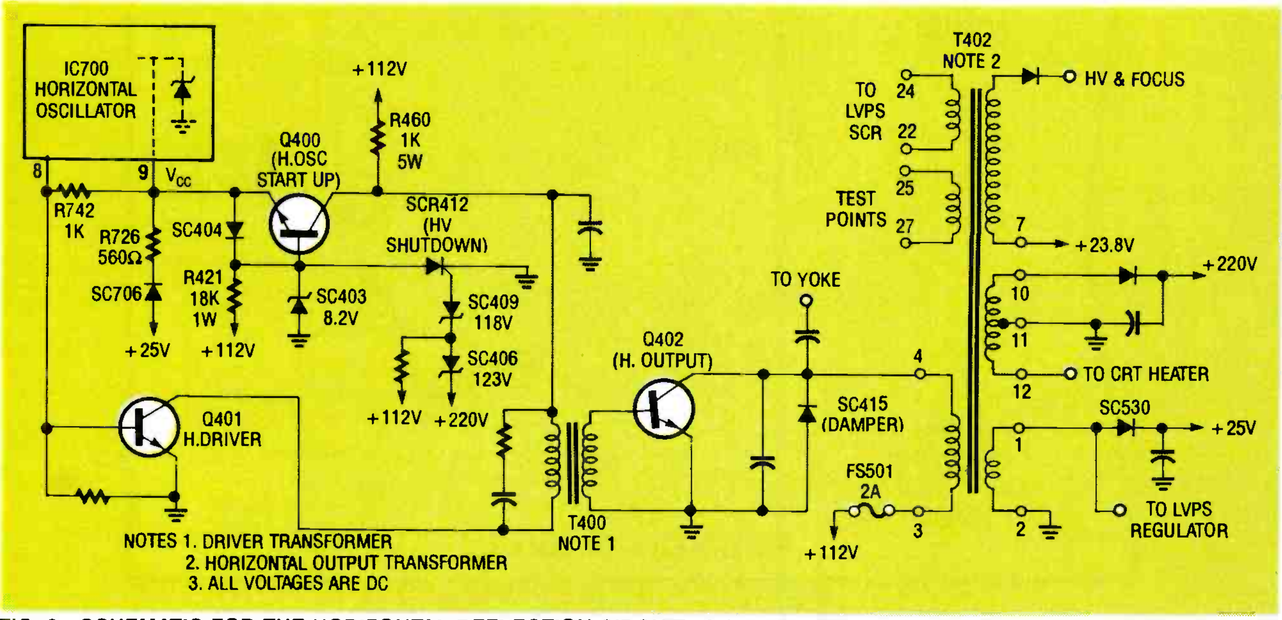


FIG. 3—SCHEMATIC FOR THE HORIZONTAL DEFLECTION CIRCUIT of the color TV receiver discussed in this case history.

goes through the primary of driver transformer T400 and on through the collector and emitter of horizontal driver Q401 to ground.

Transistor Q401 conducts under these static conditions because its base is forward biased by resistor R742. It is necessary, then, that Q400's collector be reverse biased. This was accomplished by applying about +40 volts to the +112-volt line. A convenient access point to the +112-volt line was found at fuse FS501. (This voltage is high enough to perform the reverse-bias function, and low enough to minimize damage to other components if there are circuit faults).

By applying both external voltages to the circuit and monitoring the base lead of horizontal output transistor Q402 with an oscilloscope, it was seen that horizontal drive was being generated. It shows up as a positive-going square wave that lasted about one half a line with an amplitude of approximately 0.7 volts (due to base-emitter clamp) and about 10 volts of negative spike at turn-off.

Transistor Q402 was replaced, and its collector was monitored with the oscilloscope. The waveform showed random pulses between the normal horizontal deflection pulses, as shown in Fig. 4-*a*. From experience, it can be expected that this symptom will be caused by one of the three following faults:

- Circuit loading due to shorted turns in the horizontal output transformer T402.
- A bad yoke on the cathode-ray tube (CRT).
- Excessive loading on one of the voltages developed by transformer T402.

In applying the external 40-volt test voltage, it was known that transistor Q402 would not be damaged because only 40 volts was being applied to the +112-volt line. However, as expected, the temperature of Q402's case rose. After the CRT yoke was disconnected at its plug, the waveform did not improve. The plug was then reconnected to the yoke.

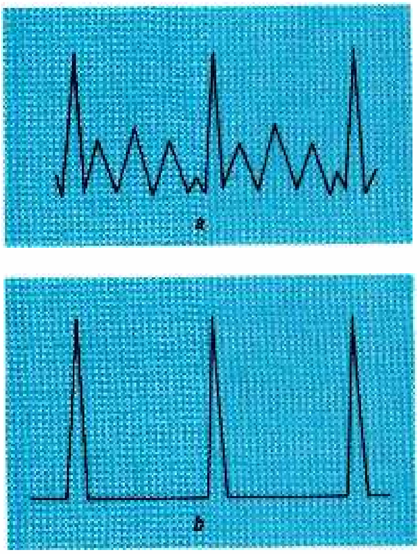


FIG. 4—OSCILLOSCOPE PATTERNS of spikes from horizontal output transistor Q402: with defective output transformer (*a*), and with new transformer (*b*)

Transformer T402 was then removed from the PC board and all of its wires were disconnected. Pins 3, 4, and 7 were reconnected with alligator-clip-terminated jumpers. With the application of the test voltages, the collector waveform of Q402 remained abnormal. The waveforms across the open windings were checked with an oscilloscope. The attempt to measure across pin 12 to pin 11 (ground) resulted in a half-inch spark discharge.

The spark discharge was an indication that transformer T402 had an internal short in its high-voltage winding. The short did not show up with a continuity check, indicating that the breakdown occurred only when voltage was applied to the transformer.

Transformer T402 was replaced, and all wiring connections were resoldered. The 25- and 40-volt test voltages were applied as before. The oscilloscope waveform taken at the collector of Q402 showed a waveform with only "clean" vertical pulses, as shown in Fig. 4-*b*.

The external power supplies were removed and fuse FS501 was replaced. It was now clear that the faulty tranformer was the cause of the problem. Power was applied through the isolation transformer in series with a variable transformer.

The oscilloscope was connected to test points 25 and 27 of T402, and the voltage was slowly increased while the oscilloscope pattern was observed. In addition, the +112-volt DC line was monitored with a digital voltmeter. When the voltage reached about 90 volts on that line, a picture appeared on the CRT screen.

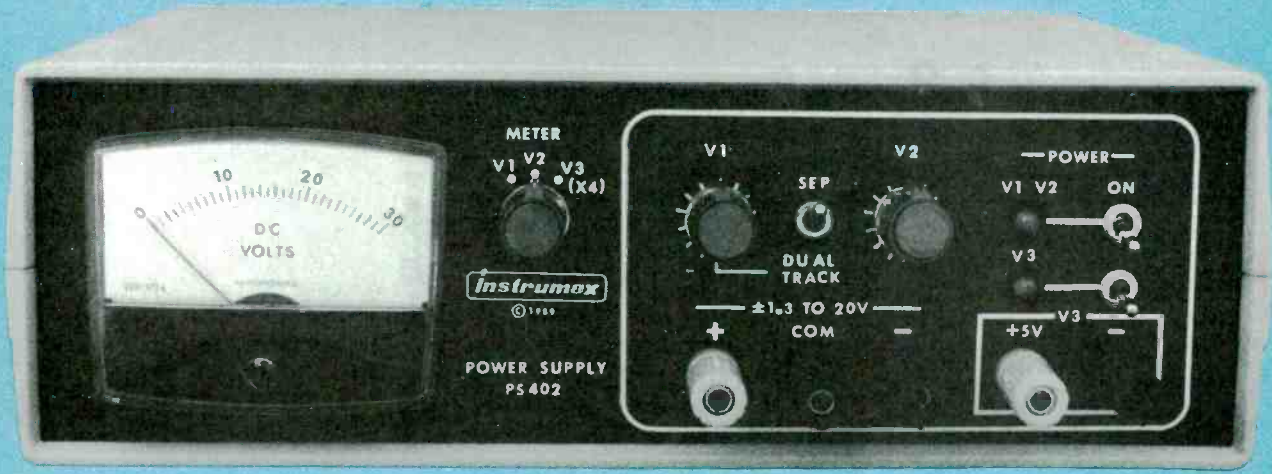
The AC line voltage was increased further until the +112-volt DC line reached its nominal value. Further increases in the input AC voltage did not cause a corresponding increase in voltage on the +112-volt DC line. This was an indication that the pulse-width regulator was functioning properly and not contributing to the problem.

The variable transformer was set to 120 volts on the AC line. Then a digital voltmeter was set to its DC-voltage scale, and its probes were placed between the +112-volt line (FS501) and ground. Potentiometer R521 was adjusted until a reading of +112 volts DC appeared on the meter. That measurement showed that B+was properly set. The TV set was then turned off and the test equipment was disconnected.

To verify that the TV set had been repaired, it was powered up again and allowed to run for several hours to see if any problems would occur. A visual and touch test was made on the operating TV set to confirm that there was no abnormal heating. The vertical sweep controls were adjusted so that the picture filled the screen properly. This completed the repair. The TV set was then ready to be returned to the customer.

The repair would not have been successful if the three basic steps of successful TV servicing were not carried out. The first step, as obvious as it might seem, is to correctly identify the symptoms of the fault. Second is to study the circuitry to diagnose the cause of the problem. Only then can the repair be undertaken with the hope of successfully completing the job. Ω

TRIPLE-OUTPUT DC POWER SUPPLY



Build a triple-output power supply—a power source you'll find quite useful around the home and shop.

JOHN F. KEIDEL

A DC POWER SUPPLY IS REQUIRED for nearly all electronic circuits. Some circuits are passive and don't need a power supply, and others draw power from some other source. However, all stand-alone active circuits need a power supply. It is difficult to find an off-the-shelf benchtop power supply that's both versatile and inexpensive—that's why you want to build it yourself. If you are looking for a multiple-output, bench-type power supply, look no further.

The power supply in this article features metered voltages on all sources, vernier controls (based on 10-turn potentiometers) on its plus and minus 1.3- to 20-volt outputs, and separate adjustments or dual-tracking operation for those same supplies. It also has a precise, fixed 5-volt logic supply that's completely independent of the variable supplies.

This triple-output power supply boasts exceptional line regulation: less than 1 millivolt output change for a 10% change in line voltage. Ripple and noise figures are less than 1 millivolt peak-to-peak at full-load. The maximum current available at each of the variable outputs is 200 milliamperes, and the fixed 5-volt supply can output 300 milliamperes.

Design considerations

Preregulator circuits precede the output regulators on all three supplies. The preregulators dissipate heat and maintain the voltage across the output regulators at a constant 3 volts. Also, a 30- to 40-milliampere thermal-stabilizing current is drawn by all supplies. That improves load regulation, and keeps the voltage-reference element contained within each output regulator at a constant temperature. The normally high heat dissipation of the regulators is greatly reduced by the preregulators.

Circuit operation

Figure 1 is the schematic of the positive and negative variable supplies; look at the positive supply. Tracking preregulator IC1, an LM317T, maintains a constant 3-volt drop across output-regulator IC2. The preregulator works as follows: Resistor R1 in conjunction with IC1's internal reference voltage (1.25 volts) causes a specific current to flow through R2 which, in turn, drops 1.7 volts across it. Those two voltages added together equal approximately 3 volts, which always appears across IC2.

Regulator IC2 establishes a programming current (1.25 volts divided by R3) that flows through front-panel control R18 (a 10-turn potentiometer), which thereby sets a positive output voltage equal to the adjustable drop across R18 plus the 1.25-volt reference. Resistor R4 provides the thermal-stabilizing current that was previously explained.

Capacitor C4 improves output ripple rejection. Capacitors C2, C3, and C5 bypass and stabilize their respective regulators by preventing spurious oscillations.

Regulator IC2 is protected from capacitive discharges caused by short circuits external to the supply. Diode D2 prevents C4 from discharging through IC2 by providing an alternate path.

Dual tracking keeps the positive and negative variable outputs at the same voltage level, but with opposite polarities. The dual-tracking function is made possible by IC5, a TL071 JFET op-amp configured as an inverting amplifier. In that configuration, IC5 tries to adjust its output so that both input voltages are equal. Since pin 3 of IC5 is tied to ground, it will therefore adjust its output in an attempt to make pin 2 equal to 0 volts.

Note that regulator IC4 is contained within the negative feedback loop of IC5 when S3 is in the DUAL TRACK position. Resistor R20 is the input to the IC5 inverting amplifier and R21 is its feedback resistor. Set up that way, IC4 automatically adjusts its output so that the voltage at the R20-R21 junction (pin 2 of IC5) is at 0 volts, thus matching the voltage at pin 3 of IC5. Because the value of R20 is equal to R21, and because the voltage at pin 2 of IC5 should equal 0 volts, IC4's output must match IC2's output, but with opposite polarity.

In the dual-tracking mode, R18 controls both output voltages. When switch S3 is in the SEPARATE position, R19 controls the negative voltage output while R18 still controls the positive output.

Because the circuit arrangement and operation of both the negative variable supply and the 5-volt logic supply shown in Fig. 2 are virtually the same as those for the positive supply, operating details of those two supplies will not be given. Note, however, that the 5-volt supply has a different ground (and ground symbol on the schematic) than the variable supplies.

Figure 3 shows the meter circuit. Switch S4 selects the output voltage to be displayed on the meter, and also handles the polarity and switches in the appropriate multiplier resistor (R24 to R26). Resistor R23 compensates for variations in different meters. Note that the ground connections for the bipolar supply and the logic supply are independent of each other, so unlike symbols are used in Fig. 3.

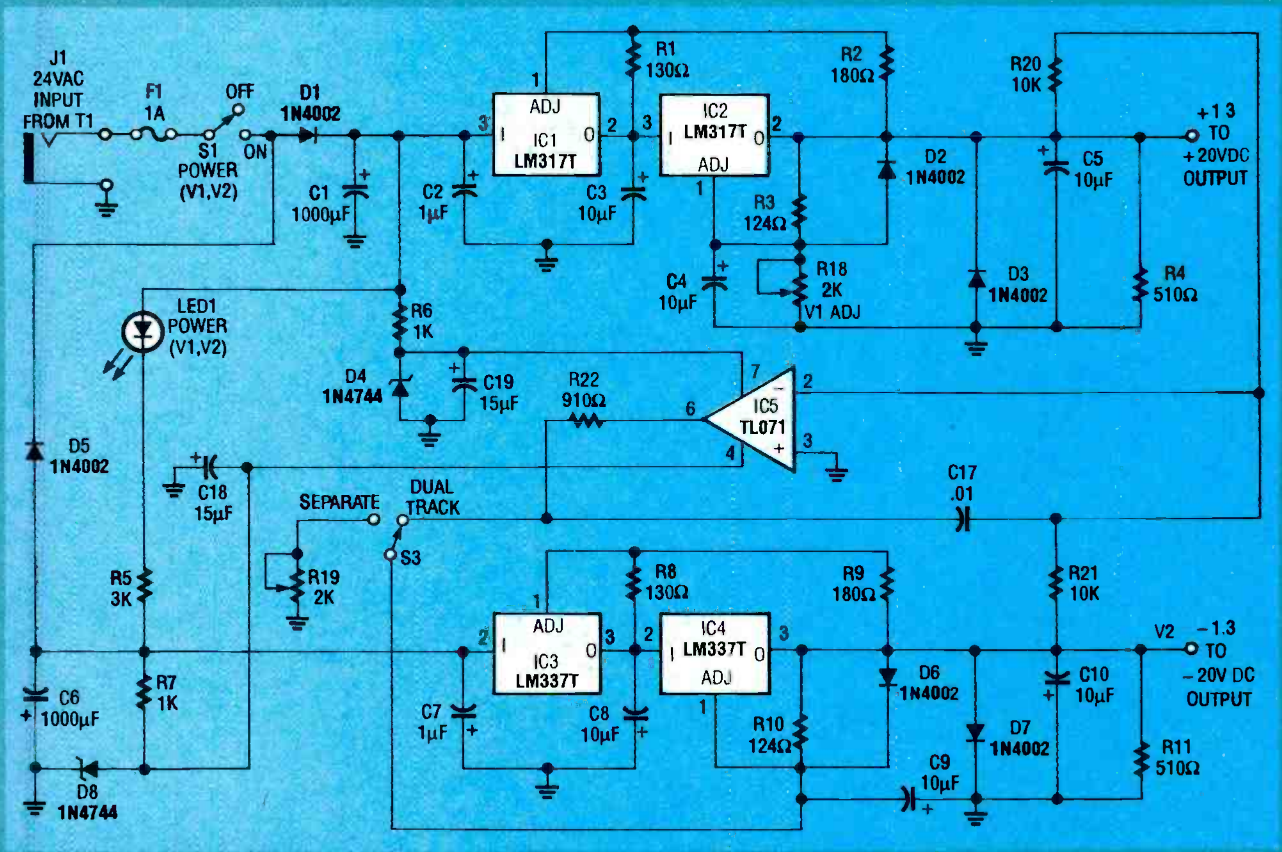


FIG. 1—SCHEMATIC DIAGRAM of variable bipolar 20-volt supplies. Switch S3 controls the dual-tracking option.

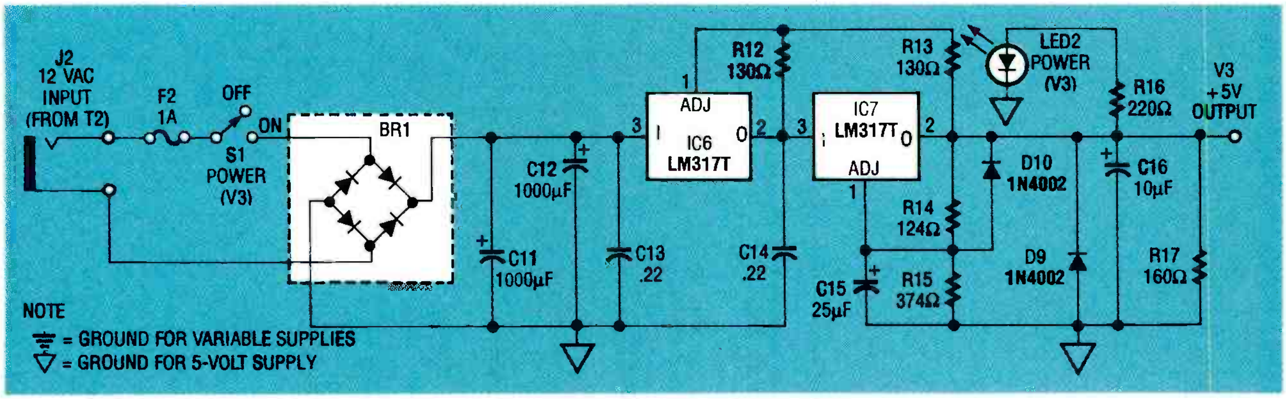


FIG. 2—FIVE-VOLT SUPPLY. The operation of this circuit is similar to the variable supplies, although it has a separate ground.

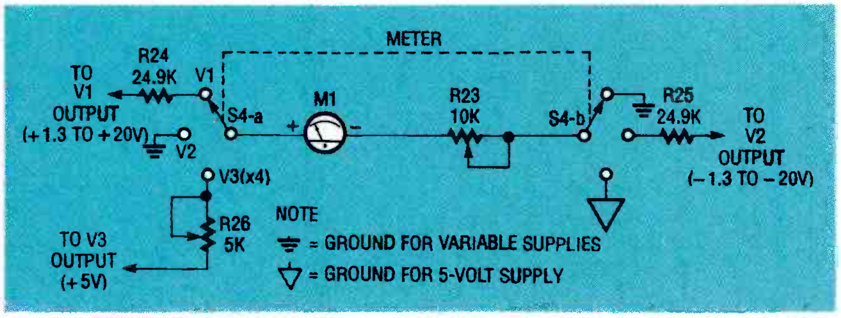


FIG. 3—METER CIRCUIT. This circuit allows the meter to display the output voltage.

