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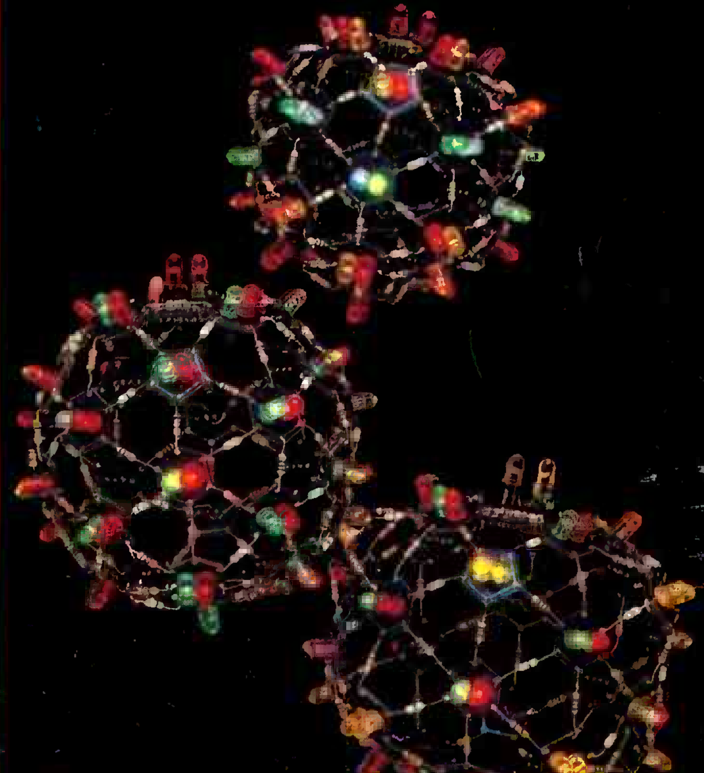

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The Fluke 79: More Of A Good Thing

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It's got the features you'd expect from Fluke. Including high resolution. Fast autoranging. Patented, automatic Touch Hold®. A quick continuity beeper. Diode test. Automatic self-test. Battery-conserving sleep mode. And it's just as rugged and reliable as the rest of the 70 Series II family. Easy to operate, too — with one hand.

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Hz

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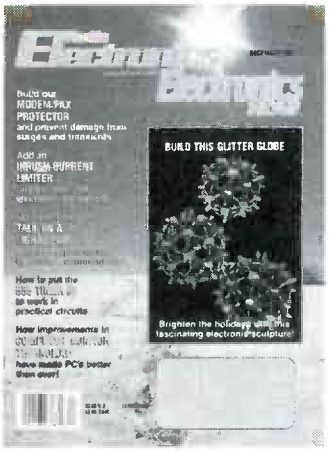
December 1992 Electronics NOW®

Vol. 63 No. 12

ON THE COVER



Once again, the holidays are just around the corner, and it's time to start thinking about gift giving and tree trimming. If you agree with us that hand-made items make the nicest gifts and add special sparkle to the holiday decor, be sure to check out the Glitter Globe. Not an ordinary ornament, this sophisticated piece of "electronic sculpture" is made entirely of electronic components and small circuit boards. The two LED's on each PC board "chase" each other, creating the illusion that the Glitter Globe is spinning. Hanging on the tree, or in a window, it's a sure attention-grabber! Turn to page 35 for all the details.

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	MAR-1 1.04	MAR-2 1.40	MAR-3 1.50	MAR-4 1.60	MAR-6 1.34	MAR-7 1.80	MAR-8 1.75	
	MAV-1 1.15	+MAV-2 1.45	+MAV-3 1.55	MAV-4 1.65				MAV-11 2.15
CERAMIC SURFACE-MOUNT	RAM-1 4 95	RAM-2 4.95	RAM-3 4.95	RAM-4 4.95	RAM-6 4.95	RAM-7 4.95	RAM-8 4.95	
PLASTIC FLAT-PACK	MAV-1 1.10	+MAV-2 1 40	+MAV-3 1.50	MAV-4 1.60				MAV-11 2.10
	MAR-1 0.99	MAR-2 1.35	MAR-3 1.45	MAR-4 1.55	MAR-6 1.29	MAR-7 1.75	MAR-8 1.70	
Freq.MHz,DC to	1000	2000	2000	1000	2000	2000	1000	1000
Gain, dB at 100MHz	18 5	12.5	12.5	8.3	20	13.5	32.5	12.7
Output Pwr. +dBm	1.5	4.5	10.0	12.5	2.0	5.5	12.5	17.5
NF, dB	5.5	6.5	6.0	6.5	3.0	5.0	3.3	3.6

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

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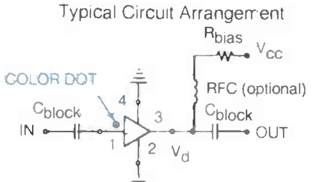
Typical Circuit Arrangement



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EDITORIAL

IT'S NOW OR NEVER

Now. This moment, this instant—it lives but a microsecond. Then it moves on and changes and becomes something new and different and better.

That's exactly what our magazine—our magazine, yours and mine—is doing. I grew up on *Radio-Craft* and *Radio-Electronics*. You've probably grown up on *Radio-Electronics*. The next generation of electronics professionals may not even remember *Radio-Electronics*, but they will know **Electronics Now**. For this new, yet old, publication will be their introduction to electronics. It will be their primer, their teacher, their guide, their companion. It will travel with them through their career just as *Radio-Electronics* has through yours. As long as there are electronics professionals, as long as there are people who follow the wonderful ever-changing world of electronics, **Electronics Now** will be there.

Electronics Now is not a new magazine, it is simply a refinement of what has always been. It's an evolution to something better, something wiser, something stronger. A magazine more closely matched to electronics today. Carefully designed, tailored and directed by selected experts who can point you, our reader, through our pages, toward tomorrow.

Electronics Now is *your* magazine. It is the culmination of almost 100 years of progress from the *Electrical Experimenter* to *Radio-Electronics* and finally **Electronics Now.**

If our founder, Hugo Gernsback, were here today, he'd probably note that we should have acted sooner. Perhaps he would have been right. But no matter what, we know we are correct in taking you and us on this new adventure. Join us as we go. Revel in the excitement of today and the adventure of tomorrow. Tell us what you like, what you hate, what we should do, and what we shouldn't.

Write our editors, contact our bulletin board, send me your ideas, comments, and criticisms. Help us make **Electronics Now** exactly the kind of magazine you know it should be. And never forget we may now bear the name **Electronics Now**, but at heart we are *Radio-Electronics, Radio Craft, Shortwave Craft*, *Television*, and the *Electrical Experimenter*.

Larry Steckler

Larry Steckler, EHF/CET
Editor-in-Chief and Publisher

WHAT'S NEWS

A review of the latest happenings in electronics.