Construction

A PC board is strongly recommended for the assembly of the power supply. You can make your own board using the foil pattern provided here, or order one from the source given in the Parts List. Mount all components as shown in parts-placement diagram Fig. 4. Check to see that all diodes, the bridge rectifier, and electrolytic and tantalum capacitors are positioned with the proper polarity before soldering them. A socket is recommended for IC5.

If the PC board is mounted in the recommended case, mounting bosses are provided as an integral part of the case. However, if you use a metal case rather than a plastic one, make sure the heatsinks don't touch the metal side panel. Similarly,

PARTS LIST

All resistors are ¼-watt, 5%, unless otherwise indicated.
R1, R8, R12, R13—130 ohms
R2, R9—180 ohms
R3, R10, R14—124 ohms, 1%, metal film
R4, R11—510 ohms, 2 watts
R5—3000 ohms, 2 watts
R6, R7—1000 ohms, 2 watts
R15—374 ohms, 1%, metal film
R16—220 ohms
R17—160 ohms, ½ watt
R18, R19—2000 ohms, 10-turn cabinet-mounted potentiometer (Digi-Key 73JB202-ND or equivalent)
R20, R21—10,000 ohms, 1%, metal film
R22—910 ohms
R23—10,000 ohms, PC-mount potentiometer
R24, R25—24,900 ohms, 1%, metal film
R26—5,000 ohms, PC-mount potentiometer

Capacitors
C1, C6—1000 µF, 50 volts, electrolytic
C2, C7—1 µF, 50 volts, tantalum
C3–C5, C8–C10, C16—10 µF, 35 volts, tantalum
C15—25 µF, 25 volts, tantalum
C11, C12, 1000 µF, 25 volts, electrolytic
C13, C14—0.22 µF, 50 volts, ceramic disc
C17—0.01 µF, 50 volts, ceramic disc
C18, C19—15 µF, 35 volts, tantalum

Semiconductors
IC1, IC2, IC6, IC7—LM317T adjustable positive regulator Motorola or equivalent
IC3, IC4—LM337T adjustable negative regulator Motorola or equivalent
IC5—TL071 JFET-input op-amp
D1–D3, D5–D7, D9, D10—1N4002 diode
D4, D8—1N4744 15-volt, 1-watt zener diode
LED1, LED2—red panel-mount light-emitting diode
BR1—Bridge rectifier, 1-amp, 50-volt (Digi-Key DB101-ND, or equivalent)

Other components
M1—15-volt DC panel-mount meter (Radio Shack 270-1754, see text)
J1, J2—Coaxial power-input jack (Radio Shack 274-1563 or equivalent)
S1, S2—Panel-mount SPST switch
S3—Panel-mount SPDT switch
S4—Panel-mount, 2-pole, 3-position rotary switch (Mouser Electronics 10WA155 or equivalent)
F1, F2—1-amp, 120-volt slow-blow fuse
T1—120 to 24 VAC wall transformer with female plug (Jameco Electronics AC2410 or equivalent)
T2—120 to 12 VAC wall transformer with female plug
Miscellaneous: project case (Jameco Electronics H2507), five binding posts, three instrument knobs, four 5-watt heat sinks (for IC2, IC4, IC6 and IC7, Digi-Key HS116-ND); two 10-watt heatsinks (for IC1 and IC3, Digi-Key HS114-ND), one 6-pin IC socket, two fuse holders, two LED sockets, wire, solder, hardware.
Note: The following is available from Instrumex, PO Box 490, Blue Bell, PA 19422:
• Ready-to-use PC board and silkscreened plastic front panel, both to fit case noted above—$23.00 + $2.00 S&H
PA residents include 6% sales tax. Allow -4 weeks for delivery.

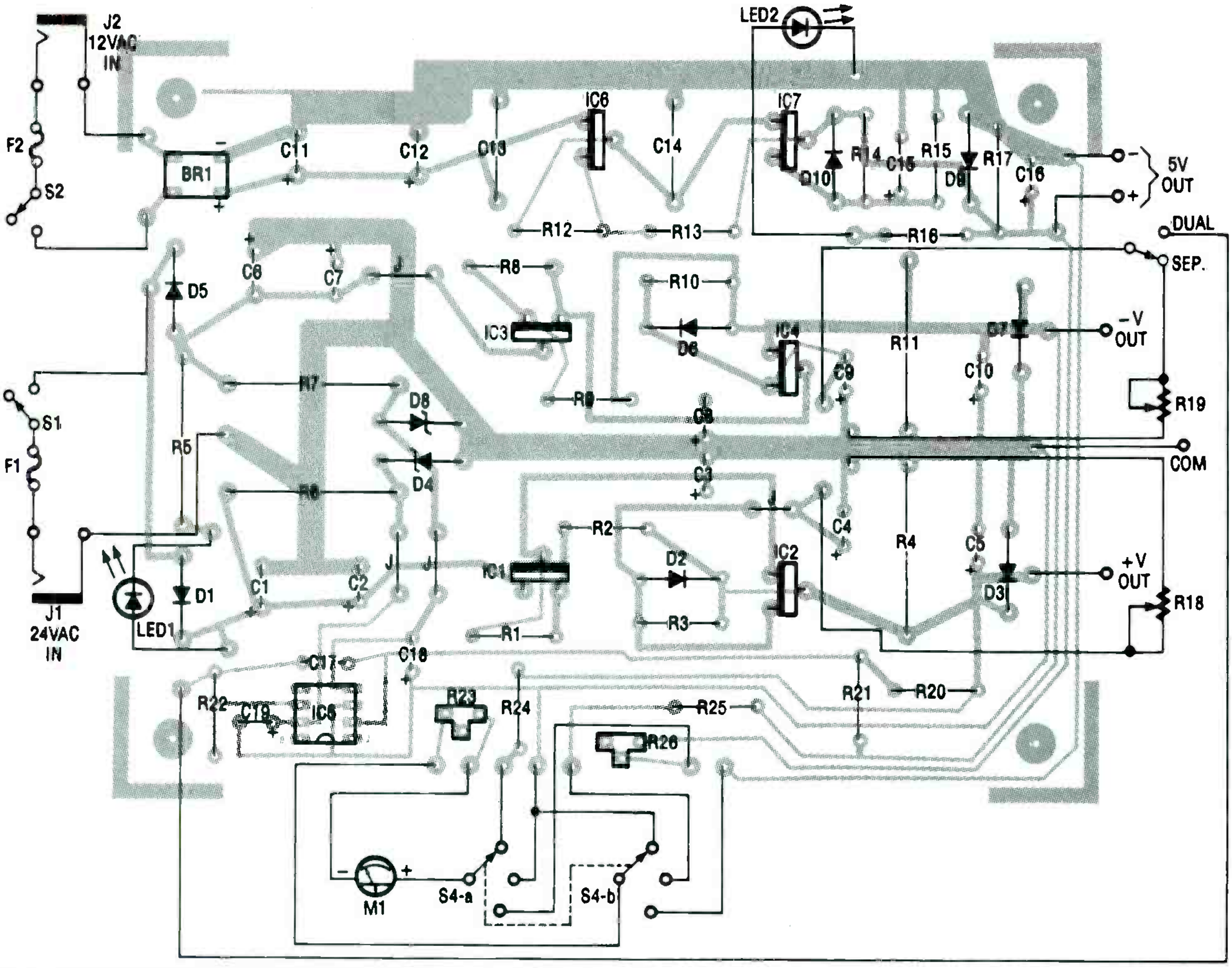


FIG. 4—**PARTS PLACEMENT DIAGRAM.** Be sure to heatsink the voltage regulators.

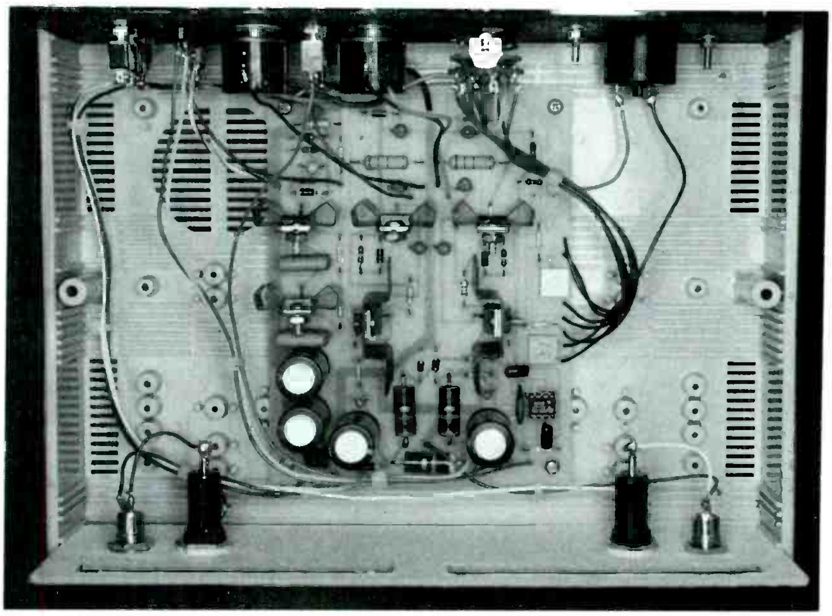


FIG. 5—**THE CIRCUITRY IS INSTALLED** in a plastic case with slots cut into the rear panel to allow heat to escape. Power input jacks and fuse holders are located below the vent slots.

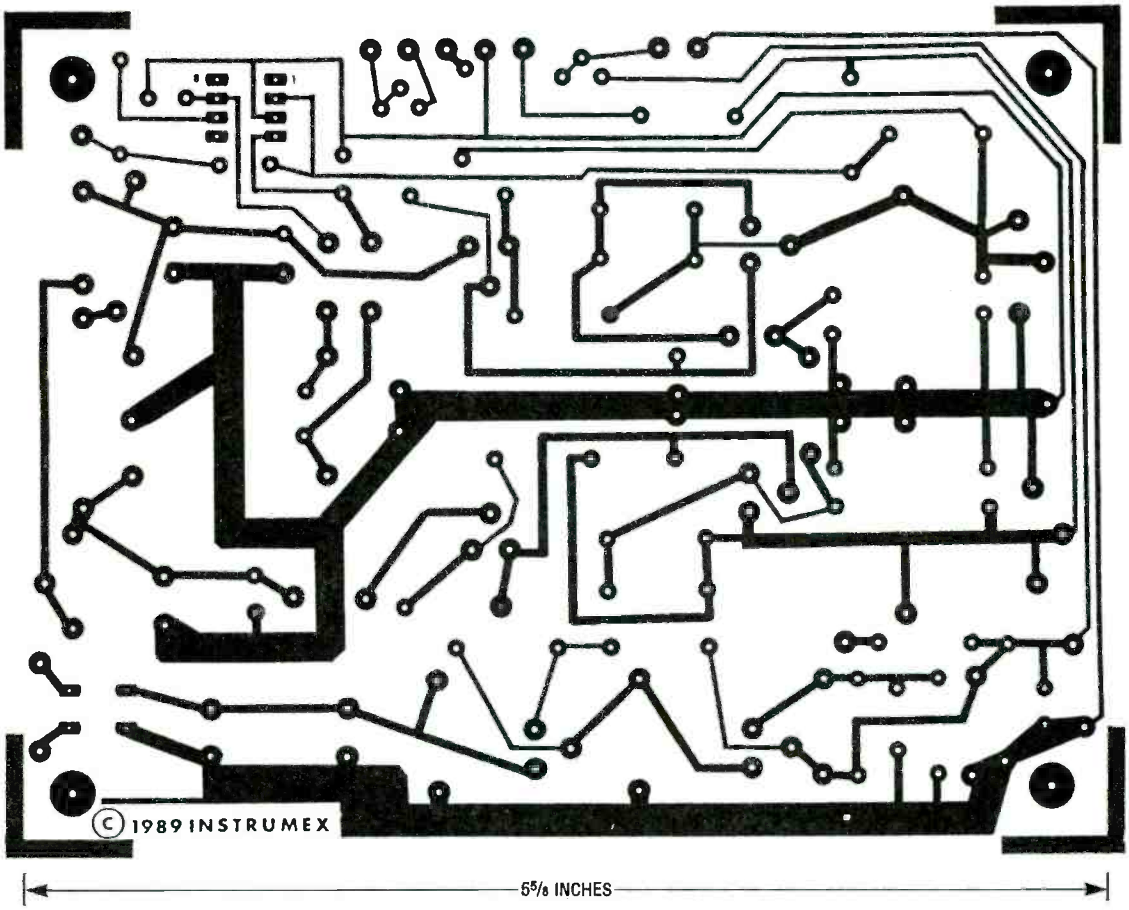
if the supply is constructed on perforated circuit board, make sure that the heatsinks for the different sources cannot touch one another.

Figure 5 shows the inside of the prototype unit. Notice the wiring arrangement for the back- and front-panel controls. Power line wires run along the side of the case from their respective fuse holders to power switches S1 and S2, and then they return to input pads on the rear of the PC board.

Use short lengths of 18-AWG copper wire from output pads on the PC board to the binding posts. Be sure to account for all the wiring connections shown in Fig. 4.

Meter M1 can be re-labeled to read from 0 to 30 volts, but that task requires a lot of care. Remove the meter's bezel and use white paper correction fluid to cover the original numbers. Then carefully remove the adhesive-backed meter face and apply new numbers (0, 10, 20 and 30) using rub-on transfer numbering.

When labeled replace the meter face and shift the pointer as required with the zerp ad-



FOIL PATTERN for the power supply.

justment. Avoid touching the fragile meter pointer!

The plastic case specified in the Parts List is the recommended choice for the project. However, holes in the panels can be difficult to drill because the plastic is brittle and is easy to crack. Alternatively, the panels can be made from sturdy 0.1-inch art board (rigid cardboard) purchased from a stationary or art-supply store. All holes can then be made with a hobby knife. You can also buy a silkscreened front panel from the source given in the Parts List.

Venting the cabinet is very important. Two 4-inch slots, ½-inch wide, were cut in the rear panel to let heat escape. Large rubber feet, although not included with the case, provide that "store-bought" look and prevent the power supply from sliding on the bench.

Calibration

Set the meter switch S4 to the V1 position and S3 to the "separate" position. Adjust the output of the positive variable supply to an exact 20 volts with an accurate external voltmeter. Adjust trimmer potentiometer R23 until the panel meter M1 reads exactly 20 volts. Next, set S4 to the V3 ($\times 4$) position, and adjust R26 until M1 reads 20 volts (5 volts $\times 4$). An external voltmeter can be used to verify the exact 5.0-volt output.

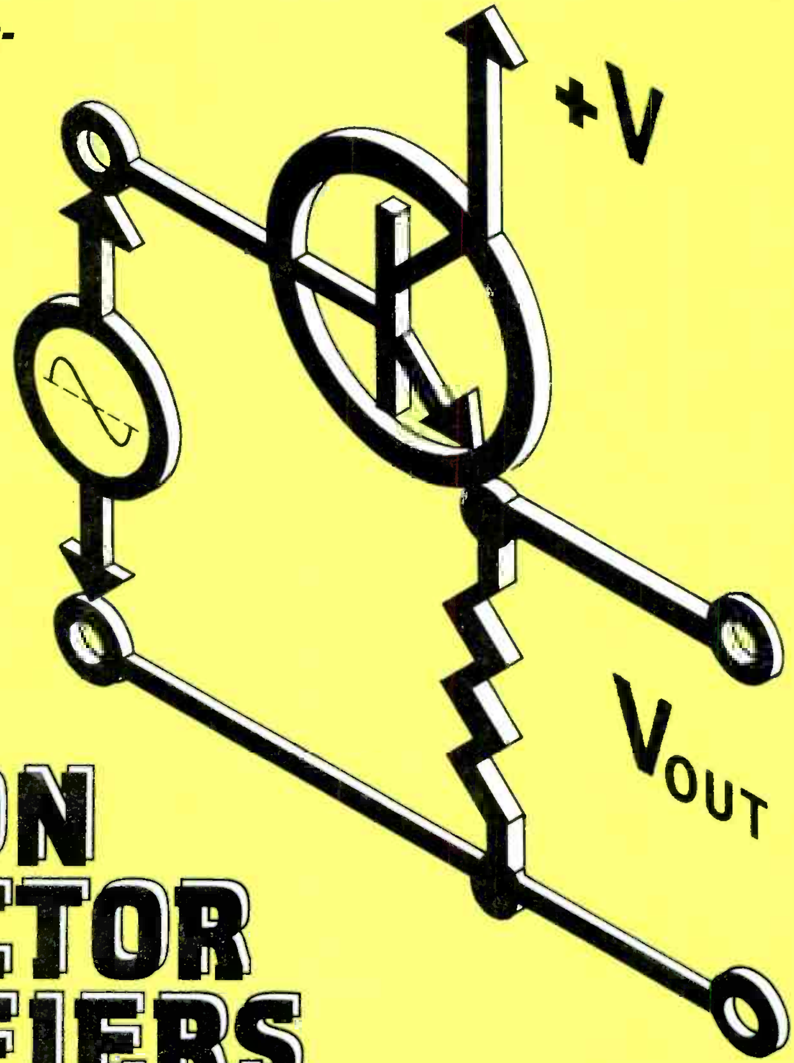
Using the supply

The variable bipolar and fixed logic power sources are completely independent of one another, so they can even be used to power separate projects. Both sources are also "floating," which permits a variety of configurations. For example, by connecting across the outputs of both variable supplies, a 2.6- to 40-volt output of either polarity, at 200 milliamperes can be obtained. By connecting the fixed logic source in series with the arrangement just described (aiding or opposing), a +7.6- to +45-volt or −2.4 to +35-volt output, respectively, at 200 milliamperes is produced.

When powering op-amps that require equal and opposite voltage sources for $+V_{CC}$ and $-V_{EE}$, use the power supply's dual tracking mode. When S3 is set to the "dual" position, potentiometer R18 simultaneously adjusts both variable bipolar sources. Otherwise, leave switch S3 in the "separate" position for independent adjustment.

All outputs are protected against short circuits in the external load by current limiting and thermal overload protective devices, which are built-in features of the voltage-control output regulators.

Any one binding post of a given supply can be connected to the common return of the circuit being powered. Also, that same terminal can be connected to earth ground for optimum safety, if required. Avoid electrically elevating the supplies by connecting them in series with other supplies. Ω



Learn about common-collector bipolar junction transistor (BJT) transistor amplifiers and apply this knowledge to the circuits that you design.

COMMON COLLECTOR AMPLIFIERS

RAY MARSTON

BIPOLAR JUNCTION TRANSISTOR (BJT) amplifiers are still widely used in modern electronic circuitry. This article focuses on practical variations of the common-collector or emitter-follower amplifier based on discrete transistors and Darlington pairs. Figure. 1 shows the basic common-collector amplifier and compares it with the common-base and common-emitter amplifiers. Table 1 sums up the performance characteristics of these three bipolar amplifiers.

The fundamentals bipolar of transistors were presented last month and the specifications of two widely available and typical discrete devices, the NPN 2N3904 and the PNP 2N3906 were given. The 2N3904 is included in most of the schematics in this article.

The expression h_{FE} in Table 1, known as a hybrid parameter, is the common-emitter DC forward-current gain. It is equal to the collector current divided by the base current ($h_{FE} = I_C/I_B$). The value of this variable for the 2N3904 NPN transistor is typically between 100 and 300, but in this article it is considered to be 200.

A lot of useful information can be gained simply by studying both Fig. 1 and Table 1. The common-collector amplifier (also widely known as the *emitter-follower*) has its input applied between its base and collector and its output is taken across its emitter and collector. The circuit is also referred to as the *grounded-collector* amplifier. In practical configurations its load resistor is in series with its emitter terminal.

The mathematical derivations of the results shown in Table 1 can be found in most basic electronics texts. However, for the purposes of this article, the important characteristics of the common-collector/emitter follower amplifier to keep in mind are:

- High input impedance
- Low output impedance
- Voltage gain approximately equal to unity
- Current gain approximately equal to h_{FE}

By contrast, notice that while

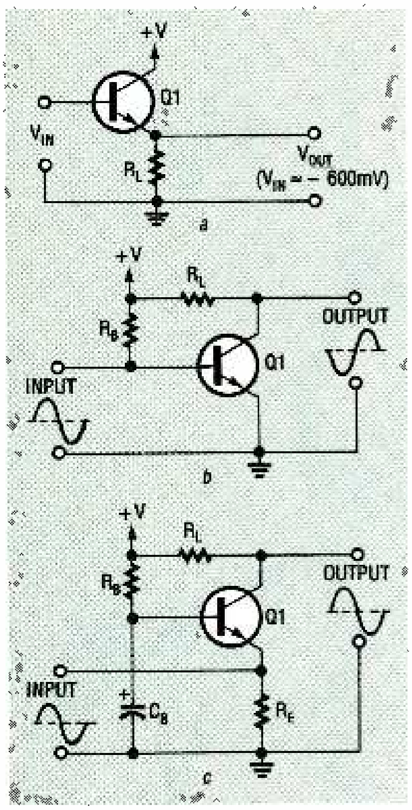


FIG. 1—THREE BASIC BIPOLAR transistor amplifier configurations.

the common-emitter and common-base amplifiers provide high voltage gain they offer only low-to medium input impedance. The applications for these circuits are governed by these characteristics.

Digital amplifiers

Figure 2 is the schematic for a simple NPN common-collector/emitter-follower digital amplifier. The input signal for this circuit is a pulse that swings between zero volts and the positive supply voltage. When the input of this circuit is at zero volts and the transistor is fully cut off, and the amplifier's output is also zero volts—indicating zero voltage phase shift.

When an input voltage exceeding +600 millivolts (the minimum forward bias for turn-on) appears across the input terminals, the transistor turns on and current I_L flows in load resistor R_L, generating an output voltage across R_L. Inherent negative feedback causes the output voltage to assume a value that *follows* the input voltage. The output voltage is

TABLE 1
CHARACTERISTICS OF THE THREE BASIC TRANSISTOR AMPLIFIERS

Parameters		Common Collector	Common Emitter	Common Base
Input impedance	Z_{IN}	High ($\approx h_{FE} \times R_L$)	Medium ($\approx$1.0K)	Low ($\approx 40\Omega$)
Output impedance	Z_{OUR}	Very low	$\approx R_L$	$\approx R_L$
Voltage gain	A_V	≈ 1	High	High
Current gain	A_I	$\approx h_{FE}$	$\approx h_{FE}$	≈ 1
Cutoff Frequency	—	Medium	Low	High
Voltage phase shift.	—	0°	180°	0°

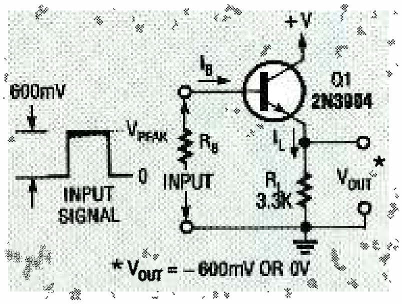


FIG. 2—COMMON-COLLECTOR digital amplifier.

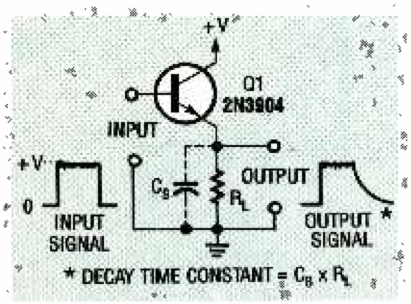


FIG. 3—EFFECT OF CAPACITOR C_S on output pulses.

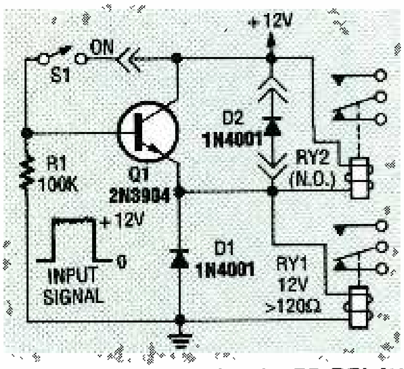


FIG. 4—EMITTER-FOLLOWER RELAY driver.

equal to the input voltage minus the voltage drop across the base-emitter junction ($\approx$ 600 millivolts).

In the Fig. 2 schematic, the input (base) current is calculated as:

$I_B = I_L/h_{FE}$

Because the circuit can have a maximum voltage gain of one, it presents an input impedance calculated as:

$Z_{IN} = R_L \times h_{FE}$

Inserting the values shown in Fig. 2 yields: Z_{IN} = 3300 ohms $\times$ 200 = 660,000 ohms

The circuit has an output impedance that approximately equals the value of the input signal source impedance (R_S) divided by the h_{FE} value of the transistor.

Because the circuit shown in Fig. 3 exhibits all of the common-collector amplifier characteristics previously discussed, it behaves like a unity-gain *buffer* circuit. If high-frequency pulses are introduced at its input, the trailing edge of the output pulse will show the time constant decay curve shown in Fig. 3. This response is caused by stray capacitance C_S (represented by dotted lines) interacting with the circuit's load resistance.

When the leading edge of the input pulse switches high, Q1 switches on and rapidly *sources* or feeds a charge current to stray capacitance C_S, thus producing an output pulse with a sharp leading edge. However, when the trailing edge of the input pulse goes low, Q1 switches off and effective capacitor C_S is unable to discharge or *sink* through the transistor.

However, C_S can discharge through load resistor R_L. That discharge will follow an exponential decay curve with the time to discharge to the 37 % level equal to the product of C_L and R_L.

Relay drivers

The basic digital or switching

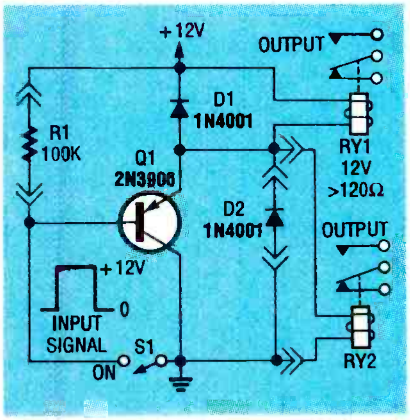


FIG. 5—PNP VERSION OF EMITTER-follower relay driver.

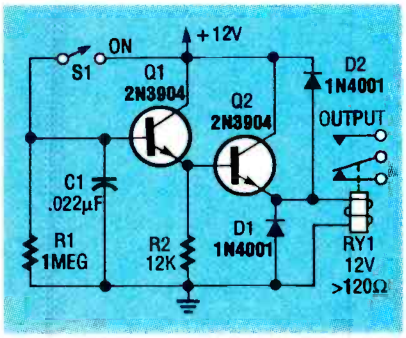


FIG. 6—NPN DARLINGTON EMITTER-follower relay driver.

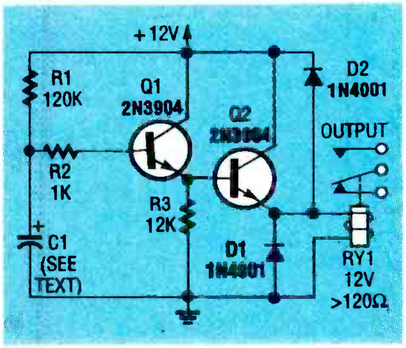


FIG. 7—DELAYED SWITCH-ON relay driver.

circuit of Fig. 2 can be put to work driving a wide variety of resistive loads such as incandescent filament lamps, LEDs or resistors. If the circuit is to drive an inductive loads such as a coil, transformer, motor, or speaker, a diode must be included to limit an input-voltage surge that could destroy the transistor when the switch is closed.

The schematic in Fig. 4 is a modification of Fig. 3 with with the addition of diode D1 across the load, in this case a relay coil, and switch S1 in the collector-base circuit. It can act in either the *latching* or *non-latching* modes. The relay to be actuated either by the input pulse or switch S1.

Relay RY1's contacts close and are available for switching either when a pulse with an amplitude equal to the supply voltage is introduced or S1 is closed. The relay contacts open when the input pulse falls to zero or S1 is opened.

Protective diode D1 damps relay RY1's switch-off voltage surge by preventing that voltage from swinging below the zero-volt supply level. Optional diode D2 can also be included to prevent this voltage from rising above the positive power supply value. The addition of normally open relay 2 (RY2) makes the circuit self-latching.

Figure 5 shows a same relay driver circuit organized for an PNP transistor. Again, the relay can be turned on either by closing S1 or by applying the input pulse as shown.

Both the circuits shown in Figs. 4 and 5 increase the relay's sensitivity by a factor of about 200 (the h_{FE} value of Q1). Consider a relay requires an activating current of 100 milliamperes and has a coil resistance of 120 ohms. The effective input impedance of the circuit (Z_{IN}) will be:

$Z_{IN} = R_L \times h_{FE} = 120 \times 200 = 24{,}000$ ohms

Only an input operating current of 1/200 of 100 milliamperes or 0.5 milliamperes is required.

Circuit sensitivity can be further increased by replacing transistor Q1 with the Darlington transistor pair of Q1 and Q2, as shown in Fig. 6. This circuit presents an input impedance of about 1 megohm and requires an input operating current of about 12 microamperes. Capacitor C1 protects the circuit from false triggering by high-impedance transient voltages, such as those induced by lightning or electromagnetic interference.

The benefits of the Darlington pair are readily apparent in relay-driving circuits that require time delay, such as those shown in Figs. 7 and 8. In those circuits, the voltage divider formed by resistor R1 and capacitor C1 generates a waveform that rises or falls exponentially.

That waveform is fed to the relay coil through the high-impedance Q1-Q2 voltage-following Darlington buffer. The circuit forces the relay to change state at some specified delay time after the supply voltage is applied. With the 120 K resistor R1 shown in both Figs.

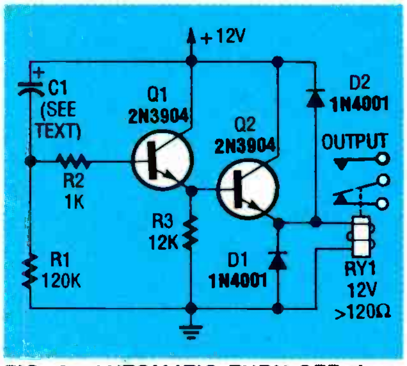


FIG. 8—AUTOMATIC TURN-OFF time-delay circuit.

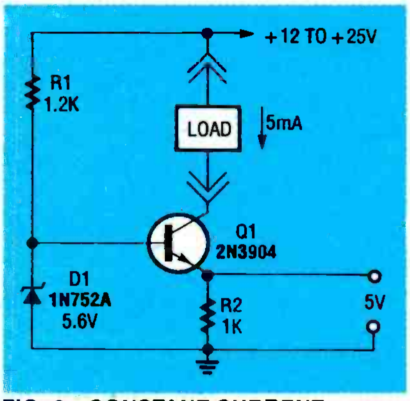


FIG. 9—CONSTANT-CURRENT generator provides 5-milliamperes.

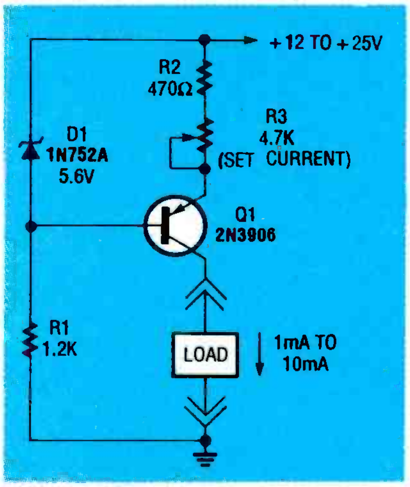


FIG. 10—GROUND-REFERENCED variable constant-current generator (1 to 10 milliamperes).

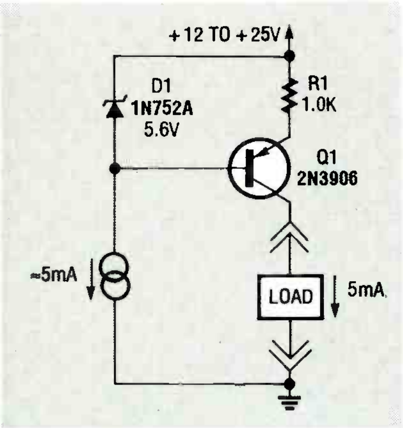


FIG. 11—PRECISION CONSTANT-current generator.

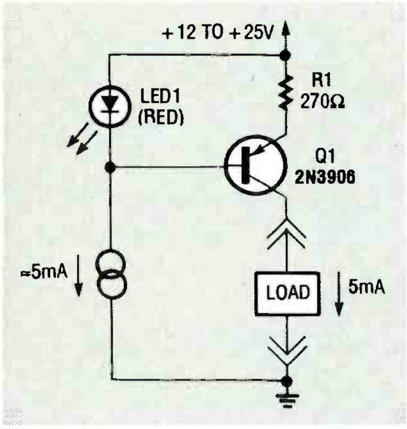


FIG. 12—THERMALLY STABILIZED constant-current generator with a LED voltage reference.

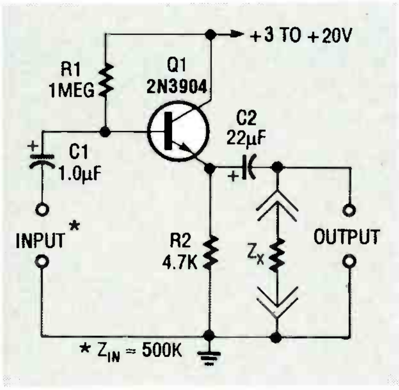


FIG. 13—SIMPLE EMITTER-FOLLOWER.

7 and 8, operating delays will be about 0.1 second per microfarad of capacitor value. For example, if C1 equals 100 microfarads, the time delay will be 10 seconds.

In the Fig. 7 circuit, consider that C1 is fully discharged so that the R1-C1 junction is at zero volts and relay RY1 is off (contacts open) when the power supply is connected. Capacitor C1 then charges exponentially through R1, and the increasing voltage is fed to the relay circuit through Darlington pair Q1 and Q2. That causes relay RY1's contacts to close after a time delay determined by the product of R1 and C1.

Consider that capacitor C1 in the Fig. 8 circuit is also fully discharged when the power supply is connected. The junction of R1 and C1 is initially at the supply voltage, and the relay contact close at that moment. Capacitor C1 then charges exponentially through R1, and the decaying voltage at the R1-C1 junction appears across the coil of relay RY1. The contacts of RY1 open after the delay determined by R1 and C1 times out.

Constant-current generators

A BJT can serve as a constant-current generator if it is connected in the common-collector topology and the power supply and collector terminals function as a constant-current path, as shown in Fig 9. The 1000-ohm resistor R2 is the emitter load. The series combination of resistor R1 and zener diode D1 applies a fixed 5.6-volt reference to the base of Q1.

There is a 600-millivolt base-to-emitter drop across Q1, so 5 volts is developed across emitter resistor R2. As a result, a fixed current of 5 milliamperes flows through this resistor from Q1's emitter.

Because of a BJT's characteristics, emitter and collector currents are nearly identical. This means that a 5- milliampere current also flows in any load that is connected between Q1's collector and the circuits's positive supply. This will occur regardless of the load's resistance value—provided that the value is not so large that it drives Q1 into saturation. Therefore, these two points are constant-current source terminals.

Based on the previous discussion, it can be seen that constant-current magnitude is determined by the values of the base reference voltage and emitter load resistor R2. Consequently, the value of the current can be changed by varying either of these parameters.

The Fig. 10 circuit takes this concept a step further. It can be seen, for example, that the circuit of Fig. 9 was *inverted* to give a ground-referenced, constant-current output. Adjustment of trimmer potentiometer R3 provides a current range of from 1 to about 10 milliamperes.

The most important feature of the constant-current circuit is its high dynamic output impedance—typically hundreds of

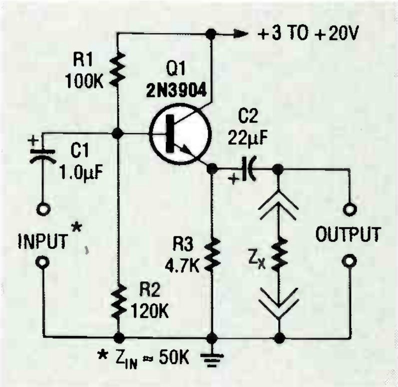


FIG. 14—HIGH-STABILITY EMITTER-follower.

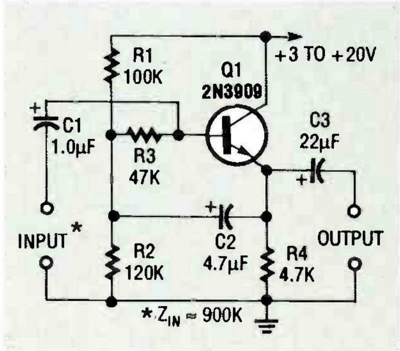


FIG. 15—BOOTSTRAPPED EMITTER-follower.

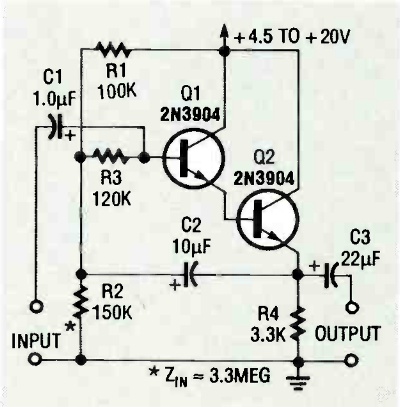


FIG. 16—BOOTSTRAPPED Darlington emitter-follower.

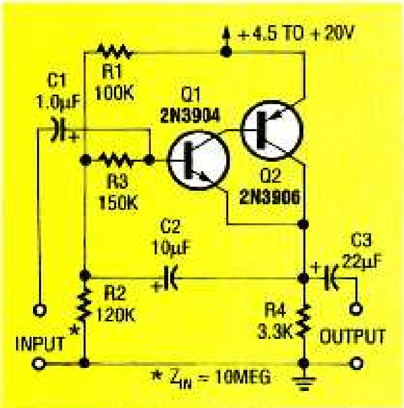


FIG. 17—BOOTSTRAPPED complementary feedback pair.

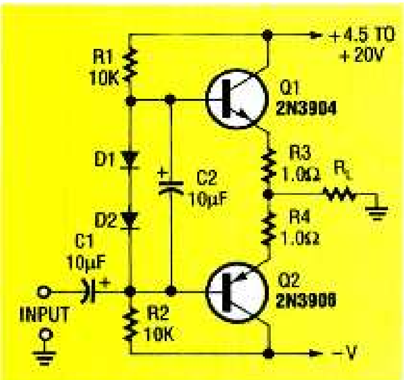


FIG. 18—COMPLEMENTARY EMITTER-follower with a split power supply and direct-coupled output load.