Fluke and Philips restructuring

John Fluke Mfg. Co., Inc. (Everett, WA) and Philips Electronics N.V. (Eindhoven, The Netherlands) on August 26 announced their intention to restructure their five-year-old alliance in the test and measurement business. Under the plan, which is expected to take several months to finalize, Fluke would acquire most of Philips' test and measurement operations for cash and stock. Once the contingency factors have been met (approval by Fluke shareholders and the Philips Board of Management, and review by the appropriate social and regulatory organizations), Fluke would acquire essentially all existing Philips' test and measurement businesses, with the exception of professional TV test equipment and power supplies. Fluke would then assume direct responsibility for worldwide marketing, development, manufacturing, sales, and support of most of the combined companies' present product lines. That includes the acquisition of sales and service operations in Europe. About 900 Philips employees would transfer to Fluke.

The management of both companies see the move as a logical progression in their alliance. According to Bill Parzybok, Fluke Chairman and CEO, "All along, we have been evolving the alliance to optimize our performance and improve our position in a changing marketplace. It has become apparent to both companies that a unified management structure, aligned under a single mission, would accelerate our growth and success." That mission, he said, is to position Fluke as the leader in compact, professional electronic test tools. The single focus is expected make the combined company more effective in product definition, design, and marketing, leading to streamlined production and better time-to-market for new products. In addition, Fluke hopes its European presence will allow the company to take advantage of EC'92.

The transaction is expected to add about $125 million to Fluke's revenues, and to favorably impact Fluke's earnings per share beginning in the first year of operations. Fluke expected to issue its proxy statement to shareholders in early November.

See-through magnetic material

Scientists at Xerox Corporation's Webster Research Center (Webster, NY) have produced a transparent magnetic material with potential applications in color imaging, computer information storage, magnetic fluids, and even magnetic refrigeration. (When a magnetic material is moved into a magnetic field it heats up; when moved out, it cools down. That so-called magnetocaloric effect can theoretically be used to build refrigerators. Although magnetic refrigerators have been built, none have worked at anything near room temperature.) The crystalline material is chemically identical to the gamma ferric oxide that has been used for decades to coat audio and video recording tape. But the crystals that make up the physical form of the new material are far smaller than those of conventional magnetic material. The Fe_2O_3 crystals comprising the magnetic material range in size from two to ten nanometers. With such small crystals, the material loses its usual ferromagnetic property and becomes superparamagnetic—a state in which the crystals will stick to a magnet but not to each other.

The transparency is an added bonus that is not generally found in magnetic materials at room temperature. The scientists have not yet determined why the nanocrystals are more transparent than the larger crystals of conventional Fe_2O_3. Although some transparent magnetic materials already exist, their magnetic properties are either too weak to be useful, or they function only at temperatures near absolute zero.

World's most powerful laser-light beam

A breakthrough in the international race to create the world's most powerful laser-light beam has been achieved by scientists at The University of Michigan (Ann Arbor, MI) and the French National Atomic Energy Commission. The 55-terawatt beam of laser light—one terawatt is equivalent to one trillion watts—was produced in April 1992 at the Centre d'Etudes de Limeil-Valenton (Limeil, France). The previous record, set last year in Japan, was 30 terawatts. The beam was produced by the Center's P-102 laser with a laser amplification technique and a second preamplifying laser developed by Gerard A. Mourou, professor of electrical engineering and computer science at Michigan, and his co-researchers.

During the brief laser burst, researchers produced the 55-terawatt of power—the equivalent of 100 times the total electrical power generated in the United States. According to Mourou, "The laser beam can be focused over a spot smaller than the diameter of a human hair to produce extremely high power densities." The researchers say that the most immediate application of the new technology will be to determine what happens when extremely intense laser beams interact with matter.

Preliminary experiments showed that when high-powered laser pulses are shot through plasma, shock waves are created that are capable of accelerating electrons close to the speed of light in very small distances. That could lead to

Continued on page 74

VIDEO NEWS

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

DAVID LACHENBRUCH

• **Nintendo goes 32-bit.** Taking its competitors by surprise, Nintendo announced that, unlike other video-game manufacturers, it will skip the current generation of 16-bit games and go directly to a 32-bit processor when it introduces its CD-ROM accessory next year. The company announced that it had developed a proprietary "Super FX" chip that will make possible 16-bit cartridge games with "true 3D effects." Because its next-generation cartridge games will be 16-bit, the company decided that it would need an enhanced CD-ROM to offer customers a "truly superior game experience."

The new CD-ROM drive will function within the CD-ROM/XA environment, Nintendo said, which theoretically would make it compatible with Philips' CD-I.

• **VIS vs. CD-I.** Tandy's Video Interactive System, or VIS, designed to play CD-ROM's through consumer TV sets (**Electronics Now**, November 1992), formally carries a suggested list price of $699, which includes Compton's *Multimedia Encyclopedia*. Philip's incompatible CD-I system also lists at $699, after recent price reductions, and dealers have been selling it at $599. Consumers who bought players at higher prices are being mailed coupons good for $100 worth of free software. In addition, purchasers returning warranty cards are sent coupons that are good for transfer of their photos to a Photo CD. The CD-I format is compatible with Kodak's Photo CD system (but VIS currently isn't).

• **TV's are growing.** Larger picture sizes continue to grow as a share of the television-receiver market. In the first half of 1992, sales of direct-view sets with tubes 30 inches and larger (diagonally) were up 64% from the same period of 1991. Projection TV sales were up 14%, but the larger sized projectors (50 inches and larger) rose by more than 21%.

• **Who's number one?** Number one in TV set sales, that is. That position is still held by RCA as the leading brand in the United States, with just over 16% of the market. Zenith continues as number two, with a little more than 10%, followed by Magnavox with 9%. Sony is fourth with 7%, and Sharp is fifth with 5½%. The rankings are by *Television Digest*, which has been surveying TV market shares for 26 years. In the first brand rankings for projection TV, Mitsubishi was the clear winner with 22.6% of the market, followed by Magnavox with 4% and RCA with 13%.

• **Digital HDTV works.** The first report on digital high-definition TV by the Advanced Television Test Center (ATTC), which is testing proposed systems for the FCC, offered great encouragement for the future of digital TV transmission. Reporting on the first digital system it tested—General Instrument's DigiCipher—the ATTC's results indicated generally good picture quality with low levels of interference. Contrary to doubts expressed in Europe and Japan, where analog systems are espoused, the tests showed that DigiCipher produces less interference with other broadcasts than the analog NTSC system used in the United States. The tests also appeared to show that the DigiCipher system can provide the same coverage distance from the transmitter as the NTSC system, but at 13-dB lower power. However, digital HDTV does appear to be more sensitive to phase noise, which can probably be overcome by the development of improved filters in TV sets.