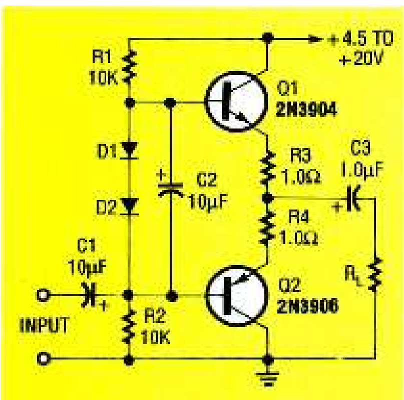


FIG. 19—COMPLEMENTARY EMITTER-follower with a single-ended supply and AC-coupled output load.

kilohms. The precise magnitude of constant current is usually unimportant in practical circuits. The circuits shown in Figs. 10 and 11 will work satisfactorily in many practical applications.

If more precise current generation is required, the characteristics of the reference voltages of these circuits can be improved to eliminate the effects of power source variations and temperature changes.

A simple way to improve the circuits in Figs. 9 and 10 is shown in Fig. 11. Resistor R1 in both circuits can be replaced with a 5-milliampere constant-current generator. (The symbol for a constant-current generator is a pair of overlapping circles.) With a constant-current generator installed, the current through zener diode D1 and the voltage across it is independent of variations in the supply voltage.

True high precision can be obtained if the industry standard reference zener diode D1 is replaced with one having a temperature coefficient of 2 millivolts/°C to match the base-to-emitter temperature coefficient of transistor Q1. However, if a zener diode with those characteristics cannot be located, satisfactory results can be obtained by substituting a forward-biased light-emitting diode, as shown in Fig 12.

The voltage drop across LED1 is about 2 volts, so only about 1.4 volts appears across emitter resistor R1. If the value of R1 is reduced from 1000 to 270 ohms, the constant-current output level can be maintained at 5 milliamperes.

Analog amplifiers

The common-collector/emitter-follower amplifier can amplify AC-coupled analog signals linearly if the transistor's base is biased to a quiescent value of about half the supply voltage. This permits maximum signal swings without distortion due to clipping. As shown in Figs. 13 and 14, the analog signals are AC-coupled to the base with capacitor C1, and the output signal is taken from the emitter through capacitor C2.

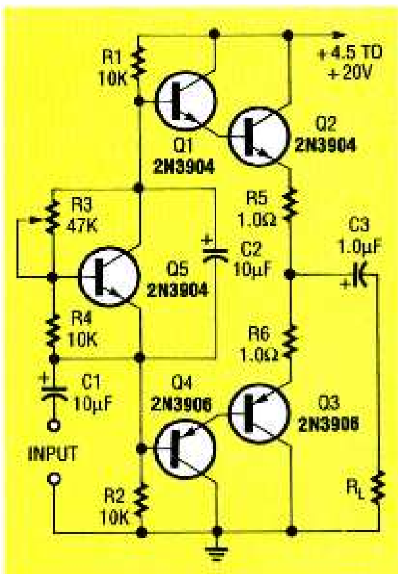


FIG. 20—DARLINGTON complementary emitter-follower with "amplified diode" biasing from transistor Q5.

Figure 13 shows the simplest analog common-collector/emitter-follower circuit. Transistor Q1 is biased by resistor R1 connected between the voltage source and base. The value of resistor R1 must be equal to the input resistance R_{IN} of the emitter-follower stage to obtain half-supply biasing. Input resistance R_{IN} (and thus the nominal R1 value) equals the 4.7 K value of R2 multiplied by the h_{FE} value of the Q1. In this circuit:

$$R_1 = 200 \times 4700 \approx 1 \text{ megohm}$$

A slightly more elaborate biasing method is shown in Fig. 14. However, its biasing level is independent of variations in transistor Q1's h_{FE} value. Resistors R1 and R2 function as a voltage divider that applies a quiescent half-supply voltage to Q1's base. Ideally, the value of R1 should equal the value of R2 in parallel with R_{IN}. However, the circuit works quite well if resistor R1 has a low value with respect to R_{IN}, and resistor R2 is slightly larger than R1.

In the circuits shown in Figs. 13, and 14, the input impedance looking directly into the base of transistor Q1 equals $h_{FE} \times Z_{load}$, where Z_{load} is equal to the combined parallel impedance of R2 and any external load Z_X that is connected to the output.

In these circuits, the base impedance value is about 1 megohm when Z_X is infinite. In practical circuits, the input impedance of the complete emitter-follower circuit equals the combined parallel impedance of the base and bias network. The circuit shown in Fig. 13 has an input impedance of about 500 kilohms, and the circuit shown

Continued on page 83

HEAT Management Techniques

Proper heat management ensures that components have a long and healthy life.

STEPHEN J. BIGELOW

WHENEVER CURRENT FLOWS through an electronic component, that component dissipates power. The power that the part dissipates depends on both the current flowing through the part and the voltage across it, and can be expressed by the relationship $P = IV$. Heat is an unavoidable byproduct of power dissipation.

For many circuits and components, heat generation is negligible or so small that the component can easily shed its heat buildup directly into the air. Some components, however, can not give up heat fast enough, and excessive heat buildup occurs. When that happens, the device can be permanently damaged. Thermal management techniques, such as the two common heatsink arrangements shown in Fig. 1, must be used to improve the component's heat dissipation. This article will explain the concepts of heat management and show you how to use manufacturers' specifications to optimize component operation. You can use these techniques with most semiconductor devices.

Thermal circuits

A *thermal circuit* is a graphic representation of thermal energy's path from its source to ambient air. In many ways, thermal circuits are analogous to electronic circuits as shown in Fig. 2.

Notice that there is resistance to the flow of heat between the heat source and the air. Such thermal resistance is generally defined as the difference in temperature across two points, divided by the power being dissipated between those two points. Thermal resistance is symbolized by the Greek letter theta (θ) and is measured in degrees Celsius per watt (°C/W). As a rule, thermal resistance should be as small as possible between the power-dissipating semiconductor junction(s) and the ambient air. Low thermal resistance between junctions ensures minimum junction temperature.

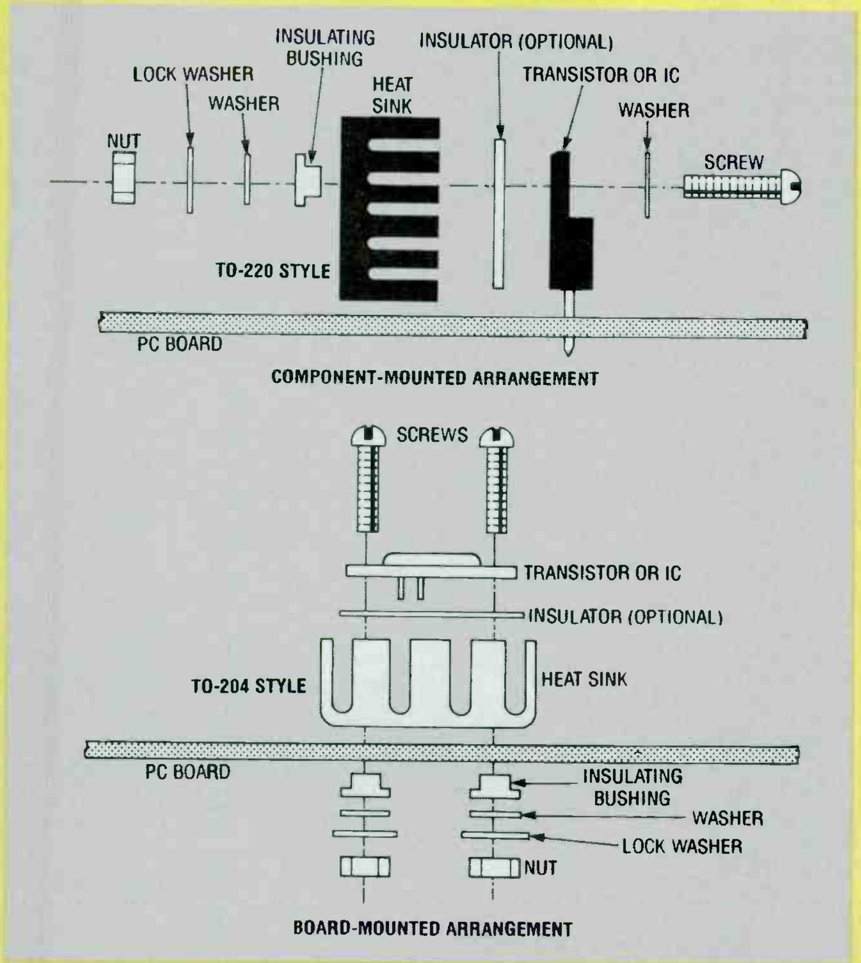


FIG.1—THERMAL MANAGEMENT TECHNIQUES, such as these two common heatsink arrangements, must be used to improve a component's heat dissipation.

Heat sources

Heat is generated by a semiconductor device when it dissipates power. A diode dissipates power at its anode-cathode junction. Junction power can be defined as the current through the junction multiplied by the voltage drop across the junction (typically 0.6 volt DC for a silicon diode). Power dissipated by a transistor is the voltage drop between the collector and emitter multiplied by the collector current. The power dissipated by an integrated circuit is the total power dissipated by all of the integrated circuit's transistors.

Thermal resistance

The heat generated in a semiconductor junction does not dissipate directly to the ambient air. Instead, a number of thermal resistance factors must be taken into account. The use of an external heatsink typically involves three major thermal resistances: (1) between the semiconductor junction and the device's case, (2) between the case and the attached heatsink, and (3) between the heatsink and the ambient air. Additional thermal resistance might be encountered if an electrical insulator is included between the case and heatsink.

For components that do not use an external heatsink, two thermal resistances must be considered: (1) between the semiconductor junction and the case, and (2) between the case and the ambient air. The total thermal resistance of a semiconductor arrangement can be summarized as shown in Table 1.

The junction-case resistance (θ_{JC}) represents the flow of heat from a device's junction(s) to its outer case. The value of θ_{JC} is specified by the manufacturer in his data sheet. A smaller number represents better heat flow. Junction-case thermal resistance is dependent on a number of physical characteristics. These include the size and shape of the semiconductor die and its mount, the quality of the die-to-mount bond, and the thermal conductivity of the die, mount, bond, and any interconnecting wires.

Although you have no control over θ_{JC}, you can select a particular case style that minimizes the thermal resistance. Figure 3 shows what the different case styles look like. For example, a transistor in a TO-220 case has better (lower) θ_{JC} than a similar device in a TO-92 case. Table 2 shows a selection of typical θ_{JC} values for a variety of case styles. If you do not have access to manufacturer's data, Table 2 can provide a good approximation.

The use of a heatsink can have a tremendous impact on a component's operating temperature. For some devices, a good heatsink can mean the difference between a successful project and a failure. The goal of a heatsink is to move as much heat as possible away from the device's junction, and that's accomplished through the choice of heatsink, mounting arrangement, and mounting materials.

Thermal resistance at the case-sink barrier (θ_{CS}) is a function of many factors: (1) the cross-sectional contact area be-

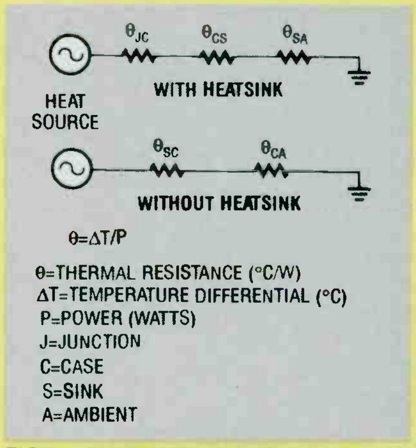


FIG.2—A THERMAL CIRCUIT is a graphic representation of thermal energy's path from its source to ambient air. Thermal resistance is defined as the difference in temperature across two points, divided by the power being dissipated between those two points. Thermal resistance should always be as small as possible.

TABLE 1—THERMAL RESISTANCE SUMMARY

$\theta_{JA} = \theta_{JC} + \theta_{CS} + \theta_{SA}$	A) Total thermal resistance with a heatsink only.
$\theta_{JH} = \theta_{JC} + \theta_{CS} + \theta_{INS} + \theta_{SA}$	B) Total thermal resistance with a heatsink and electrical insulator.
$\theta_{JA} = \theta_{JC} + \theta_{CA}$	C) Total thermal resistance with no heatsink.

θ_{JA} = thermal resistance, junction to ambient
θ_{CS} = thermal resistance, case to sink
θ_{JC} = thermal resistance, junction to case
θ_{SA} = thermal resistance, sink to ambient
θ_{INS} = thermal resistance, of electrical insulator
θ_{CA} = thermal resistance, case to ambient

*All values of θ are in °C/W.

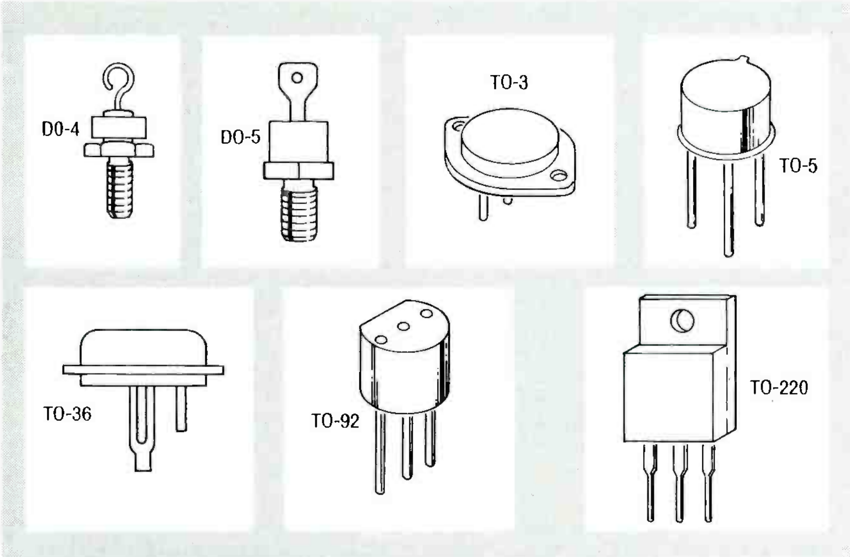


FIG. 3—DIFFERENT COMPONENT PACKAGES vary in their ability to dissipate excess heat. Here are some of the more popular styles.

TABLE 2—θ_{JC}

Device Case	Thermal Resistance (°C/W) Low	Typ.	High
DO-4	2.0	—	7.0
DO-5	1.0	—	1.5
TO-3 (TO-204)	0.5	1.5	6.0
TO-5	20.0	35.0	50.0
TO-6	0.5	0.8	1.0
TO-8	1.5	7.0	15.0
TO-36	0.5	0.8	1.0
TO-61	0.5	1.0	2.0
TO-63	0.4	1.0	2.0
TO-66 (TO-213)	1.5	7.0	15.0
TO-92 (TO-226)	175.0	—	200.0
TO-116 (kovar)	59.0	—	91.0
TO-116 (copper)	30.0	35.0	40.0
TO-225	4.0	9.5	15.0
TO-127	1.0	—	2.0
TO-202	15.0	20.0	25.0
TO-220	1.7	3.0	5.0

tween the case and sink, (2) the mating surface finish and flatness, (3) the contact force (or pressure) applied between mating surfaces, and (4) the thermal resistance of any electrical insulating material needed between the case and sink. You have a lot of options in determining each of these factors.

There are some general rules to follow in determining the characteristics of your heatsink. It is important that the surface areas of the component case and heatsink be as flat and smooth as possible. Thermal joint compound conducts heat very well, and can be applied between the case and heatsink to help overcome any surface irregularities. Large contact areas between the case and heat sink are helpful because larger mating areas will improve heat conduction. Wherever screws are used to attach a heatsink to a case, be sure they are securely fastened to flatten any concave or convex mating surfaces and achieve good contact pressure.

The actual θ_{CS} for a heatsink is specified for each particular model in a manufacturer's catalog, but Table 3 provides a typical range of thermal resistance values for several major classes of heatsinks.

When electrical insulators are used to isolate a case from a heatsink, heat must still be transferred as effectively as possible. Unfortunately, most electrical insulators will add some thermal resistance (θ_{INS}) to the case-sink interface. Table 4 shows a selection of various electrical insulators. If your mounting arrangement requires the use of an insulator, add θ_{INS} to θ_{CS} from Table 3. Notice that an insulator's thermal resistance depends on the type of semiconductor package being insulated.

The ability of any heatsink to dissipate heat depends on a complex combination of conduction, convection, and radiation. With all three of these factors working together, it's difficult to calculate the specific thermal resistance of any one particular heatsink. Fortunately, manufacturers typically list the sink-ambient thermal resistance (θ_{SA}) of their various models. However, if you don't have manufacturer's information, Table 5 lists values that permit good approximations.

As a general rule, larger, thicker heatsinks with more substantial surface area have a lower θ_{SA} than small, thin heatsinks. Also notice that Table 5 shows θ_{SA} for both still and moving air; when air is in motion, the effect of convective cooling is enhanced, and more heat is carried away—in other words θ_{SA} is much lower.

Every kind of semiconductor case differs in its ability to dissipate heat directly into the air, but no case does this as well as heatsinks. The major reason is that air does not support conduction or radiation very well—most heat is carried into the air by convection. When a heatsink is used, heat from a device's case is carried into the heatsink directly by conduction. Without a heatsink, however, a device must rely solely on convection to take the heat away. As a result, the thermal resistance from a case to the ambient air (θ_{CA}) is usually quite high, and heavily dependent on the size and shape of the particular case. Generally speaking, larger metal cases (such as a TO-3) dissipate heat better than small, low-profile plastic cases (such as a TO-92).

Manufacturer's specifications for a device might list θ_{CA} along with θ_{JC}, but don't count on it. Table 6 shows some common values of θ_{CA} for a variety of case styles. Note that small cases can have large thermal-resistance values that can seriously limit the device's ability to handle power.

Total resistance

Here is a practical example of how to calculate total thermal resistance from the junction to ambient air (θ_{JA}) for a TO-3 case transistor using a large metal heatsink in still air with no electrical insulator. Remember that a TO-3 is a metal-case-mounted semiconductor. From Table 2 you know that θ_{JA} is the sum of θ_{JC}, θ_{CS}, and θ_{SA}. Junction-case thermal resistance can be found on a manufacturer's data sheet, or approximated from Table 2 (typically 1.5 °C/W). Case-sink thermal resistance for a metal-cased, case-mounted semiconductor can be approximated from Table 3 (0.5 °C/W). Table 4 is not needed because we're not using an insulator. The sink-ambient thermal resistance for a large metal heatsink operating in still air can be found in manufacturer's data for the heatsink, or approximated from Table 5 (5.0 °C/W). These characteristics yield a total thermal resistance of 1.5 + 0.5 + 5.0, or a θ_{JA} of 7 °C/W.

As a second example, under the same conditions as the previous example, you can determine the total thermal resistance when no heatsink is used. From Table 1 you know that the value of θ_{JA}—with no heatsink—is the sum of θ_{JC} and θ_{CA}. Junction-case thermal resistance remains the same as in the previous example (1.5 °C/W), but the value of case-ambient thermal resistance is now obtained from Table 6 (30 °C/W). This yields a new θ_{JA} of 1.5 + 30.0, or 31.5 °C/W—a very significant increase.

Safe operation

It is often desirable to estimate the junction temperature of a semiconductor to determine if it will work within its safe operating range. This technique can be handy for estimating heatsink performance.

The maximum junction temperature (T_j) of a semiconductor device is normally specified on the manufacturer's data sheet. However, maximum junction temperature will not exceed 100 °C for a germanium device, or 200 °C for a silicon device. If T_j is exceeded, even for a brief period of time, the device will probably be destroyed.

Junction temperature can be calculated from the relationship shown in Table 7. Power dissipation (P_d), total thermal resistance (θ_{JA}), and ambient temperature must be known. For most practical purposes, ambient temperature can be considered to be room temperature, or 25 °C. Steady-state power dissipation in a semiconductor device can easily be calculated from Ohm's Law as the voltage drop across a device multiplied by the current flowing through the device. Total thermal resistance can now be approximated from the contents of Tables 2 through 6.

By comparing the specified maximum junction temperature with the value calculated from present operating conditions, you can estimate a device's operating temperature. If

TABLE 3—θ_{CS}

Heatsink Application, Type	Typical (w/ joint compound)	Common Devices Covered
Metal-case, case-mounted	0.1 to 0.7	TO-3, 66
Plastic-case, lead-mounted (screw-on sink)	0.9 to 1.3	TO-126, 127, 220
Plastic-case, lead-mounted (clip-on sink)	1.0 to 2.5	TO-126, 127, 220
Plastic-case, lead-mounted (clip-on sink)	2.0 to 5.0	TO-92
Metal-case, lead-mounted (screw-on sink)	1.5 to 2.7	TO-5, 8, 18
Metal-case, lead-mounted (clip-on sink)	0.9 to 1.5	TO-5, 8, 18
IC's (screw-on sink)	0.5 to 1.2	DIP 0.3 in. wide
IC's (clip-on sink)	2.0 to 5.0	DIP 0.3 in. wide

TABLE 4—θ_{INS}

Insulator Material	Device	Thermal Resistance (°C/W)
Beryllium oxide	TO-3 (TO-204) TO-66 TO-220	0.22 0.45 1.4
Mica	TO-3 (TO-204) TO-66 TO-220	1.6 1.6 5.2
Plastic	TO-3 (TO-204) TO-66 TO-220	0.8 1.6 5.2
Silicone rubber	TO-3 (TO-204) TO-66 TO-220	1.2 2.4 7.9
Other elastomers	TO-3 (TO-204) TO-66 TO-220	0.7 1.4 4.6

Note: Joint compound is assumed to be used with all insulators except those with silicone rubber and other elastomer insulation.

TABLE 5—θ_{SA}

Heatsink Application,	Type	Range	Small	Medium	Large
Metal-case, Case-mount	Still air Moving air	4.0–29.0 1.5–8.0	20.0 8.0	13.0 5.0	5.0 15.0
Plastic-case, Lead-mount (screw)	Still air Moving Air	5.0–30.0 2.0–10.0	30.0 10.0	17.0 6.0	6.0 2.0
Plastic-case, Lead-mount (clip)	Still air Moving air	30.0–40.0 9.0–10.0	40.0 10.0	35.0 9.5	30.0 9.0
Plastic-case, Lead-mount (clip)	Still air Moving air	83.0–150 60.0–77.0	150 77.0	130 68.0	85.0 60.0
Metal-case, Lead-mount (screw)	Still air Moving air	6.0–33.0 3.0–11.0	32.0 10.0	18.0 7.0	6.0 3.0
Metal-case, Lead-mount (clip)	Still air Moving air	40.0–150 15.0–45.0	150 45.0	80.0 30.0	40.0 15.0
IC's (screw)	Still air Moving air	7.0–30.0 3.0–18.0	30.0 18.0	20.0 12.0	7.0 3.0
IC's (clip)	Still air Moving air	21.0–30.0 7.0–10.0	30.0 10.0	25.0 8.5	20.0 7.0

your calculations indicate a temperature well below the maximum T_j, the device will probably run safely. If, however, your calculations indicate a temperature close to or higher than the maximum T_j, the device will be in a region where it can destroy itself. Power dissipation, thermal resistance, or ambient temperature must be reduced to reduce the junction temperature to a safe level. Although ambient temperature can be adjusted, it is usually impractical to do so.

Here are some basic examples. According to a manufacturer's data sheet, the maximum junction temperature for a TO-220 transistor is 150 °C. Determine if the transistor is operating safely if it's dissipating 2 watts of power in still air. It has a medium-sized, bolt-on heatsink and a beryllium oxide insulator attached.

Because power dissipation (2 watts) and ambient temperature (assumed 20°C) are known, it is necessary to estimate the value of total thermal resistance. Total thermal resistance (θ_{JA}) is the sum of θ_{JC}, θ_{CS}, θ_{INS}, and θ_{SA}. From Tables 2 through 5 you know that the junction-case thermal resistance is 7.0°C/W (Table 2), case-sink thermal resistance for a plastic-cased, lead-mounted semiconductor is 1.1°C/W (Table 3), insulator thermal resistance is 1.4°C/W (Table 4), and the thermal resistance for the associated heatsink is 17.0 °C/W (Table 5). Therefore, the total thermal resistance is 26.5°C/W.

Next, the junction temperature can be calculated from the relationship given in Table 7. A device consuming 2.0 watts of power at 26.5°C/W yields a temperature rise of 53.0°C (2.0°C × 26.5°C) above ambient temperature. Adding the ambient temperature yields a junction temperature of 78°C (53.0°C + 25.0°C). Since the calculated value of T_j is far below the specified maximum of 150°C, the TO-220 transistor should be operating safely within its limits.

As another example, remove the heatsink and insulator from the transistor in the previous example and determine whether or not the transistor will still be operating safely. Keep in mind that power dissipation (2 watts), maximum specified T_j (150°C), and ambient temperature (25°C) remain the same—the factor that changes substantially is the total thermal resistance. Without a heatsink, θ_{JA} can be estimated as the sum of junction-case and case-ambient thermal resistance. Since the transistor remains unchanged, the junction-case thermal resistance remains unchanged at 7.0°C/W (Table 2). The case-ambient thermal resistance for a TO-220 transistor can be estimated from Table 6 (60°C/W). That yields a total thermal resistance of 67.0°C/W (7.0°C + 60.0°C). Using the formula of Table 7, the new junction-temperature rise would be 134.0°C (2.0 × 67.0) above ambient. The junction temperature would then be 159°C (134.0°C + 25.0°C).

Our calculations indicate that, without a heatsink, power dissipation will result in a destructive temperature at the device junction of 159°C which exceeds the specified limit of 150°C. Although the device might work for some time at that level, thermal breakdown is almost inevitable. To prevent damage to the device, it is necessary to replace the heatsink or reduce power dissipation.

Maximum power

Instead of calculating a junction temperature to determine whether or not a semiconductor is operating safely, you can use the formula in Table 7 to calculate the maximum allowable power dissipation for a desired set of operating conditions. This approach allows you to select a desirable junction temperature (below the specified maximum T_j) and then find the maximum power dissipation that will not exceed the desired junction temperature.

The first step in calculating maximum power is to determine the maximum junction temperature for the semiconductor device that you are using. A T_j rating is usually listed on a manufacturer's data sheet. Power dissipation can then be calculated from the relationship given in Table 8. Ambient temperature is still considered to be 25°C. The total thermal resistance (θ_{JA}) can be estimated from Tables 2 through 6.

It is usually undesirable to operate the device at or around its maximum T_j. Use a smaller value in your calculations to allow a safety margin. For example, a 20% safety margin for a maximum T_j of 160°C would be 128°C (160 – (160 × 0.2)). A 50% safety margin would be 80 °C (160°C – (160°C × 0.5°C)). Incorporating a safety margin into the calculations ensures that the device will be running within safe limits at all times.

TABLE 6—θ_{CA}

Device Case	Thermal Resistance (typical)
TO-3 (TO-204)	30.0
TO-5	150.0
TO-8	75.0
TO-18	300.0
TO-36	25.0
TO-39	150.0
TO-46	300.0
TO-60	70.0
TO-66	60.0
TO-92	100.0
TO-126	80.0
TO-127	70.0
TO-220	60.0

TABLE 7—T_j FORMULA

$$T_j = (P_d)(\theta_{JA}) + T_a$$

T_j = Junction temperature (°C)
P_d = power dissipation (watts)
θ_{JA} = total thermal resistance (°C/W)
T_a = ambient temperature (°C)

TABLE 8—P_d FORMULA

$$P_d = \frac{T_j - T_a}{\theta_{JA}}$$

P_d = Power dissipation (watts)
T_j = desired junction temperature (°C)
T_a = ambient temperature (°C)
θ_{JA} = total thermal resistance (°C/W)

Look at another example. A transistor in a TO-66 case has a maximum T_j of 180°C. The transistor has a metal case and a case-mounted, medium-sized heatsink with a mica insulator. You want a 40% safety margin for the junction temperature, so you can estimate the maximum allowable power dissipation for the device in still air.

First estimate the total thermal resistance of the arrangement from Tables 2 through 5. Total thermal resistance (θ_{JA}) is the sum of θ_{JC} (7°C/W from Table 2), θ_{CS} (0.5°C/W from Table 3), θ_{INS} (1°C/W from Table 4), and θ_{SA} (13°C/W from Table 5). That yields a sum of 21.5°C/W total thermal resistance.

The desired junction temperature is the maximum specified T_j minus a 40% safety margin. That works out to a desired junction temperature of 108°C (180°C – (180°C × 0.40°C)).

Finally, use the formula in Table 8 to determine the maximum allowable power dissipation for the device. With a temperature difference of 83.0°C (108°C – 25°C) and a thermal resistance of 21.5°C/W, the maximum allowable power dissipation (P_d) for the device is 3.9 watts (83/21.5).

With the same transistor and desired junction temperature from the previous example, let's estimate the maximum allowable power dissipation for the device in still air with a large heatsink and no insulator. A large heatsink and no insulator will substantially reduce the total thermal resistance of the arrangement. Total thermal resistance is now the sum of θ_{JC} (7°C/W from Table 2) θ_{CS} (0.5°C/W from Table 3), and θ_{SA} (5.0°C/W from Table 4); θ_{JA} is now 12.5°C/W, a large decrease from the last example. The desired junction temperature stays the same at 108°C, so the temperature difference between junction and ambient remains constant at 83°C. Finally, use Table 8 to find the value of maximum allowable power dissipation. The value of P_d is 6.6 watts (83/12.5).

As you can see, just using a larger heatsink and removing the insulator can virtually double the allowable power of the device, and still keep the device's junction temperature 40% below its maximum rating. After allowable power is calculated, you can work backwards with Ohm's law to gauge the appropriate voltage and current for operating the transistor. In some instances, minor circuit changes might be necessary to limit voltage or current.

Power derating

The power that a device can

dissipate is closely related to its junction temperature. Once a certain junction temperature is reached, the maximum allowable power drops off in a linear fashion as junction temperature continues to increase—and the junction temperature can only climb to T_j before permanent device damage occurs.

Most manufacturers will show a detailed plot of power dissipation vs. junction temperature with their specifications. This type of plot, known as a *power derating curve*, is illustrated in Fig. 4. The derating factor (DF) is essentially the slope of the line that represents how quickly allowable power will drop off as temperature increases. Expressed another way, DF is the inverse of the junction-case thermal resistance ($1/\theta_{JC}$). Remember that power derating is for the device alone—it does not consider the effects of an attached heatsink.

TABLE 9—MAXIMUM POWER

$P_X = P_M - (T_X - T_O)DF$

P_X = Allowable power dissipation (watts)
P_M = maximum power dissipation (from derating curve) (watts)
T_X = desired temperature point (°C)
T_O = derating temperature knee (°C) (from derating curve)
DF = derating factor (W/°C)

The maximum safe power rating anywhere within the linear region of the derating curve is given by the formula in Table 9. To determine power at any linear point, calculate the derating factor from either the line's slope, or from the inverse of θ_{JC}. Then use the relationship in Table 9. Look at the following example.

Using the power derating curve of Fig. 3, find the maximum allowable power dissipation for the device at a junction temperature of 130°C. First it's necessary to calculate the power derating factor (DF) of the curve. Figure 3 shows that DF is equal to the maximum allowable power (10 watts), divided by the difference between the maximum junction temperature (180°C) and the temperature where derating begins (100°C). The DF is then 0.125 (10/(180°C – 100.0°C)). Then, use the formula in Table 9 to find allowable power at the desired temperature point (130°C). Allowable power (P_x) is equal to 6.25 watts (10 – ((130 – 100) × 0.125)).

Notice that when its junction temperature is below 100 °C, the device can dissipate up to its maximum power of 10 watts. Above a junction temperature of 100°C, the amount of power that the device can dissipate will decrease at a rate of 0.125 watts for every 1°C of junction temperature increase. If a heatsink is used, junction temperature will be reduced and the device can dissipate increased power.

Conclusion

Whether you are evaluating the design of a project, or designing a project of your own, heat management plays an important role in your work. When a component must handle any sizable amount of power, the inevitable byproduct—heat—can destroy or damage part's operation and overall reliability. The objective of heat management is to carry enough heat away from the power-dissipating junctions of a device to allow reliable, long-term operation. The ample use of heatsinks is an effective and economical means of removing heat from a device. But there are a variety of important thermal resistance factors that must be considered to ensure that a heatsink arrangement will function as desired. Ω

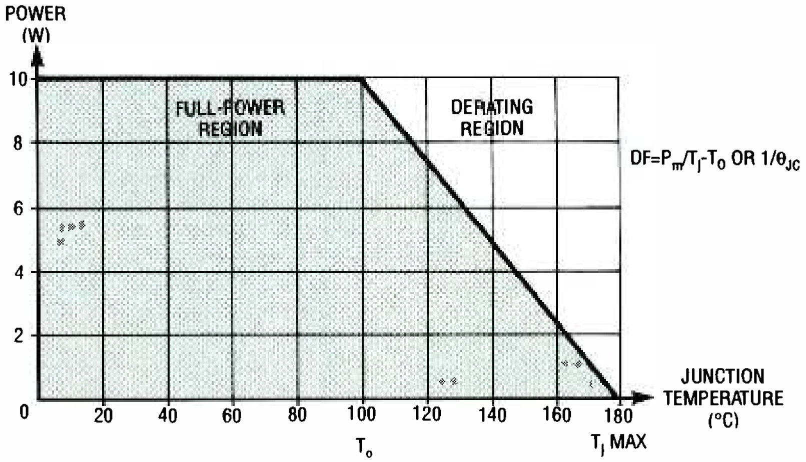


FIG. 4—A POWER DERATING CURVE shows how allowable power drops off as temperature increases.

PC TEST EQUIPMENT

continued from page 43

surement, the counter must sample data at a rate sufficient to satisfy the Nyquist criterion. (See the box entitled analog-to-digital and return.) Most time- and frequency-measurement applications require at least 1000 samples per second.

Any universal frequency-counter board that is compatible with Guide Technology's product, (the most popular counter board today), can be converted into a time-interval analyzer with Guide Technology's VIEWMOD software. This does not mean, however, that there is no longer a need for a universal frequency counter. One attractive model is Optoelectronics' PC10, selling for only $335, that can measure frequencies up to 2.4 GHz.

Related test devices

The PC-based test instrument market is flooded with support instruments such as digital multimeters (DMM) and interface multiplexers. These can be used in conjunction with other instruments to round out an ATE setup or instrument cluster. Choosing the support device that's right for an specific system should be done on an individual basis.

From dream to reality

As the number of installed personal computers increases, more PC-based testing applications are being developed. In the same way word processing led to desktop publishing, PC-based test instruments are leading to new methods for making tests and measurements not previously visualized.

The economies of production and improved manufacturing processes made possible by the worldwide proliferation of entertainment electronics and the price battle among the world's personal computer makers has forced down the price of many of the key components in PC-based test instruments. The result is that you can get more for your money. Ω

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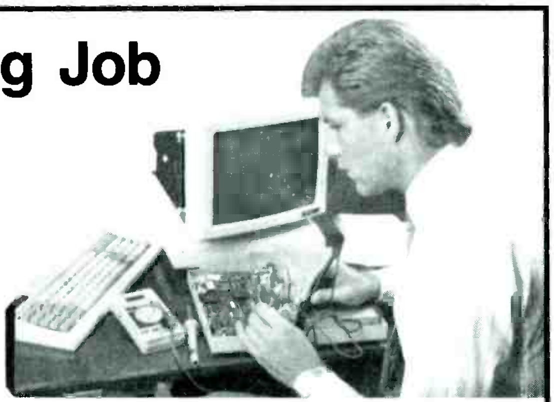

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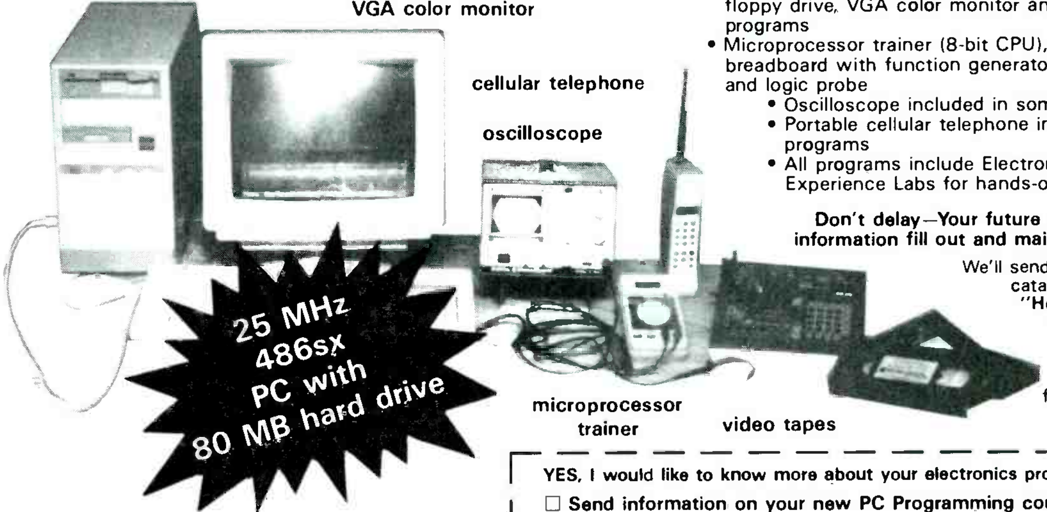

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HARDWARE HACKER

Pulse monitor secrets, an update on free energy, a new wireless communication magazine, thermoelectric guidelines, and aerobic exercise software.

DON LANCASTER

An update to last month's free energy resource sidebar: The *International Association for New Science* newly released their 540 page proceedings from their latest *International Symposium on New Energy*. At $49.50.

All of the usual topics are covered—antigravity, Reed motors, pulsed magnetics, zero point scalar energy, homopolar generators, Tesla earth resonance, perpetual motion, element transmutation, cancer cures, alternate fusion, the whole bit.

My view is that the proceedings are a fascinating and wondrously bizarre work of fiction. Many of the papers presented emit an aura of outright hogwash.

On the other hand, the first step in researching any controversial topic is to find out who is doing what to whom. Even totally absurd and "not even wrong" notions can lead to useful and innovative new concepts. Forums should exist for all controversial thought. Which makes the symposium worth a look.

Thermoelectric review

Judging by the helpline calls lately, there seems to be a lot of interest in the solid-state thermoelectric coolers that are now cropping up in surplus channels. Sadly, most hackers don't pick up on the fact that there are several *very* rude surprises awaiting when they try to use these in the real world.