• **Priming HDTV's pump.** The fact that HDTV is technically possible doesn't necessarily mean that it will proceed rapidly once a system is chosen. As a matter of fact, it's difficult to determine how the first HDTV pictures will be delivered—by terrestrial broadcast stations, direct satellite, cable, or even possibly by prerecorded media such as videotape or laserdisc. Although the FCC-sponsored tests are designed to determine the best system for terrestrial HDTV broadcasting, it's entirely possible that broadcasters will take a wait-and-see attitude toward HDTV before going to the tremendous expense of adding new studio and transmission equipment—and quite likely new antenna towers to disseminate two separate types of broadcasts during the interim period of HDTV's introduction while NTSC signals are still being broadcast.

When color TV was introduced, TV station owners were extremely reluctant to add color origination equipment because the lack of audience meant that they couldn't charge advertisers a premium for color broadcasts. And it wasn't until 10 years after the introduction of color TV that consumers bought a million sets in any year. (The figure is now well over 20 million a year.) Broadcasters say they can't be certain that there is any market for HDTV—but they do see a lucrative by-product of the current HDTV tests. All digital HDTV systems rely on data compression to squeeze four times the current information into a single 6-MHz channel. So broadcasters are asking whether it might be more lucrative for them to use compression technology to cram two or more standard-definition broadcasts onto a single channel, and thus help on-air broadcasters attain the multi-channel capacity that will let them compete with cable.

Cable itself is in a better position than broadcasters to provide early

Continued on page 74

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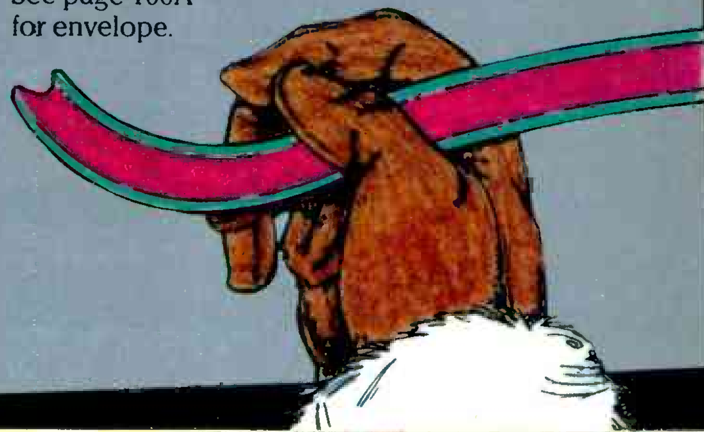
See page 100A for envelope.



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

50-OHM TERMINATION

I recently bought a card for my PC that lets me control things like motors and relays. My problem is that the instructions tell me that each line to the relay or motor must be terminated with at least 50 ohms. I'm not exactly sure what that means, and I was hoping you could explain it to me.—G. Cherben, Nighten, IN

I'm not exactly sure what kind of hardware you bought for your PC, but no matter what it is, yours is the kind of question I like—nice and easy.

All the instructions are telling you is that each of the card's outputs want to see a load of 50 ohms. That kind of termination is standard for computer networks and other things. If you're having a hard time understanding why it's needed, think for a minute of the power-amplifier outputs on a stereo. It's never a good idea to leave them unconnected to anything because an infinite load like that (that's what an open connection is) can put an unnecessary strain on the stereo's output transistors.

The same is evidently true for your controller card. Just as it doesn't want to see a direct short on the control lines, it doesn't want to see too high a resistance either.

I'm a bit surprised that an external termination is required since it would have been easy for the card's designers to include it on the card itself. Most motors and relays have fairly low winding resistances, so the addition of a 50-ohm resistor is pretty silly—kind of like putting a 10-amp fuse on a line that will draw a maximum of only 1 amp. Remember that adding a 50-ohm resistor in parallel to a motor winding with a resistance of 3 ohms or so isn't going to add much to the equivalent total resistance of the pair.

You can buy 50-ohm terminators or just solder a 50-ohm resistor on the line. By the way, for all intents and purposes, a 47-ohm resistor is close enough.

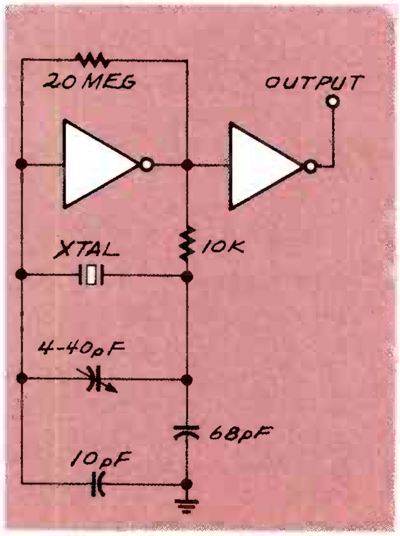


FIG. 1—CRYSTAL OSCILLATOR. If you use an inverting hex buffer like the 4049, powered from a 5-volt supply, the circuit will work with crystals as high as 14 MHz.

CRYSTAL OSCILLATOR

I'm building a circuit that requires a crystal oscillator, but I'm not sure which design to use. I don't have to worry about any extreme temperatures, and I have a bunch of spare gates left over on the board. Most of the crystal oscillator designs I've seen require the addition of special chips, and I don't have a lot of room left on the board. Have you got a simple circuit that will do the job?—J. Gillan, Hendon, NH

If your requirements are as simple and straightforward as you say, the circuit in Fig. 1 is exactly what you need. It can be made from the extra gates you have, is self-starting, and is also extremely reliable.

The circuit will work well with as little as a 5-volt supply, and the crystal frequency limit really depends on the amount of gain there is in the gate you use. Something like a 4049 will work with crystals as high as 14 MHz. If you use more than 5 volts for the supply, you should be able to go even higher.

One interesting variation on this circuit is to use a two-legged gate instead of a simple inverter. That will let you turn the design into a gated oscillator so you can turn it on and off under circuit control. I don't know if that's important in your application, but it's a good thing to keep in the back of your mind.

SCAN RATES

I know this information has probably been printed somewhere before, but could you tell me what the scan rates are for the various kinds of IBM video? I have several monitors available, and I'm not sure which ones can be used with which graphics cards.—S. Heller, New York NY

The variety of IBM video standards has always caused confusion.

IBM VIDEO STANDARDS

VIDEO TYPE	ACRONYM	COLOR	SCAN RATE
MONOCHROME DISPLAY ADAPTER	MDA	B&W	18432 kHz
HERCULES GRAPHICS ADAPTER	HGA	B&W	18432 kHz
COLOR GRAPHICS ADAPTER	CGA	8	15750 kHz
ENHANCED GRAPHICS ADAPTER	EGA	16	21800 kHz
PROF. GRAPHICS ADAPTER	PGA	256	30480 kHz
VIDEO GRAPHICS ARRAY	VGA	256	31500 kHz

It's usually a problem when people want to upgrade their video. In any event, the IBM standards are listed in Table 1. Notice that it doesn't include any of the super VGA frequencies. The reason for that is simply because super VGA frequencies can be anywhere from the regular VGA standard to as high as 50 kHz with a 70-Hz vertical refresh rate. That usually shows up when you get into super VGA with interlaced or non-interlaced video.

QIC AND EASY

I have a QIC-40 tape backup in my computer, and I have just increased the size of my hard drive to 120 megabytes. I know I can back up the drive on several different tapes, but it's a pain in the neck to tag a bunch of files, back them up, then tag another bunch, back them up, and so on. Is there an easier way or will I have to buy a tape drive with a larger capacity?—D. Tunn, Tenafly, NJ

I can't accept the idea that having to use a couple of tapes to back up your new, larger, drive is such a chore. You've obviously forgotten what it was like to back stuff up on floppies. But there are several alternatives you can try.

The first, and most obvious, is that the software that drives the tape usually gives you a way to build a tag list and, by specifying that you want to back up everything in the listed directories, you should be able to avoid having to tag the files individually.

Most tape software also allows you to compress the files on the tape so you can effectively turn a 40-megabyte tape into a larger one. The number of extra files you can get on the tape depends on what kind of files you have to back up, and how effective the software's compression algorithm is. Text and other data files will squeeze down by at least 70%. That is only an estimate, but you should be able to get a substantial savings by compressing the files as you back them up.

If the software that came with your tape drive doesn't have any of those features, there are other programs that will provide them. QIC-40 is a standard that allows a tape recorded on any QIC-40 drive to be read on any other QIC-40 drive.

Another alternative to shelling out bucks for a new tape drive is to use a DC 2120 cartridge rather than the standard DC 2000 that you're probably using now. Those cartridges are compatible with your drive and, because thinner Mylar is used for the tape itself, you can format it to about 60 megabytes. When you add data compression, you should be able to get over 100 megabytes on the tape.

If you are interested in buying a new tape drive, QIC-80 tape drives double the storage capacity of QIC-40 drives by packing twice as much data on the same tape. A QIC-80 drive formats a DC 2120 tape to 120 megabytes, and roughly doubles that to about 250 megabytes using software compression. A new drive won't even set you back by much—QIC-80 drives, such as the Colorado Memory Systems' Jumbo 250, sell for as little as $250, mail order.

LESS THAN MTS

I have an RCA stereo TV that I'm happy with for the most part. It's just that, on occasion, a stereo broadcast will sound like it's coming out of a seashell. I'd love to blame the cable company—and I usually can—but my VCR doesn't suffer the same problem. Friends have told me that the problem is because my TV isn't a true MTS-compatible set. Is this true?—M. Johnson, Lindenhurst, NY

Many people have complained about problems similar to yours—including the folks over at dbx, whose noise-reduction circuitry *must* be incorporated into any stereo TV circuitry in order for it to be called MTS. Lots of manufacturers insist that they can meet the MTS specifications without using dbx, but that's usually done to avoid paying licensing fees to dbx. I suspect that your RCA TV does not have dbx, while your VCR does. If the noise really bothers you, and you're not ready to buy a new TV—with dbx noise reduction—then just use your VCR as the tuner for as long as you have to. **R-E**

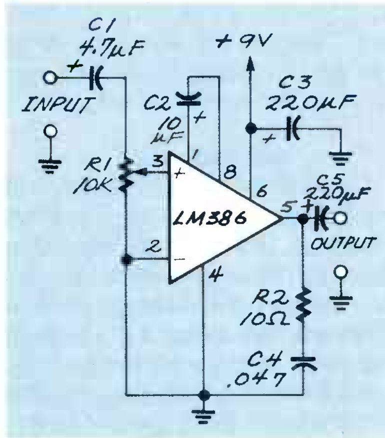
LETTERS

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

DISTORTIONLESS POCKET STEREO AMP

I have some information regarding the "Pocket Stereo Amp" (*Ask R-E*, **Electronics Now**, August 1992) that might be helpful to the person who was having distortion problems when using an LM386. I've experimented extensively with that IC, and while simplicity has its merits, we must remember that a job worth doing is worth doing well. Because pocket stereos often have excellent sound quality, steps should be taken to maintain that quality when building an add-on amplifier for it.

The bare-bones design shown in Fig. 2 of the article might work, but the inclusion of a few junk-box components will yield better results. I've been using the design shown to the right, which is the one that generally shows up in projects that incorporate an audio section. Though the values sometimes differ slightly, all of these components usually appear in the circuit.



The first time I built this amplifier, I omitted capacitor C3 thinking that it would be unnecessary with a battery supply that contains no ripple. That resulted in severe distortion even at low input signal levels. The amplifier even tended to oscillate at times. After some head scratching, I connected a large-value electrolytic capacitor between pin 6 (supply) and ground, which eliminated the problem completely.

The amplifier can be driven with a line-level signal from an auxiliary output or from the headphone jack of a pocket stereo. In the latter case, with R1 adjusted for maximum volume level, the pocket stereo's volume control should be adjusted to the minimum level that will provide adequate sound. That will prevent the possibility of overdriving any LM386's. Once that is done, R1 can be used to adjust the volume.

If two such amplifiers are being used for stereo, C3 can be connected between the common supply line and ground. If you use a power supply that contains a filter capacitor, C3 might not be necessary. C2 is optional as stated in the original article, depending on the need for gain. I recommend using it because even though the amplifier in the pocket stereo provides gain, most of that gain will be lost when the controls are adjusted to limit the level of the input signal.

Capacitor C1 can be omitted if there is no DC component on the input signal line. There probably is none if the source is an earphone jack or auxiliary output of a CD player or cassette player. I have occasionally seen pin 7 (bypass) connected to ground through a capacitor, but it doesn't seem to make any noticeable difference in this application, so I've never used it.

The design shown in Fig. 1 gives a surprisingly good sound considering the low cost of the IC.

As always, I'm grateful for the *Letters* column in **Electronics Now** that allows the exchange of information among readers.

STEVE BABBERT
Worthington, OH

THEFT OF SERVICES

I fail to understand you guys. Is **Electronics Now** a socialist magazine, advocating ripping off cable companies because they are Robber Baron Capitalist Fat Cats, or something? Robert Grossblatt says, "If the cable companies put the signal on your wire, you should have the right to use it." Does he steal from coin newspaper boxes too? After all, his quarter has purchased him access to the box, right? Hasn't he ever heard of "implicit contracts?"

When he took his cable service, he agreed to take the services he paid for. I agree that he should have the right to experiment. But if he steals programming, he isn't just stealing from the Fat Cat Cable Company—he steals from a lot of other people: technicians who work for the cable company, artists who do the programming, electronics manufacturers who supply products to the cable companies, and ultimately from little electronics companies like mine. We design and repair cable, and that work keeps a technician and an engineer employed. That's how *I* see it. And I think that the law agrees with me.

P. MIHOK
Don Mills, Ontario, Canada

TURN-SIGNAL FLASHER UPDATE

The circuit suggested by Timothy Brooks in September's *Letters* column, designed to augment the too-faint click of the automobile turn-signal flashers (a 47-µF capacitor in series with a small speaker connected across the flasher unit) works fine. However, there must be a current-limiting resistor in the circuit. Without it, the speaker's voice coil soon opens up.