So, one more time: These thermoelectric modules are *extremely* inefficient and need *extremely* good heatsinks. They are strictly limited to very low power uses. They also *demand* simple and obvious heat flux calculations which most hackers positively refuse to make. For most hacker uses most of the time, the *thermoelectric cooling modules simply do not work.*

Let's see why this is so.

Solid-state thermoelectric modules using the *Peltier* cooling effect were developed over three decades ago and have not changed or improved one whit since. The players change every few years in an industry that's been chronically unprofitable. One supplier is *Melcor*. They offer data sheets and design notes.

Figure 1 shows a typical heat pumping curve for a 20-watt module. Applying a DC current across the device causes heat to be moved from one surface to another. This module might need 15 volts at 3 amps for operation.

Note that the heat pumped depends inversely on the temperature drop across the device. Yes, you can pump 20 watts of heat through a *zero* temperature difference. Or you can pump zero watts of heat across a 50-degree temperature difference. That would be, of course, with *zero* efficiency.

More typically, you'll want to both pump heat and have a high *delta-T*, or change in temperature. A typical operating point might be a 25-degree drop when pumping 10 watts.

The data sheets seem to bury the module efficiency figures for most normal operating points. Often, *three* watts of energy are required to move one. This is an EER (*Energy Efficiency Rating*) of a laughable 0.33. Compare this against a US air conditioner with an EER of 12 . Or a Japanese one with a superb EER of 17.

Low efficiency would not be all that bad if all of the excess heat was not generated in the wrong place at the wrong time. But what you have done when you use a thermoelectric module is *add* heat precisely where you are trying to eliminate it.

It is trivially easy to get more delta-T rise between your module hot side and ambient than the delta-T cooling the module is providing!

Let's use an aquarium cooler as an example. Now, there is another name for any large aquarium. It is called a *super efficient heatsink*. So, let's take our super efficient heatsink and then remove some heat from it. Because of the thermoelectric module's inefficiency, we may have to add three new watts of heat for every one removed and put it into a new heatsink.

Naturally, we would not want the new heatsink to rise up as far above ambient as the aquarium goes below, or we will simply be heating up the ambient air. So, we'll shoot for an output temperature rise of only a quarter the cooling drop.

Your final heatsink will have to be 16 times better than your aquarium! A handy heatsink would be a second aquarium that is 16 times larger than the one you want to cool.

Just how much heat are we talking about here? That's what doing heat flux calculations is all about. Let's review the basics.

The two key numbers you have to look for are your *watts of cooling required* and your *heatsink thermal impedance*. Going back to square one, a *BTU*, or *British Thermal Unit* is the amount of energy needed to

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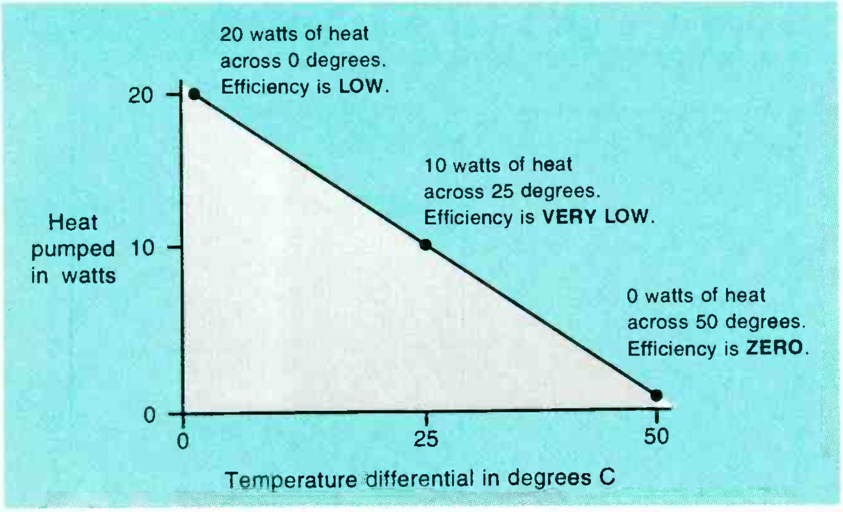

FIG. 1—TYPICAL HEAT PUMPING CURVE for a larger thermoelectric module. Note that the efficiency goes down as the temperature differential increases.

raise or lower the temperature of one pound of water by one degree Fahrenheit.

There are around eight pounds of water per gallon, so eight BTU 's are needed to shift the temperature of a gallon of water by one degree F. A temperature rate of one BTU per minute will occur when 17.58 watts of power are input to the system.

Heat flux ends up proportional to temperature difference. For a given heatsink, you'll get twice the delta-T for twice the watts passed through. Math similar to plain old Ohm's law defines the *thermal impedance*.

A typical heatsink might have a thermal impedance of between 2 and 10 degrees Celsius per watt. If the thermal impedance is 5 degrees per watt, and if you are transferring 8 watts, the thermal rise will be a total of 40 degrees.

To get below 1 degree per watt, you usually have to go to forced-air cooling. To get under half a degree per watt, a pumped-water cooling system is often the best choice.

The key problem is that *the heat rise of the hot side of the thermoelectric module above ambient can easily exceed the net cooling of the module itself!*

For instance, you might have your module doing a 30-degree cooling, but your heatsink hot side might have a 40-degree rise above ambient. The net result is 10 degrees of *heating*. That's the exact opposite of what you are trying to do. The module also operates at a much less efficient point on the thermoelectric response curve.

In the case of the aquarium, you can easily measure your heat flux. The results will depend on the surface area of the aquarium, the ambient air flow, the temperature drop required, and the amount of water present.

Temporarily remove the fish and fill the aquarium with ice water. But otherwise let it run with the usual lights, pumps, and whatever. Next, carefully measure your temperature versus time as the ice melts and slowly reaches room temperature. The *Radio Shack* #277-0123 digital thermometer is ideal for this.

Then plot the temperature rise versus time on a graph. Next, find the *slope* of the warming curve *at your target temperature*, in degrees per minute. To hold the target temperature, the degrees-per-minute cooling needed will equal the degrees per minute warming taking place.

Multiply the pounds of water times the degrees per minute of cooling needed to get the BTU 's

1. The area to be cooled *must* be superinsulated. All avoidable sources of heat gain *must* be carefully excluded.
2. Realistic heat flux calculations and heatsink thermal impedance calculations *must* be carefully made ahead of time.
3. Current thermoelectric modules are an inappropriate solution if more than twelve watts of actual cooling are called for.
4. The rise of the module hot side temperature above ambient *must* be kept as low as possible. This rise must *never* exceed a small fraction of the total temperature drop desired.
5. Very large and extremely high quality heatsinking is a must. Use forced air cooling at the very least. Pumped water cooling may be required to achieve an acceptable efficiency.
6. Power sources *must* have very low ripple and hum, since the ripple peaks heat much worse than the troughs cool.
7. Surfaces contacting the module *must* be ultra-flat. 100% contact is essential. Thermal grease *must* always be used.

FIG. 2—USE THESE GUIDELINES for all of your thermoelectric module designs. Otherwise, you are likely to end up heating instead of cooling!

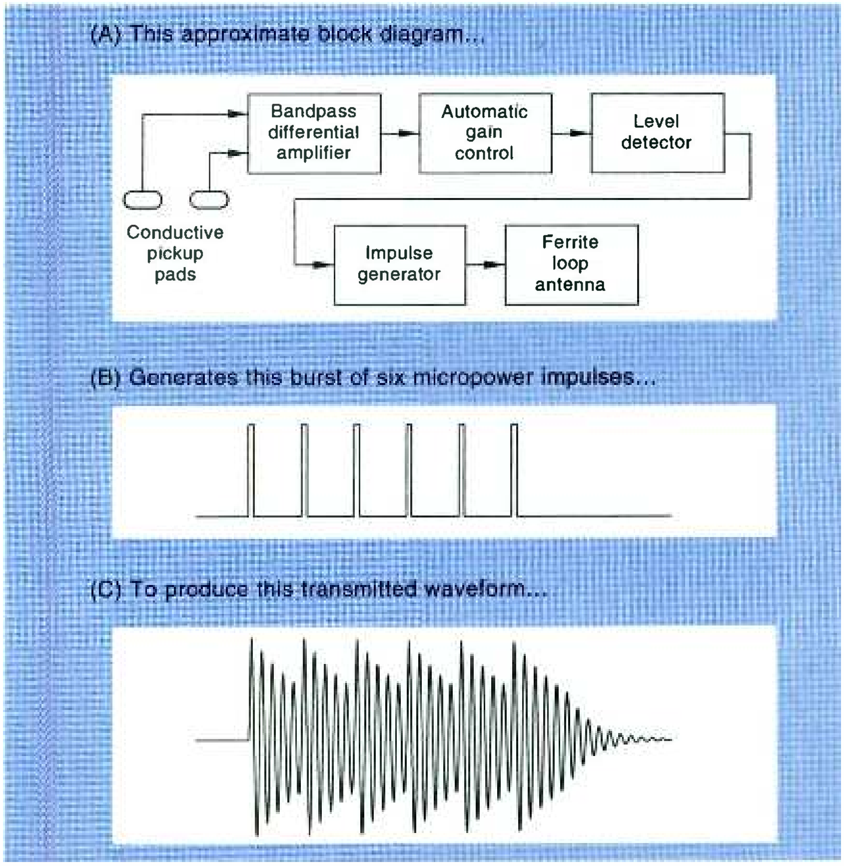

FIG. 3—THE MYSTERY WAVEFORMS inside a typical "chest type" pulse monitor revealed. The transmitted signal approximates a 36 cycle burst of 5 kiloHertz sinewaves. One burst per pulse event. What you really have here is plain old inductive coupling using an air core transformer.

per minute required. Multiply that by 17.58 to get the cooling watts needed. Finally, multiply the result by some fudge factor like 1.5 for a safety margin.

The chances are that the final cooling power required will be *hundreds* of times higher than what can be done using thermoelectric modules.

I haven't actually run this warming test, but I'd guess that 300 watts of cooling would not be an unreasonable value for keeping a large aquarium fairly cool. And if you do burn up 3 watts of inefficiency for every single watt pumped, something like 1200 watts of heat will have to go out through your heatsink. With a 1-watt per degree C rise heatsink, the thermoelectric module's hot side temperature will try to go to 1200 degrees. *Thirty* of the 20-watt modules would be needed!

Do those new CPU thermoelectric coolers work? I'd be willing to bet that if you removed the cooler and coupled the heatsink directly to the CPU case itself, the results would end up as good or better—simply because you are not adding extra heat at a 3:1 premium where you don't want it.

A related story: Years ago there was this total federal solar fiasco involving a school in the rural south. This was to be a pilot demonstration project of a solar adsorption cycle cooler. The results weren't quite as good as expected, so they added a new five-ton evaporative cooler to the output to improve the heatsinking to ambient air. Sure enough, the cooling then met the specification.

Then someone asked this rather embarrassing question: How much evaporative cooling would have been needed if the solar adsorption cooling was not in use at all? The answer? *Three* tons!

Using thermoelectric modules for many hacker applications can end up the same as building a bonfire inside an icebox.

Are there any applications at all for thermoelectric modules? Cer-

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tainly. *If* you have carefully made your heat flux measurements. And *if* you are moving only tiny amounts of heat out of a superinsulated region. And *if* you are dumping into a big heatsink with a very low delta-T.

You also have to use super smooth surfaces, proper thermal grease, and avoid *all* ripple in your power supply. The tiniest amount of ripple will foul things up because the ripple troughs heat six times better than the peaks will cool.

Figure 2 shows guidelines for proper use of thermoelectric modules. These modules can be a surefire winner for any science fair, where you can easily feel all the heat going from your thumb to your finger, even with a single "D" cell. They are also useful for chilled-mirror dewpoint instruments. And handy in high-vacuum applications where moving parts are a no-no.

Thermoelectric modules are great for cooling microscope stages, special astronomy instruments, and infrared detectors. But the modules don't seem useful for cooling the low-noise amplifiers used in satellite dishes because the gain drops faster than noise figure improves.

What are the practical alternates to thermoelectric modules? Small compressors are not that big a deal. Obvious sources are drinking fountains, refrigerators, icemakers, and reworked auto air conditioners. One source of info on these is *HVAC Contractor*. A drinking-fountain compressor will need only 60 watts of new energy to pump 300.

But the neatest substitute for thermoelectric modules are called *vortex coolers*. These second cousins to perpetual motion machines seem to blatantly violate thermodynamic laws. But, of course, they do not.

A vortex cooler is simply a magic Tee-shaped pipe that contains no moving parts at all. Ordinary air is blown into the middle. Hot air comes out one end, and cold air out the other—down to −40 degrees Fahrenheit.

Leading suppliers include *Vortec* and *Exair*. Some important applications for vortex coolers are for cooling electronics and stopping needle breakage on industrial sewing machines.

I would guess that a vortex CPU cooler could be produced very simply and easily. And it would work much better than a thermoelectric module. As far as I know, nobody has even tried.

Pulse monitor discoveries

Warnings: Do not ever modify an EKG-type pulse monitor in any way for any reason! Do not ever attempt to build your own units of this type! What follows is not in any manner to be construed as medical advice.

I've been developing some aerobic exercise software for a client—using PostScript, of course. I have found it to be the greatest universal hacker's language anywhere ever. I have also been looking closely at the pulse monitors and have found some fascinating new electronic concepts that you might like to expand upon in one way or another. These concepts should apply beautifully to short-haul telemetry applications.

But *please* be careful to heed all the above warnings.

One way to deal with exercise, of course, is to get yourself a corned beef and pork fat sandwich, add a helping of eggs Benedict, and chow down until the urge goes away. There are others who feel that sustained exercise programs provide positive benefits towards longevity, physical conditioning, well being, and can be beneficial in medical therapy.

The harder you exercise, the higher your heart rate. The goal of an *aerobic* (or "with oxygen") exercise is to reach an elevated pulse rate *target zone* and maintain it for a fairly long time. Say half an hour to an hour of cycling, group aerobics, swimming, jogging, or fast walking.

A conditioning target zone might be 60 to 75 percent of the maximum heart rate. The maximum rate in turn depends upon sex, age, and upon the advice of your physician or aerobics instructor. For instance, a 30-year-old male might have a target zone of 114 to 142 beats per minute.

The old "thumb and stopwatch" method of measuring pulse rate has some problems, not the least of which is that it woefully disrupts the program in progress. There are two alternative methods to measure pulse, the *plethsymograph*, and the *EKG (electrocardiogram)*.

The plethsymograph is based on finger or toe capillaries expanding and contracting with each pulse beat. Shine infrared light through your finger, and its transmission will vary with your pulse. Opacity depends on how much blood is present. The variations can be amplified, conditioned, and digitally averaged to extract the current pulse rate. The method is cheap, simple, and noninvasive.

Infrared plethsymographs are easy to find, even as $19.95 specials at K-mart. Unfortunately, many of these simply do not operate properly in aerobic exercise situations. The main problem involves *motion artifacts*. Any relative motion between sensor and finger will give a false output and highly erratic, near-useless results.

Better yet, there are *EKG-style* or "chest type" monitors that directly measure the electrical activity of the heart. These are usually offered in two pieces, a small chest strap, and a stopwatch-type display that is either worn on your wrist or mounted on the exercise gear.

The cost of these systems is often in the $70 to $200 range. But they are totally free of motion artifacts. And you can *instantly* check your pulse at any time during the activity by simply glancing at the display. Many systems also offer settable alarms that trip if you wander outside your target zone. Clock and stopwatch functions are included.

One typical unit is the *Edge Heart Rate Monitor* distributed by *Polar* and stocked by such yuppy outdoor stores as *REI*. I tried that one in

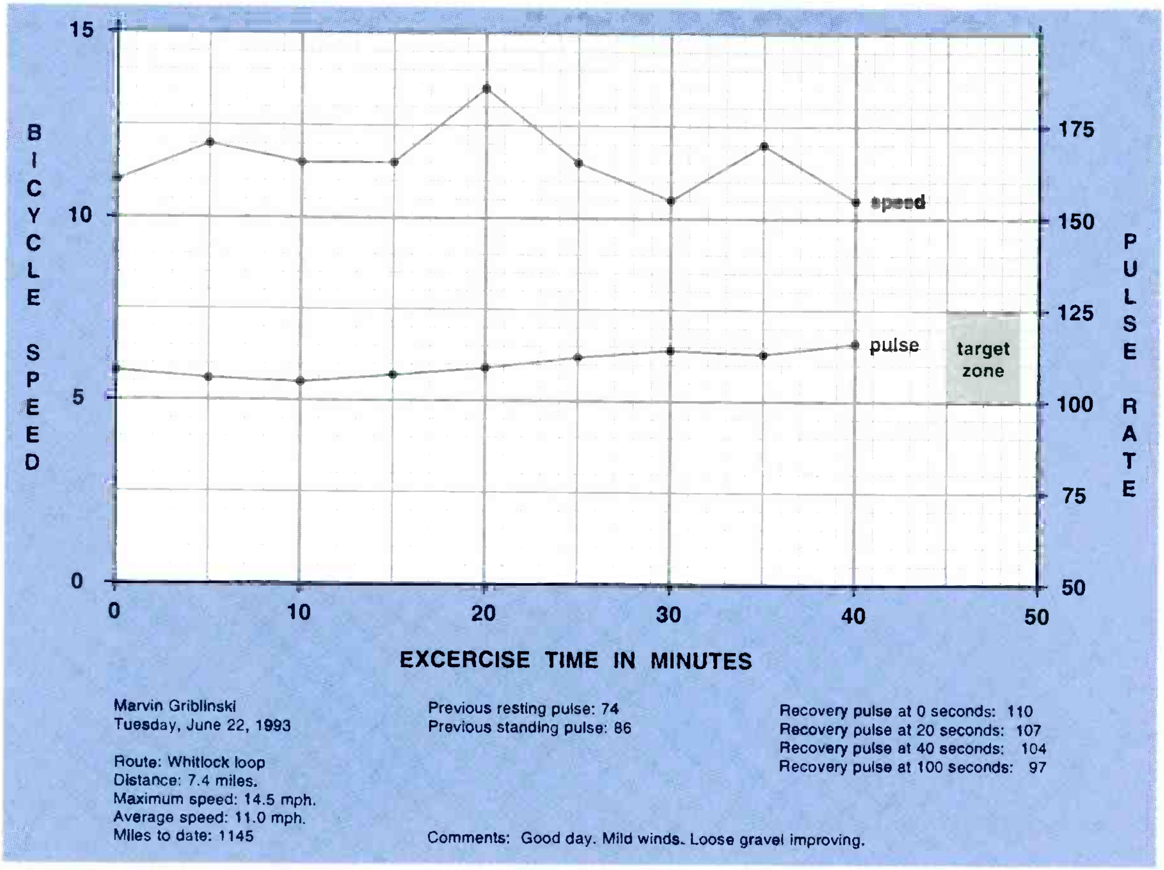

FIG. 4—AEROBIC EXERCISE RECORD written in PostScript. Fully editible source code appears on GEníe PSRT.

combination with a *Trek* bicycling computer. A second brand is *Favor*. Combination monitor and bike computers in one unit are available, such as the *Vetta* HR-1000 also offered by *REI*. At $95 list.

How do they work?