F.G. HUTCHINSON
Redwood City, CA

ANOTHER FLASHER UPDATE

The letters in the September issue of **Electronics Now**, suggested different complicated electronic solutions for amplifying an automobile's turn-signal sound. There is a much simpler solution to the weak turn-signal sound problem; I have been using it for a number of years. Many automotive departments of retail stores stock replacement flashers. Look for an Ideal Loud Turn-Signal Flasher No. 577V (Ideal Division, St. Augustine, FL 32084).

It can replace any 12-volt, two-terminal flasher. Only one problem might be encountered: The loud-flasher's case is slightly more than twice as long as a regular flasher's case. That becomes a problem only if there is a lid covering the terminal box containing the flasher. In that case, you can cut a hole in the lid to accommodate the new flasher, or leave the lid off entirely.

VINCENT M. SARITI
Dover, NJ

DISKETTE CONVERSION

In the *Q&A* column in the September issue of **Electronics Now**, there was a discussion of double- and high-density diskettes, and whether or not there really is a difference between them I have converted 3.5-inch "floppy" disks from double-density to high-density by forming a hole in their cases, and I have found that the converted disks work fine without problems. However, *be very careful not to let any small material chips get inside the disk case.*

When a hole is made in the proper place, a small opening into the disk case is created. If a chip from the drilling or punching gets into that hole, it could cause serious damage to the disk—or, even worse, to the disk drive. I consider drilling the hole to be out of the question, and recommend using a very sharp and sturdy punch. Several of these are now on the market.

EMERSON M. HOYT
Beaverton, OR R-E

EQUIPMENT REPORTS

Beckman Industrial HD160 Digital Multimeter

Many people who use digital multimeters—even those who use one every day—consider DMM's to be little more than commodity items. Other people, especially those whose livelihoods depends on the DMM, know the importance of a well designed meter. They'll want to know about a new DMM from Beckman Industrial Corporation (Instrumentation Products Division, 3883 Ruffin Road, San Diego, CA 92123-1898): the *HD160* heavy duty digital multimeter.

The *HD160* is the latest entry in Beckman Industrial's "HD" line of heavy-duty DMM's. It is housed in a sleek, bright yellow case that measures about 6.8 × 2.8 × 1.3 inches. A black rubber holster is supplied with the DMM to provide extra protection. Although the holster adds significant bulk to the meter, it can actually make handheld operation easier, thanks to two probe holders on the holster. The user can hold the meter with one attached probe in one hand, and the remaining probe in the other. The probe holders also provide a secure, safe place to store the probes when the meter is not in use.

The holster also provides a tilt stand that is particularly convenient for bench-top use; a tilt bale provides fixed tilt angles of 20 or 60 degrees from perpendicular. We would expect the *HD160* to be used away from the benchtop as often as not. If you've ever used a DMM while at the top of a ladder or while perched on the service platform of a large industrial machine, you've undoubtedly found that three hands could come in very handy. The *HD160* offers what might be the next best thing: a "Flex-Strap." The Flex-Strap is a Velcro-covered fabric strap that lets you hang the meter vertically from a wide variety of pipes, beams, and the like. Pipes up to about three inches in diameter will serve just fine.

A meter for heavy-duty professionals

CIRCLE 10 ON FREE INFORMATION CARD

The face of the meter is agreeably uncluttered. A large, 7-position rotary control sets the main function selections: AC volts, DC volts, resistance, diode test/continuity, DC current, and AC current. Below the rotary control are four input jacks: a common, one for voltage and resistance measurements one for current measurements of 40 milliamps or less, and one for current measurements up to 20 amps.

At the top of the meter's face, below the 4-digit (10,000-count) LCD readout, are three round pushbuttons: MENU, SELECT, and CLEAR. The sensible menu system is what helps keep the meter face so uncluttered. When the meter is first powered up, it is in its autoranging mode. To change the range, you would press the menu key; a four-item menu (RANGE, HOLD, REL, and MIN MAX) flashes above the digits. With the first press, the menu cursor is on the range selection. Successive pushes of the SELECT button changes the range. Successive pushes of the MENU button changes the cursor position. The CLEAR button can clear a given entry, or it can clear the entire menu, resetting the meter. We found the menu system to be intuitive.

The meter's hold mode, which Beckman Industrial calls "Probe Hold," automatically freezes the meter's display when a stable reading is reached. That means the meter user can keep his hands on the probes, not on the meter—an important feature if you work around dangerous voltages.

The relative mode lets the meter measure values with respect to a reference other than zero. The feature works in the voltage, resistance, current, and diode-test modes.

The max min mode lets the meter measure and record the minimum and maximum values of input signals. The feature works with all functions except diode test. The mode is not useful for capturing transients, but it can be used to measure the operating parameters of a circuit. The automatic power-down feature does not, fortunately, operate in max min mode.

An analog bar graph, made up of forty LCD segments, is useful for peaking circuits; they respond faster than the digital display (20 updates a second as opposed to 2 updates a second), and—as with an analog moving-coil meter—small changes are more obvious.

The *HD160* offers true-rms measurement capability depending on the input signal's crest factor. The crest factor is the ratio of a signal's peak voltage to its rms value. A sine wave has a crest factor of 1.414, a full-wave rectified sine wave has a crest factor of 3.247. Signals with crest factors up to 5.0 can be measured when the display is at or below 2500 counts. At half scale

Continued on page 96

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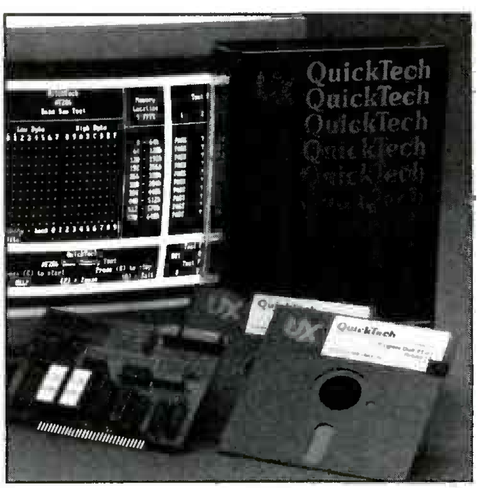

What's more, you now go on to install and test a powerful 40 meg IDE hard disk drive—today's most-wanted computer peripheral—included in your course to dramatically increase your computer's data storage capacity while giving you lightning-quick data access. But that's not all!