The chest unit is totally sealed and has an internal battery. In normal use, it gets replaced every year or two. The internal battery is pur-

NAMES AND NUMBERS

Antique Radio Laboratories
Rt 1, Box 41
Cutler, IN 46920
(317) 268-2214
CIRCLE 330 ON FREE INFORMATION CARD

Exair
1250 Century Circle North
Cincinnati, OH 45246
(513) 671-3322
CIRCLE 331 ON FREE INFORMATION CARD

GEnie
401 N Washington Street
Rockville, MD 20850
(800) 638-9636
CIRCLE 332 ON FREE INFORMATION CARD

Heath Nostalgia
4320 196th SW, Ste B-111
Lynnwood, WA 98036
CIRCLE 333 ON FREE INFORMATION CARD

HVAC Prod News/Contractor
1350 East Touhy Avenue
Des Plaines, IL 60018
(708) 635-8800
CIRCLE 334 ON FREE INFORMATION CARD

Intl Assn for New Science
1304 S College Avenue
Fort Collins, CO 80524
(303) 482-3731
CIRCLE 335 ON FREE INFORMATION CARD

Linear Technology
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Milpitas, CA 95035
(408) 432-1900
CIRCLE 336 ON FREE INFORMATION CARD

Maxim
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Sunnyvale, CA 94086
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Melcor
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Trenton, NJ 08648
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Mondo-tronics
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San Anselmo, CA 94960
(415) 455-9330
CIRCLE 339 ON FREE INFORMATION CARD

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San Jose, CA 95135
(408) 238-8082
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Manchester, NH 03103
(603) 668-2499
CIRCLE 341 ON FREE INFORMATION CARD

Synergetics
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Thatcher, AZ 85552
(602) 428-4073
CIRCLE 342 ON FREE INFORMATION CARD

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Beaverton, OR 97005
(503) 644-3535
CIRCLE 343 ON FREE INFORMATION CARD

Vortec
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Cincinnati, OH 45242
(800) 441-7475
CIRCLE 344 ON FREE INFORMATION CARD

Wireless Design & Development
Box 650
Morris Plains, NJ 07950
(201) 292-5100
CIRCLE 345 ON FREE INFORMATION CARD

posely *not* replaceable to guarantee that the unit remains unmodifiable. There are very stringent regulations that govern anything electronic that directly attaches to your chest.

Obviously, the chest unit acts as a transmitter and the wrist unit serves as a receiver. The effective range is typically four feet or so. But what gets transmitted how? The answer to this one is yet another stunningly beautiful find in our ongoing quest for elegant simplicity.

What we really have here is short-haul telemetry. But one that has to remain totally sealed, be compact and lightweight, reliably run under micropower, and literally be a throwaway item with a five-buck maximum manufacturing cost.

The secret is a plain old inductive coupling. Figure 3 shows the secret waveforms involved. What you really have here is a 5-kilohertz air-core transformer, with the primary in the chest unit and the secondary in the wrist or handlebar receiver. Each pulse is converted into a 36-cycle burst of 5-kilohertz sinewaves.

You can easily monitor these waveforms. Just take any old coil, such as a fifty foot roll of hookup wire. Add an iron core, such as a handy pair or pliers. Center the coil near the chest unit. And then watch the results on your scope.

A pair of conductive pads pick up

continued on page 82

FAX DIRECTORY LISTING

COMPANY	FAX NUMBER
Accord Electronic Systems, Inc.	(305) 772-2568
Alfa Electronics, Inc.	(609) 275-9536
A.M.C. Sales, Inc.	(303) 494-4924
B.G. Micro	(214) 271-2462
Caig Laboratories, Inc.	(619) 451-2799
Chemtronics, Inc.	(404) 717-2111
Communications Specialists, Inc.	U.S. – (800) 424-3420 Int'l – (714) 974-3420
C&S Sales, Inc.	(708) 520-0085
Danbar Sales Company	(909) 592-2940
Electronic Rainbow, Inc.	(317) 291-7269
Fair Radio Sales Co., Inc.	(419) 227-1313
Fusion Electronics, Inc.	(516) 599-6495
Global Specialties	(203) 468-0060
Goldstar Precision Co. Ltd.	(310) 921-6227
Hameg Instruments	(619) 630-6507
Interactive Image Technologies Ltd.	(416) 368-5799
Jameco Electronic Components & Computer Products	(800) 237-6948
Mark V Electronics, Inc.	(213) 888-6868
MCM Electronics	(513) 434-6959
Moody Tools, Inc.	(401) 885-4565
Mouser Electronics	(817) 483-0931
MWK Industries	(909) 278-4887
Northeast Electronics	(508) 695-9694
Number One Systems Ltd.	011 44 480 494042
PC Boards	(205) 933-2954
People's College of Independent Studies	(407) 847-8793
Print Products International	(800) 545-0058
Howard W. Sams & Company	(317) 298-5604
Sencore, Inc.	(605) 339-0317
Sibex, Inc.	(813) 726-4434
Startek International, Inc.	(305) 537-5577
Suncoast Technologies	(904) 596-7599
The Engineers Collaborative, Inc. (TECI)	(802) 525-3451
Toroid Corp. of Maryland	(410) 860-0302
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AUDIO UPDATE

What's happening?

LARRY KLEIN

We live in strange times. Despite the stagnant economy, home electronics, like most other high-tech areas, continues to progress. For several years now, new and competing electronic entertainment formats have been introduced regularly, apparently faster than consumers are prepared to absorb—or pay for—them.

The Japanese and other overseas manufacturers seem to believe that you can separate consumers from their cash—however depressed the economic conditions—if new products are whiz-bang enough.

Deja vu?

Today's inert consumer reaction to the proliferation of new audio formats reminds me of what happened during the years of the four-channel follies (1969–1977). There were at least five competing quad formats, the technology didn't work very well much of the time, and the public, despite the massive hype campaign, just wasn't very interested.

In contrast, today's MiniDisc (MD) and Digital Compact Cassette (DCC) both work well and deliver near CD-quality sound. And, in certain areas (size and playing stability for MD, fidelity for DCC), they are superior to their predecessors. Are audio consumers rushing to trade in and up? It appears not. Of course, there's some question whether the data-compression techniques used in both formats cause fidelity problems, but I don't think that's the stumbling block. For the vast majority of listeners, both formats sound fine. The lagging sales, I suggest, are because of price, not performance. In other words, as someone once said, "It's the economy, stupid!"

With the recordable MiniDisc, you can dub your existing musical library onto the new format, but given the time, effort, and expense involved, it doesn't seem like a sensible undertaking. The ability of the DCC decks to play conventional cassettes, in my view, made them a winner. But according to one industry friend, neither one of the formats is selling very well. I can understand the MiniDisc getting off to a slow start, but as some readers may remember, I thought DCC was going to take off.

Given my miscall on DCC I decided that it might be time to recalibrate my crystal ball. After several hours of conversations with several knowledgeable industry friends, this is what I found to be happening hi-fi marketwise.

Home theater up, stereo down

Dolby Pro Logic home-theater electronics represent an important part of today's home equipment marketplace. But to put that fact in perspective, you should be aware that, overall, the hi-fi marketplace is in deep doldrums. True, Dolby Pro Logic home-theater sales are up, but at the expense of medium-priced, conventional stereo gear. High-end audiophile equipment is suffering less, but their usual level of overseas sales are down because the strong dollar has significantly raised the costs of this equipment to foreign consumers.

Big speakers are out, and small speakers and subwoofer/satellite systems have taken up the slack—which makes sense given the need for five or more separate speakers in a full-fledged home-theater setup.

Overall, it appears that the interest in home theater is unfortunately not dragging the rest of the audio industry out of its recession. One of my audio consultants was able to put the situation succinctly: He said that home-theater systems are an important part of what's left of the hi-fi stereo business.

A sales manager of a well-respected U.S. electronics company raised an interesting point. He claimed that some manufacturers are cutting corners (and costs) in their multichannel units, thus causing them to fall short in power, current capability, and bandwidth. As an example, he cited some units rated at 100 watts per channel that are likely to clip at under 80 watts when measured with standard EIA test techniques.

I hope this does not presage a return to the bad old days. Old timers will remember the years when amplifier power ratings had a very poor fantasy-to-fact ratio. Even the good guys who were trying to maintain legitimacy in their ratings found that they had to fudge their specs in order to remain competitive in the power numbers game.

It appears that the intense competition for a piece of the shrinking hi-fi pie has driven some manufacturers to skimp on their power supplies. That lowers the price of the product, but also its performance. Given the fact that the mainstream audio magazines are also struggling very hard to keep their heads above water as advertising revenues continue to fall, don't expect to see any front cover power rating exposes any time soon.

If you are about to invest in some extra amplification for a home-theater installation, look long and hard at the power ratings, making sure that the per-channel wattage is rated with all channels driven. *Caveat emptor!*

Speakers

To switch subjects slightly... Ever since I became involved in audio, speakers have been a special interest. To my mind, loudspeakers have always inhabited a sort of twilight zone where psychoacoustics, acoustics, physics, and electronics meet, not always felicitously, in an effort to reproduce music.

Forty-odd years ago, during the early days of consumer hi-fi, no two home-speaker models—even from the same company—sounded alike. Each had its characteristic colorations. Although few audiophiles at the time would admit it, you picked a speaker by choosing a model whose deficiencies annoyed you least.

In the late 1950's, things changed for the better. At the point when I was in charge of the component-testing program at *Stereo Review*, there were at least two consistently good brands, whose products were all based on the acoustic-suspension design developed by Edgar Villchur, then president of Acoustic Research. For an encore, Villchur invented the dome tweeter, which was also destined to become an industry standard.

Time marched on, and while more and more manufacturers switched to acoustic-suspension systems, the bugs were being worked out of the venerable bass-reflex/tuned-port configuration. A point was reached about 12 to 15 years ago when it was rare that a really bad speaker of either design was submitted to the magazines for testing—although they still existed in the marketplace.

Once they had a handle on the basic bandwidth and distortion problems, designers began to seriously investigate the speaker/room/ear interface questions. The studies have gone far beyond the wide dispersion/omnidirectional/bounce-the-sound-off-the-wall intuitions of the early days to far more profound analyses.

Roy Allison was one of the early investigators of the speaker/room interface. In a 1974 Audio Engineering paper, "The Influence of Room Boundaries on Loudspeaker Power Output," he spelled out in detail—including measurements—the bass performance problems engendered by typical bookshelf loudspeaker installations in typical rooms. In a nutshell, these turn out to be irregularities ranging from about 5 to 12 dB, depending upon mounting location. Allison subsequently went on to design a series of excellent systems that minimized or eliminated such problems.

I was saddened to hear early this year that Allison Acoustics had been taken over by their major foreign investor and Roy Allison was out. Edgar Villchur (remember Edgar Villchur?) apparently was also upset and rode to the rescue with an infusion of cash and, hopefully, good advice.

A new company was founded—Room Design Loudspeakers (RDL) with Allison as president and chief designer, and Villchur as a corporate director. RDL is now shipping products on a direct-sale basis to consumers—a move that Villchur had contemplated during his heyday at Acoustic Research.

For further information: write to RDL Acoustics, 26 Pearl Street, #15-EN, Bellingham, MA 02019 (800 227-0390). Ω

HARDWARE HACKER

continued from page 77

the EKG signals on either side. These microvolt-sized signals are strongly amplified in a bandpass amplifier. There is probably some type of AGC (Automatic Gain Control) loop to standardize the output levels. Then, a comparator of some sort derives a digital output for each pulse event.

Each pulse event then generates a series of six digital impulses. Each impulse is around 80 microseconds wide and has an interpulse spacing of one millisecond for a one-kilohertz repetition rate.

If very low power is your goal, you cannot use any kind of linear amp for your transmitter. Instead, the antenna is simply a 5-kilohertz resonant coil. The plots found in my *Active Filter Cookbook* tell us the Q of this coil is around 20 or so.

To transmit a signal, the resonant antenna coil gets whapped *once every five cycles*. The high Q of the coil fills in during the intermediate cycles. If you look at your scope display carefully, you will observe the modest exponential decay of the intermediate cycles between impulse whappings. The long rundown time after the last whapping is also quite obvious.

Only the bandpass amplifier draws continuous current. Both *Maxim* and *Linear Technology* make suitable amplifiers that consume only microamps. In absence of any pulse input, there is no output and no transmitted signal. Even when a burst is sent, the duty cycle to generate the burst is 10:1 and the duty cycle of the burst itself is typically 80:1 or so.

The average current ends up quite low. Very elegant.

X-raying the unit revealed a few surprises. A large lithium coin cell is used. The antenna is a ferrite rod with its long axis horizontal that is apparently tuned by unwrapping a few turns. It is resonated by a polystyrene capacitor. A 14-pin integrated circuit drives the antenna. It is probably a plain old grunt CMOS quad gate.

The majority of the input circuitry is discrete and consists of nine SOTs (Small Outline Transistors) and 24 assorted resistors and capacitors. Special techniques are required for proper noise rejection and ultra low power operation.

The receiver is just a resonant coil and a bandpass amplifier that inputs into typical micro-current stopwatch circuitry. The amplifier apparently shuts itself down in the absence of any transmitted signals. The receiver battery can be replaced and lasts a year or more. An averaging algorithm is used to smooth out the results for a stable display.

A sample printout for a routine exercise session is shown in Fig. 4. The complete PostScript code to custom run these on your favorite word processor appears on *GEnie* PSRT as #751 EXERCISE.GPS.

You could build up an automatic data acquisition system to automate the whole process. But it is simpler and cheaper just to use a one-hand cassette recorder every five minutes and talk the speed and pulse rate to it.

I've gathered several places to go for more information on pulse monitors into our resource sidebar for this month. *Creative Health Products* offer a free comparison guide for many popular monitors.

This month's contests

Let us have a bunch of different contests this month. Show me some other uses for inductive coupling in short-haul telemetry. Or find me the actual schematic of some EKG-type pulse monitor. Or find a hackable source of pulse-monitor chips.

That should be ideal for one of my *isopod* power line monitors.

Or run the aquarium ice warming test. Or show me a genuinely useful hacker application for thermoelectric modules that works in the real world. Or show me some other off-the-wall uses of PostScript for new data-to-plot applications.

There'll be all the usual *Incredible Secret Money Machine II* book prizes along with an all-expense-paid (FOB Thatcher, AZ) *tinaja quest* for two going to the best of all.

New tech lit

Up the Infinite Corridor is a new book on the history of engineering at *MIT* by Fred Hapgood. It's a really good read. But by far the best part is Fred's revival of a very ancient seven-word definition of what engineering is all about: *A sense for the fitness of things*. That says it all.

Lots of night-vision electronics and surplus infrared viewers are available from *Resources Unlimited*. A free brochure is available.

There's a new $9.95 book on the history of *Heathkit* from *Heath Nostalgia*.

Antique Radio Laboratories has a free catalog on its products for radio restoration buffs. Included are custom pins, adapters, bases, and coil forms. They also stocks manuals for older test equipment.

The *Oughtred Society* exists for the collectors of traditional slide rules and calculating instruments. It's named for the seventeenth century slide rule inventor. Meetings and classified ads cost $20.

Motorless Motion is a project book from *Mondo-tronics* on working with the shape memory "muscle wires" for robotics and similar uses. Included are fifteen easy-to-build projects and layout templates. The book is $18; $29 for the book and wires.

From *TriQuint Semiconductor*, a new *Data Communication Products* data book. It's mostly on new microwave integrated circuits such as low-noise amplifiers, mixers, downconverters, and AGC stages.

Wireless Design & Development is a new trade journal on new products for the emerging personal microwave communication services.

As we've seen a number of times in past columns, any hardware hacker involvement with the patent system is virtually certain to end up a net loss of time, energy, money, and sanity, mostly because of all the outrageous popular mythology that surrounds patents and patenting.

I have put together a new *Case Against Patents* reprint package that includes several hundred pages of proven alternates to patenting. A big directory of hundreds of inventor organizations is included. See my nearby *Synergetics* ad.

A reminder that I have arranged for a new and faster *GEnie* signup for my PSRT RoundTable. Refer to the *Need Help?* box for full details. Ω

COLLECTOR AMPLIFIERS

continued from page 61

in Fig. 14 has an input impedance of about 50 kilohms.

Both the Fig. 13 and 14 circuits offer a voltage gain that is slightly less than unity; the true gain is given by:
$A_V = Z_{load}/(Z_B + Z\ load)$
Where $Z_B = 25/I_E$ ohms and I_E is the emitter current in milliamperes

With an operating current of 1 milliampere, these circuits provide voltage gains of 0.995 when the Z_{load} = 4.7 kilohms, or 0.975 when the load = 1.0 kilohm. The significance of these gain figures will be discussed shortly.

Bootstrapping

The relatively low input impedance of the circuit in Fig. 14 circuit can be increased significantly by *bootstrapping* as illustrated in Fig.15. The 47-kilohm resistor R3 is located between the R1-R2 biasing network junction and the base of transistor Q1, and the input signal is fed to Q1's base through capacitor C1.

Notice, however, that Q1's output signal is fed back to the R1-R2 junction through C2, so that almost identical signal voltages appear at both ends of R3. Consequently, very little signal current flows in R3. The input signal "sees" far greater impedance than the true resistance value.

To make this point clearer, consider that the emitter-follower circuit in Fig 15. has a precise voltage gain of unity. In this condition, identical signal voltages would appear at the two ends of R3, so no signal current would flow in this resistor, making it "appear" to be an infinite impedance. The input impedance of the circuit would "appear" to equal R_{IN}, or 1 megohm.

Practical emitter-follower circuits provide a voltage gain that is slightly less than unity. The precise gain that determines the resistor *amplification factor*, or A_R, of the circuit is:
$A_R = 1/(1 - A_V)$.

For example, if circuit gain is 0.995 (as in Fig. 13), then A_R is 200 and the R3 impedance is almost 10 megohms. By contrast, if A¢svV = 0.975, A_R is only 40 and the R3 impedance is almost 2 megohms. This impedance is effectively in parallel with R_{IN} so, in the first example, the complete Fig. 15 circuit exhibits an input impedance of about 900 kilohms.

The input impedance of the circuit in Fig. 16 circuit can be further increased by substituting a520Darlington pair for Q1 and increasing the value of R3, as shown in Fig 16. This modification gives a measured input impedance of about 3.3 megohms.

Alternatively, even greater input impedance can be obtained with a bootstrapped *complementary-feedback pair*" circuit as shown in Fig. 18; it offers an input impedance of about 10 megohms. In this instance, Q1 and Q2 are both connected as common-emitter amplifiers but they operate with nearly 100% negative feedback. As a result, they provide an overall voltage gain that is almost exactly one. This transistor pair behaves like a near-perfect Darlington emitter-follower.

Emitter-followers

Recall from the previous article on bipolar transistors, **Electronics Now** in September 1993, a standard NPN emitter-follower can *source* current but cannot *sink* it. By contrast, an PNP emitter-follower can *sink* current but cannot *source* it. This means that these circuits can only handle unidirectional output currents.

A *bidirectional* emitter-follower (that can source or sink currents with equal ease) has many applications. This response can be obtained with a complementary emitter-follower topology— NPN and PNP emitter followers are effectively connected in series. Figures 18 to 20 illustrate some basic bidirectional emitter-follower circuits.

The circuit in Fig. 18 circuit has a dual or "split" power supply, and has its output is direct-coupled to a grounded load. The series-connected NPN and PNP transistors are biased at a quiescent " zero volts" value through the voltage divider formed with resistors R1 and R2 and diodes D1 and D2. Each transistor is forward biased slightly with silicon diodes D1 and D2. Those diodes have characteristics that are similar to those of the transistor base-emitter junctions.

Capacitor C2 assures that identical input signals are applied to each transistor base, and emitter resistors R3 and R4 protect the transistor against excessive output currents.

Transistor Q1 in Fig. 18 sources current into the load when the input goes positive, and transistor Q2 sinks load current when the input goes negative. Notice that input capacitor C1 is non-polarized.