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Your NRI training now includes a remarkable diagnostic package that allows you to quickly locate and correct defects in IBM XT, AT 80286/80386, and

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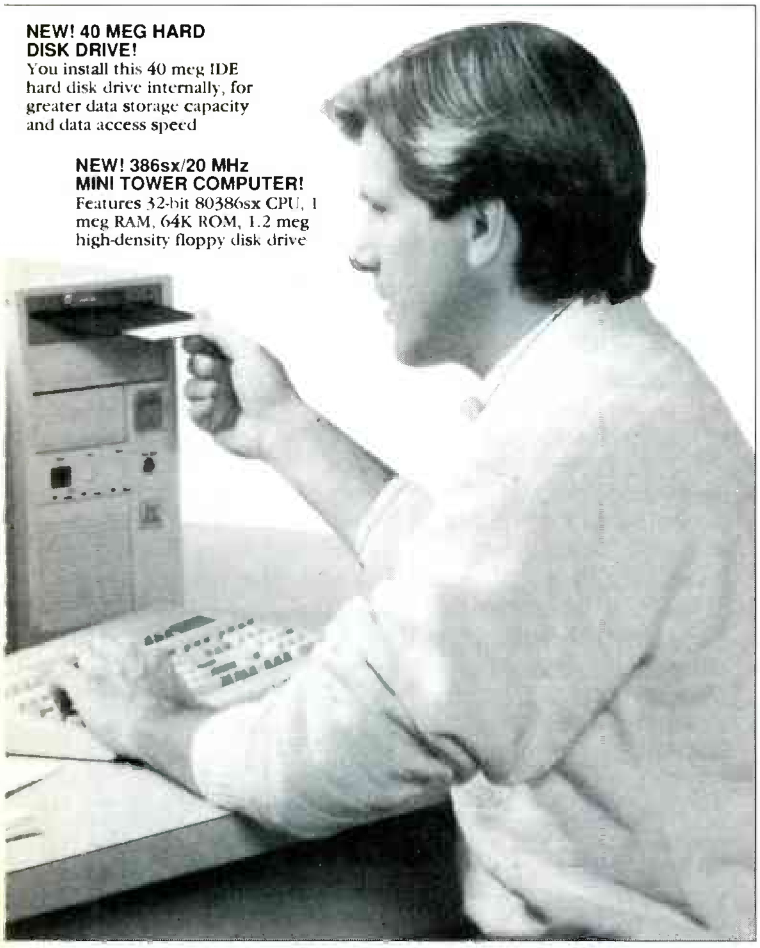

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NEW PRODUCTS

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PROGRAMMABLE PC-BOARD TESTER. You can test more than 600 TTL and CMOS digital IC's with as many as 28 pins with a new *Model 560A B + K-Precision* tester. Said to be able to perform in- and out-of-circuit tests, it was designed for both speed and accuracy.

The tester's vacuum fluorescent display and front-panel LED's prompt the user through the test procedures for a device, and clearly indicate test results and the IC pins where failure has occurred. The "loop test" continuously checks the device under test until a failure is encountered. This technique detects intermittent failures before the components are assembled in a product.

A memory stores responses from a known to be good PC-board for in-circuit testing.

Responses are permanently stored in one of two internal EEPROM's or any of the four EEPROM's located behind the instrument's front-panel access door. In out-of circuit testing, the device to be tested is inserted into the zero-insertion-force socket on the instrument, and a button is pressed so a display shows either a "pass" or "fail" and the pin numbers that have been identified as faulty.

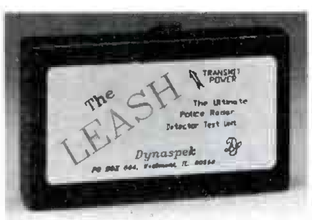
CIRCLE 16 ON FREE INFORMATION CARD

The *Model 560A* includes a device data library that contains data on more than 90% of existing 14- to 28-pin IC's. That library will be updated free of charge as new IC's are introduced. Optional *AK-560A* custom programming software, which does require a processing by a personal computer, allows users to organize tests for non-standard and custom TTL and CMOS IC's.

The *Model 560A* is sold complete with an instruction manual, condensed instructions, IC library list, power cord, in-circuit IC test clips and cables, EEPROM for board-test routines, ground cable, and a spare fuse. It has a price of $3500.—**B + K-Precision**, 6470 est Cortland Street, Chicago, IL 60635; Phone: 312-889-1448.

RADAR-DETECTOR TESTER. When you are out driving, do you worry that your radar detector might not be working correctly—and you could get caught in a speed trap?

Dynaspek eases your worries with its *Leash*, just what you need to be sure that your radar detector (and those of your friends and neighbors) are up to snuff. A handheld radar transmitter, it simulates the feared signal of an X-band police radar gun. Used to test detectors, the unit activates when a button is pressed. A single red LED indicates that it's transmitting. A full signal intensity reading will appear on your police radar detector if it is functioning properly. The "Leash" has an effective range for test purposes of up to a mile.

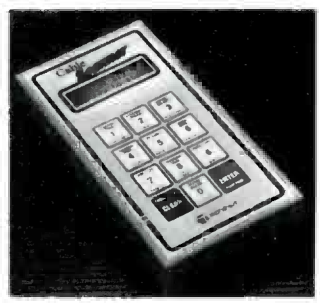


CIRCLE 17 ON FREE INFORMATION CARD

The size of an audio cassette tape, (4.5 × 2.75 × 1 inch), *The Leash* transmits at least 12 milliwatts of power at 10.525 GHz. The manufacturer specifies an 8 dB antenna gain and a 36 × 72 antenna beamwidth. A 9-volt alkaline battery will keep it on the air for about six hours of continuous use, and will power it for several months of intermittent use.

The Leash has a list price of $99.—**Dynaspek**, Box 564, Westmont, IL 60559; Phone: 708-325-7450.

CABLE SCANNER LAN TESTER. It is now possible to eliminate local-area network faults and decrease network downtime when malfunctions occur with the *Cable Scanner* LAN tester from *Contact East*. The tester works with Ethernet, ARCnet, StarLAN, Token Ring, Twisted-Pair and other networks.



CIRCLE 18 ON FREE INFORMATION CARD

A stand-alone tester, *Cable Scanner* permits system analysis to determine if the fault is within the cabling. It then assists in pinpointing the location of the faults or breaks. The scanner provides measurements of cable resistance and noise level, and gives audible continuity checks. It can accommodate a line printer to log activity.

After the fault has been located with CE's *Cable Scanner*, an internal "Tracer" circuit indicates exactly where the cable is located in the wall or above the ceiling. It picks up signals introduced into the the cable by the scanner. The *Cable Scanner* can also be coupled to a personal computer or oscilloscope for system analysis while the LAN is operating. The complete *Cable Scanner* system includes the Tracer, three adapters (Ethernet, ARCnet, and twisted-pair), printer cable, a PC program disk, printer test connector, six AA nickel-cadmium rechargeable batteries, and an operator's manual. The tester is in a case measuring 1 × 4 × 7.5 inches and weighs 2 pounds.

The LAN *Cable Scanner* is priced at $1495.—**Contact East**, 335 Willow Street South, North Andover, MA 01845; Phone: 508-682-9844.

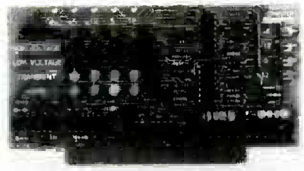
SOLDER PASTE EVALUATION KIT. Solder cream, powdered solder mixed with flux, has many advantages over conventional flux-core wire solder or preforms in electronics manufacturing. The cream can be applied more precisely to the parts to be soldered, less solder is needed, there is better control of metal deposition, and the wetting of metals to be bonded is more uniform.

CIRCLE 19 ON FREE INFORMATION CARD

ESP is offering its *Kit-5*, containing five prepackaged containers of ESP solder cream, molded dispensing tips, and a reusable hand dispenser for precise solder application to help you evaluate its product. The kit includes two tubes each of 60% tin, 40% lead solder paste alloy and lead-free 96% tin and 4% silver solder. Each 35-gram tube is supplied with both an activated rosin flux and a water-washable flux. Also included in the kit is a prepackaged tube of ESP's activated rosin paste flux for evaluating its desoldering effectiveness.

The *Kit-5* evaluation kit is priced at $89.—**ESP Solder Plus**, 14 Blackstone Valley Place, Lincoln, RI 02865-1145; Phone: 1-800-338-4353; Fax: 401-333-4954.

DIAGNOSTIC CARD. A faulty power supply can introduce errors into a computer. The *Power Good* from *Sibex* is said to be the first diagnostic card dedicated to the test of PC power



CIRCLE 20 ON FREE INFORMATION CARD

supplies. It is intended to assure the user that quality power at the specified voltage is being drawn by the computer.

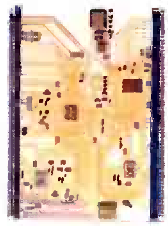
The user plugs the card

CIRCLE 188 ON FREE INFORMATION CARD

To demonstrate the value and durability of this amazing

Rest assured, no scope was injured in the making of this ad.

After all, the volunteer is a member of our new TAS 400 family of analog oscilloscopes. And every TAS has its entire acquisition system (including the vertical, horizontal and trigger functions for each input channel) housed on a proprietary hybrid circuit.



The result is a kind of scope on a chip.

One with 75% fewer parts and far greater reliability. In fact, the TAS is three times more reliable than previous scopes.

What's more, each and every TAS

CIRCLE 92 ON FREE INFORMATION CARD

into an expansion slot on his PC and observes the included LED lamps. Green LED's indicate a good power supply. Red or yellow LED's indicate problems. The unit tests each of the four voltages for high- or low-voltage conditions and the presence of ripple or noise. A built-in latch detects spikes and transients. A connector on the card allows the user to test power supplies before they are installed in the user's computer.

The *Power Good* card is priced at $139.95.—**Sibex Inc.**, 1040 Harbor Lake Drive, Safety Harbor, FL 34695; Phone: 813-726-4343; Fax: 813-726-4434.

FM COMMUNICATIONS RECEIVER. A small handheld FM radio receiver is now available for security, communications, and recreational monitoring. The Model R10 FM Communications Interceptor from *Optoelectronics* is classified by the FCC as a communications test instrument. It can measure deviation (wide and narrow band), relative signal strength, signaling tones (CTCSS), and other demodulated FM. The receiver can also test VHF, UHF, and cellular radio transmitters.

According to its manufacturer, Model R10, unlike conventional radio receivers or scanners, receives any strong signal present, and is actually stabilized by the received signal. The company says the Model R10 does not have to be tuned to a specific frequency to receive a signal. Any FM signal from 30 MHz to 2 GHz can be intercepted without any gaps in coverage.

The *Interceptor* works best in the near-field, the

CIRCLE 21 ON FREE INFORMATION CARD

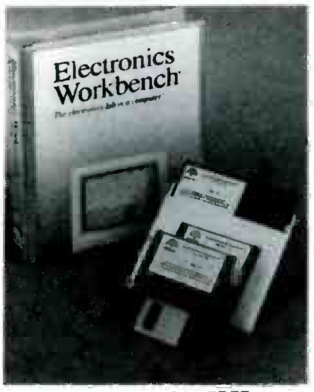
region surrounding a transmitter where signal strength is high but falls off rapidly with increasing distance. The receiving range varies, depending on the presence of strong signals in adjacent bands. But distances of 200 to 400 feet from a 5-watt UHF or VHF transmitter are typical for Model R10.

The unit is completely automatic for hands-free operation, and is small enough to be carried in a shirt pocket. For test applications, demodulated audio output is available from a stereo phone jack. The *R10* also has a built-in speaker.

A lock-release pushbutton frees the unit to lock onto a different signal. This feature is handy when several relatively large signals are present. Dual ten-segment bargraphs indicate deviation and relative signal level. A pushbutton switch selects wide- or narrow-band bargraph calibration. An internal rechargeable battery pack provides up to six hours of operation.

The *Model R10 FM Communications Interceptor* is priced at $359.—**Optoelectronics Inc.**, 5821 NE 14th Avenue, Fort Lauderdale, FL 33334; Phone: 800-327-5912 or 305-771-2050; Fax: 305-771-2052.

ELECTRONICS WORKBENCH SOFTWARE. *Interactive Image Technologies Ltd.* calls its *Electronics Workbench* software "the electronics lab in a computer." The program in a computer is said to allow users to design, assemble, and test analog and digital circuits by simulation. The company recommends its software for teaching electronics, electronics experimenting, and the prototyping of circuits. The patterns on the computer screen are identical to those that would be displayed on an oscilloscope in an actual test procedure.



CIRCLE 22 ON FREE INFORMATION CARD

The program consists of two modules: the analog module permits the simulation of electronics components and transistors as they would be done with hardware in a real lab. The digital module provides simulated ideal digital components and instruments needed to build and test logic circuits. The analog module includes SPICE simulation. This permits both transient and steady-state analysis.

Among the components that can be simulated with the software are resistors, capacitors, inductors, transformers, diodes, LED's, bulbs, fuses, Zener diodes, and transistors. Both AC and DC voltage and current sources can be simulated. A function generator provides square, triangular, and sinusoidal waves for test purposes, and a multimeter, dual-trace oscilloscope, and a bode plotter can be called up for making simulated on-screen measurements.

The digital module permits the simulation of ideal logic: and, OR, XOR, NOT, NAND, and NOR gates. Also available in the program are RS, JK, and D-flip-flop functions, a half adder, and a seven-segment LED display. The user can call up a voltmeter and an eight-channel logic analyzer to check out his work. Both logic conversion and simplification can be performed with the software.

Three versions of *Electronics Workbench* are available:

- IBM-compatible Professional—a color version that supports a math coprocessor.
- Personal Plus—for IBM PC's and compatibles, a monochrome alternative.
- Macintosh Program—available in monochrome only.

The Professional Version of *Electronics Workbench* is priced at $299.—**Interactive Image Technologies Ltd**, 908 Niagara Falls Boulevard, North Tonawanda, NY 14120-2060; Phone: 416-361-0333; Fax: 416-368-5799.