Figure 19 shows an alternative to the circuit of Fig. 18 designed for operation from a single-ended power supply and an AC-coupled output load. In this circuit, input capacitor C1 is polarized.

Notice that output transistors Q1 and Q2 in Figs. 18 and 19 are slightly forward biased by silicon diodes D1 and D2 to eliminate crossover distortion problems. One diode is provided for each transistor.

If these circuits are modified by substituting Darlington pairs, four biasing diodes will be required. In those versions, a single transistor "amplifier diode" stage replaces the four diodes, as shown in Fig 20.

The collector-to-emitter voltage of Q5 in Fig. 20 equals the base-to-emitter voltage drop oacross Q5 (≈ 600 millivolts) multiplied by (R3 + R4)/R4. Thus, if trimmer potentiometer R3 is set to zero ohms, about 600 millivolts are developed across Q5, which then behaves as a silicon diode. However, if R3 is set to its maximum value of 47 kilohms, about 3.6 volts is developed across Q5, which then behaves like six series-connected silicon diodes. Trimmer R3 can set the voltage drop across Q5 precisely as well as adjust the quiescent current values of the Q2-Q3 stage. Ω

COMPUTER CONNECTIONS

The eyes and ears of the world.

JEFF HOLTZMAN

If society is an organism, and if information is the lifeblood of the organism, then by comparison, its sensory systems must be viewed as primitive and disjointed. The effect is that of a beast that can in some limited ways see, hear, taste, smell and touch, but that is unable to transform those raw sensory stimuli into understanding, decision, and action.

A new strategic initiative, spearheaded by Microsoft but brought forth in conjunction with more than 60 leading vendors in most areas of technological interest, promises to link the eyes and ears of this organism with the rest of the nervous system. In so doing, it will endow it with the intelligence needed to evolve into a higher form of life, the type required for survival in the 21st Century. Table 1 summarizes some the major and many of the minor players whose support Microsoft has enlisted for MAW, or Microsoft at Work.

This initiative promises to enable communications among PCs, fax machines, fax boards, printers, copiers, telephones, and handheld computers. In this scenario, all those devices would be networkable and would contain lots of intelligence. All would contain some form of the Windows GUI (Graphical User Interface) to enable features that in many cases already exist, but that go unused because of a difficult user interface. Networking would be used to provide additional capabilities, particularly integration among disparate varieties of office equipment.

For example, today one might print a document, run it through a copy machine, manually distribute some copies, fax others, and send yet another by courier. Instead, under the new, intelligent scheme, one might "print" the document directly to a copy machine, complete with instructions on who should receive copies, and to a fax machine (or server) for transmission when rates are favorable.

By my count, this initiative is actually the third wave in Microsoft's increasingly grandiose vision for the computing future. Wave 1 came in Fall 1990, when Bill Gates announced "Information At Your Fingertips," his vision of a multimedia future in which everything one could possibly want to know about anything representable in digital form would be readily accessible.

Wave 2 followed about a year and a half later, with the "Windows Everywhere" strategy, which was designed to put Windows technology on a range of computing devices ranging from small hand-held units to desktop PCs, to RISC-based workstations, to enormous multiprocessor desktop servers.

Wave 3, Microsoft at Work (MAW), unites Waves 1 and 2 in a less visionary but much more pragmatic approach.

MAW architecture

The MAW architecture consists of five major components: A real-time, pre-emptive multitasking operating system; messaging and interactive communications; rendering technology that promises to achieve visual consistency across display screens, printers, copiers, and faxes; the Windows GUI; and software that will allow the desktop PC to function as a hub for information flow, control, and distribution. Let's examine each component in more detail.

• **Operating System** This is where Microsoft's biggest technical challenge lies. The MAW operating system must provide true pre-emptive multitasking, and must be economical in its use of RAM. On both counts, the Windows 3.1 that you and I know and love (and sometimes hate) strikes out. However, the company has in the past delivered a "small-footprint" version (Tandy's Visual Information System, discussed here in the December 1992 column), and has undoubtedly learned a few things since then. Other goals for the MAW operating system include modularity and extensibility, basic support for existing Windows API (Application Program Interface) calls (to minimize training that would be required by developers), and a PC-hosted development environment.

• **Communications** The MAW architecture will support two basic forms of communication: message-based and real-time. The message-based component will be used for enhanced Email type functions, such as a PC-based message-management system that would allow you to sort through Email, voice-mail, and faxes via a single inbox. Regardless of format (text, voice, fax), each item in the inbox would be identifiable by sender and other information, thus allowing easy prioritization. Other capabilities include "read-only" documents that can be printed, but not edited, as well as fully editable documents. For example, a "fax" might contain both a bit-mapped representation of a document and the complete set of text and graphics objects of which it is composed. The system will also support data encryption, compatibility with existing fax machines, integration with MAPI, Microsoft's Messaging API, currently used primarily for Email.

The other form of MAW communications is bidirectional and interactive. For example, as in Micro-

TABLE 1—MICROSOFT AT WORK SUPPORTERS

Technology Area	Company
Systems, system software, applications, peripherals	Microsoft, HP, Intel, Toshiba, WordPerfect Corp.
PC Based Telephone Management	Active Voice, Centigram, Dialogic, Octel
LCDs and Touch Screens	ALPS Electric
Telephone and WAN Communications	AT&T Easy Link, Bell Atlantic, BT North America, McCaw Cellular, MCI, Motorola, Sprint, US West
PC-based fax Modems, Cards, and Software	Brooktrout Technology, Cardinal Technologies, The Complete PC, DataRace, Digital Communications Associates, Delrina, Digicom, Phoenix/Eclipse, Expervision, GammaLink, GVC Technologies, Hayes, National Semiconductor, Nuko, OAZ Communications, Optus, Pacific Image, Practical Peripherals, Smith Micro Software, Supra Corp., Thought Communications, U.S. Robotics, Inc., Yamaha Corp. of America, ZOOM Telephonics
PC-based OCR Software	Caere Corp., Calera
Standalone copy and fax machines	Canon, Minolta, Mita, Murata/ Muratec, NEC, OKI, Ricoh, Tokyo Electric, XEROX
Network-based fax servers	Castelle, Cheyenne Software, SofNet, VMX
Hand-held computers/communicators	Compaq Computer Corp., Casio
Telephone systems (PBXs, etc.)	Ericsson, NEC, Northern Telecom, Philips, Rolm
Ingetrated circuits and chip sets	Exar, Casio, National Semiconductor, Rockwell Intl., Sierra Semiconductor, Toshiba
Test products	Genoa Technology

soft's current Windows Printing System, a printer could provide aural and on-screen feedback about machine status (paper jam, paper out, toner low, estimated time of completion of current job, etc.).

• **Rendering** The rendering component of MAW would provide a consistent imaging model on all computing devices. This amounts to using Windows' Graphics Device Interface (GDI) for imaging, and TrueType fonts for text. Presently, GDI calls must at some point be translated to a specific device format, be it PostScript, PCL, Group III fax, or what have you. A single imaging/font model would be desirable on numerous counts; however, the present incarnation of GDI—in Win31 (Windows version 3.1), anyway—is insufficiently rich to accomplish everything that other, more robust solutions (particularly PostScript) can do. The enhanced GDI in Windows NT does provide PostScript-like functionality, but NT has even higher resource (CPU/RAM) requirements than Win31. It's hard to imagine a standalone fax machine running NT.

In addition, the installed base of PostScript devices and applications are not things that Microsoft will be able to overcome overnight, if ever. Device drivers—and their attendant development and maintenance responsibilities—between GDI sources and output devices are likely to be with us for a long time.

• **GUI** Microsoft's intent in this area appears not so much to be intent on making the Win31 GUI canonical as in making GUIs in general ubiquitous. For example, people would probably make much greater use of advanced features of today's standard office telephones if those features had some sort of visual representation and prompting. Look for the appearance of large LCD-based touch screens, whose contents vary extensively according to task, on all sorts of common office equipment.

• **Desktop Software** All the components of this vision will come together at the individual user's desktop. By means of the technologies described here, the individual user will be able to control voice mail, Email, and faxes from his or her desktop; system administrators will be able to manage phone logging, software updates, and maintenance requirements from a central location; users will be able to keep portable organizer-style PCs synchronized with desktop and network servers; and users will ultimately gain more control over how they communicate, with whom, and when.

Vision

Microsoft has developed a compelling vision of the office of the near future. It is also a comprehensive vision, much more so than anything promoted in recent years by Digital, HP, IBM, or Sun. As reported here last time, these big companies have rallied around various efforts at cloning or circumnavigating the Windows API. Meanwhile, Gates and Company have expanded the scope of that API by developing agreements with many major providers of telecommunications and office equipment. If I were a strategic marketer for one of the big four, I'd be worried.

But as a consultant and user, I'm excited. I'd like to be able to use my PC to control my copy machine, my fax machine, and my telephone in an integrated manner. If Microsoft Windows is the underlying technology that allows me to do so, so be it.

Realistically, MAW is a *vision* kind of thing. There are no products that support it yet, and it's within the realm of possibility that there never will be. But I don't think so. I think Microsoft really has uncovered a glaring need, one that was staring us all in the face, if not knocking us upside the head with increasing urgency the past several years.

Several fax manufacturers have stated that MAW-compliant products will be released by the end of 1993. However, it will probably take a minimum of 12–18 months before it will be possible to build up a robust, integrated suite of MAW-compliant devices and applications. When that happens, our social organism, fueled as it is by information in multiple media formats, will become infinitely smarter and more competitive internationally. When that happens, there will be a fundamental change in the way many of us do business. Those who don't change the way they do things won't be conducting anything—except maybe a funeral dirge.

Digital paper

Less ambitious, but more focused, are competing products recently introduced by Adobe Systems and No Hands Software. Both software packages are in a sense attacking a subset of the problem that MAW purports to solve: efficient document distribution.

Common Ground (from No Hands) and Acrobat (from Adobe) both function as printer drivers and allow highly accurate, electronic versions of documents to be created complete with fonts and graphics. The two products differ in their underlying file formats, font treatment, costs and licensing arrangements, document fidelity, RAM and disk requirements, and overall product versatility.

No Hands Software distinguishes among three types of font treatments: font replication, font substitution, and font embedding. Common Ground uses font replication, which works by rasterizing font information at several resolutions, currently 72, 100, 200, and 300 Dots Per Inch (DPI). It stores this information in a file, along with the text and graphics. As long as you view or print at one of the predefined resolutions, you will see a very accurate representation of your document.

Acrobat, on the other hand, uses font substitution, which is based on Adobe's Multiple Master typefaces, which can emulate the height and width characteristics of many Adobe Type 1 PostScript fonts. (Common Ground supports both Type 1 and TrueType fonts.) The idea is that if a given font does not exist on a recipient's system, Acrobat will maintain line and page breaks by creating, on the fly, a multiple master typeface that mimics the original typeface.

CG's font replication provides more-accurate document representation; Acrobat allows smaller file sizes. (Microsoft has defined a system of font embedding, which allows end users to embed fonts in documents in one of two modes: read-only and read-write. A read-only embedded font may be transferred as part of another document to another machine and used in that document only; a read-write font may be transferred in one document and installed for use in other documents. However, font vendors have expressed resistance to using this scheme, which could easily promote an already high incidence of font piracy. Currently, the only product I know of that supports font embedding is PowerPoint 3.0.)

To view an electronic document created by either Acrobat or Common Ground, a special viewer is needed. Adobe is selling its viewer in single-user quantities for $50; No Hands is giving a mini viewer away for free (via BBSs and on-line services). The company is also selling a more capable viewer for $189 list.

Both products function essentially as the final stage of a unidirectional publication process. It is necessary to run a "source file" through a "document compiler" to produce a distribution file. In addition, Acrobat files can be post-edited to provide hypertext links and other features. The problem is that the one-way process ensures inefficient document maintenance. In other words, if you add hyperlinks to an Acrobat electronic document and subsequently need to update the source document, you would need to re-run the compiler and add the links again.

Acrobat functions as a limited subset of the PostScript programming language, in which strings are embedded in lines of program code. This makes text searching difficult and inefficient. (In fact, the first version of Acrobat has no search function at all.) Common Ground stores text in a more compressed format for efficient searching.

CG is currently available for the Mac, with a Windows version scheduled for release about the time you read this. Acrobat has released both Mac and Windows versions, and plans to release DOS and UNIX versions.

Because of the one-way authoring process, I find both products severely limited. In addition, Acrobat's pricing structure is less hospitable than Common Ground's. I would consider using Common Ground for small, limited-distribution projects—e.g., a README file in a software release—but neither is really suitable for large-scale information-development and distribution projects. The concept behind these products is valid; what's needed is a more universal solution. Ω

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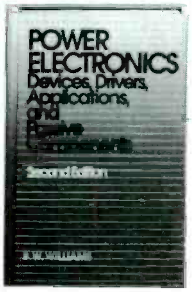

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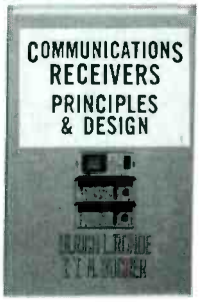

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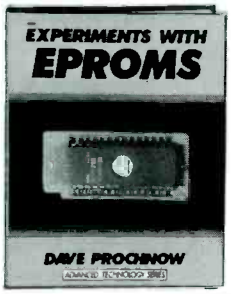

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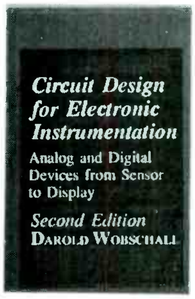

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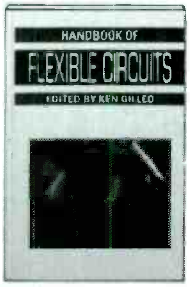

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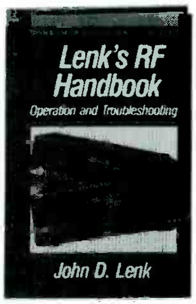

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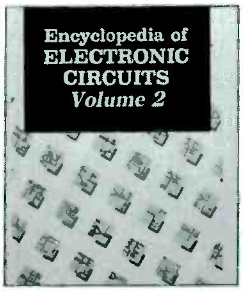

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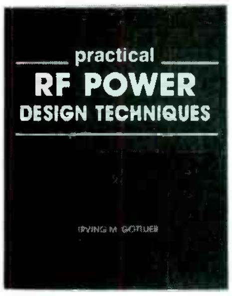

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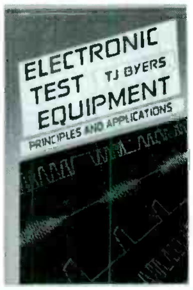

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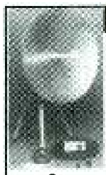

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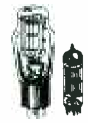

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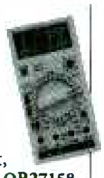

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OR26622 OR21936

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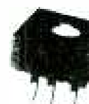

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EQUIPMENT REPORTS

continued from page 16

bytes per sector, sectors per cluster, and other useful information is contained in the table.

The final entry in the System Information menu displays the contents of the computer's CMOS memory, and permits the contents to be edited. Micro Scope can become a convenient replacement for the setup boot diskette that is usually required to access the CMOS memory on older IBM-standard AT computers.

Diagnostics menu

The Diagnostics menu permits system hardware to be tested. One series of routines verifies the proper operation of the microprocessor, math coprocessor, direct memory access (DMA) controllers, and programmable interrupt controllers. Memory tests are available for base memory, cache memory, expanded memory, and extended memory.

A sequence of tests for floppy-disk drives can help to locate the cause of disk-related problems. Even 2.8-megabyte floppy drives (as found on some of IBM's latest machines) can be tested.

Hard-disks can be tested with a similar battery of tests. Unlike most diagnostic software, Micro Scope can perform a low-level format on an IDE (intelligent drive electronics) drive. That feature can make Micro Scope pay for itself, because IDE drives that contain a bad sector or that are incorrectly formatted no longer need to be returned to the factory for reformatting.

Tests for serial and parallel ports are also included in Micro Scope, as are modem tests. A number of video tests can help to locate problems with video monitors or display adapter cards. They permit the verification of proper display attributes, screen alignment, text modes, graphics modes, and screen paging. Video memory up to two megabytes can also be tested.

Batch menu

The Batch menu allows multiple tests to be run in an automatic, unattended mode, which is especially useful for diagnosing intermittent problems, or for "burning in" new systems. Any of the tests mentioned previously can be selected; test routines can be saved to a floppy disk which can then be loaded conveniently into other systems. An error log can be printed, or it can be saved to a floppy disk. Tests can be run continuously, or the software can be set to run the tests for a user-specified number of passes.

Utilities

Several utilities are provided to help make Micro Scope a complete solution for computer service. A memory display shows the contents of memory in hexadecimal and ASCII. With that feature, it is possible to find such details as the copyright information for the system BIOS or for the ROM BIOS extensions on adapter cards. A floppy-disk editor displays the contents of a disk in both hex and ASCII, and permits the data to be modified. A similar function is available for hard drives.

One utility, which is unique as far as we can tell, rebuilds the master boot sector of a hard disk with a generic DOS boot loader progr3?[Y'tioned earlier, it can bring many virus-damaged systems back to life.

Micro Scope is a complete diagnostics tool that will be appreciated by PC service technicians, network administrators, and advanced computer hobbyists who want a thorough understanding of PC operation. Priced at $499, it might be too expensive for casual use. But in professional applications, Micro Scope's ability to do low-level formatting of IDE drives—along with its time-saving convenience—will make the program pay for itself in short order. Ω

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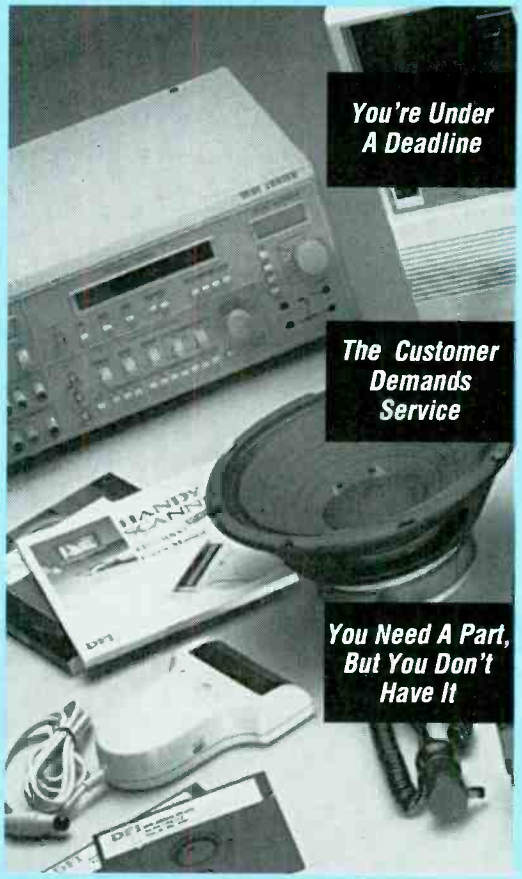

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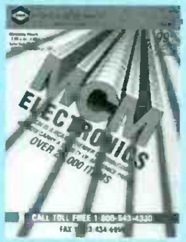

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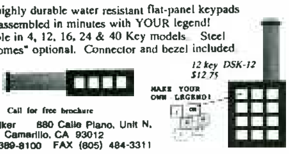

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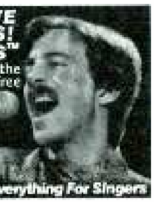

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