DC-TO-AC POWER INVERTER. Progress is still being made in the development of DC-to-AC power inverters, according to *Statpower Technologies*. The company says its new *PROwatt 800* 12- volt DC to 115-volt AC power inverter is designed for industrial applications and has a power output of 1000 watts for 10 minutes, 900 watts for 30 minutes and 800 watts continuous.

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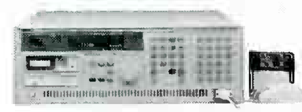
The *PROwatt* inverter is packaged in a small case measuring 3 × 9 × 10 inches and weighs five pounds. It can produce very high temporary power levels to run loads with high starting surge requirements (such as compressor motors). An LED bar-graph display provides continuous information on battery voltage and power draw. The unit can be easily connected to any deep-cycle storage battery.

PROwatt's low no-load current draw easily permits the conversion of most of a vehicle's battery power to usable AC power. Solid-state circuits regulate the output voltage and frequency. *Prowatt's* modified sinewave output is suitable for most electric motors and inductive loads. The output waveform does not change as the input voltage rises or falls. This permits it to power computers, test equipment, TV's, VCR's, and CCTV equipment from an automotive supply.

PROwatt 800 shuts down if the battery voltage exceeds its high and low limits. Audible alarms and LED indicators warn of faults so that corrective action can be taken. Once a fault is corrected, the unit will automatically restart.

The *PROwatt 800* is priced at $499.—**Statpower Technologies Corporation**, 7725 Lougheed Highway, Burnaby, BC, Canada, V5A 4V8; Phone: 604-420-1585; Fax: 604-420-1591.

RGB VIDEO GENERATOR. This programmable RGB video generator is intended for use in the design, production, service, and quality control of the most advanced computer-driven CRT and LCD monitor displays. The *Leader model 1605* handles pixel rates to 300 MHz. Its graphic user interface uses on-screen menus and graphic displays with mouse control to provide visual guidance in raster assembly, pattern selection and design, signal drive options, storage, and retrieval. Waveforms are displayed to help in organizing rasters, and patterns are assembled on the screen with a palette of 256 colors from a range of 16.7 million colors. As



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many as 100 addresses can be stored in both RAM and ROM and storage capability can be expanded to 1800 addresses on the built-in floppy disk. EPROM's can be programmed by the this video generator without additional equipment, and it will accept data from all earlier Leader RGB video generators. High-speed data transfer can be carried out with analog, TTL, and ECL outputs. Those outputs have a wide range of sync options including tri-level sync, half-line equalizers, and serrations.

The *Model 1605* RGB video generator is list priced at $18,500.—**Leader Instruments Corporation**, 380 Oser Avenue, Hauppauge, NY 11788; Phone: 800-645-5104 (in NY, 516-231-6900). **R-E**

NEW LIT

Use The Free Information Card for fast response.

1993 CATALOG; from Radio Shack, 700 One Tandy Center, Fort Worth, TX 76102; free at local Radio Shack Stores.

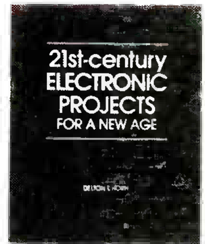
CIRCLE 40 ON FREE INFORMATION CARD

Radio Shack's 1993 catalog has a redesigned layout and organization as well as a lot of new products. The 172-page, full-color, magazine-sized catalog now has a "Quick Index" up front, and a complete index at the end. New products highlighted in this edition include the Duofone ET-499 voice-scrambling cordless telephone. It scrambles the transmission between the handset and the base so people with nearby scanners can't eavesdrop on your conversations.

Others are the Memorex Model 800 8mm home VCR with stereo sound and the portable Model 17 8mm VCR/TV combination, both with 179-channel TV tuners. Tandy is offering a 25-MHz, 486-based multimedia PC that includes a wide selection of software for voice mail, communications, travel planning, and more.

Also included in the 1993 catalog are telephones and accessories, pagers, scanners, world-band transceivers, VHS VCR's, remote controls, and automotive sound systems. There are also entries on home-control products, batteries, flashlights, multi-use testers, remote-controlled toys, computer based language and information sources, calculators, personal organizers, and notebook PC's.

21ST-CENTURY ELECTRONIC PROJECTS FOR A NEW AGE; by Delton T. Horn. TAB Books, Division of McGraw-Hill Inc., Blue Ridge Summit, PA 17294-0850; Phone: 1-800-822-8138; $16.95.



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The term "New Age," usually associated with mysticism, music, and cultural fads, has now been applied to electronics projects by Mr. Horn in his new book. This volume—from a well known and prolific writer—presents an array of unusual electronic projects intended to test and demonstrate theories underlying New Age beliefs.

Included among the projects in the book are a dual-LED visual hypnotic aid, an alpha-wave biofeedback monitor, a two-choice ESP tester, a negative-ion generator, a biorhythm clock, a Kirlian photography experimental circuit, and a magnetic-field tester. Mr. Horn does not take a stand either for or against the theories that are the subjects of his experiments. However, the underlying concepts are fully explained.

1992/1993 DISCOUNT TEST EQUIPMENT CATALOG. Print Products International, 8931 Brookville Road, Silver Spring, MD 20910; Phone: 1-800-638-2020 or 1-301-587-7824; Fax: 1-800-545-0058 or 1-301-585-5402; free.

Here is another discount equipment catalog. This one has 68 pages filled

CIRCLE 38 ON FREE INFORMATION CARD

with entries on bargain-priced test and measurement equipment from such well-known manufacturers as Kenwood, B+K, Avcom, Pace, Philips, Hitachi, and Leader. Included in the catalog's coverage are oscilloscopes, power supplies, meters, and spectrum analyzers. In addition, the catalog describes new lines of closed-circuit TV systems for security and monitoring. **R-E**

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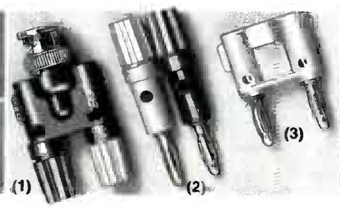

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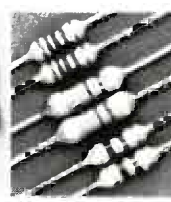

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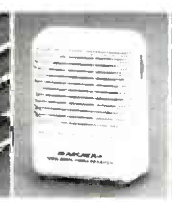

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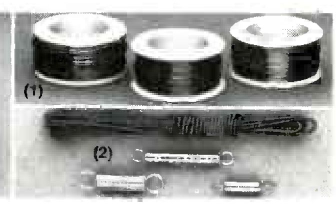

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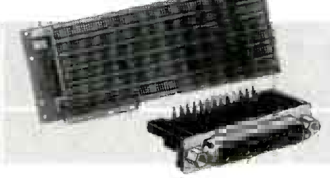

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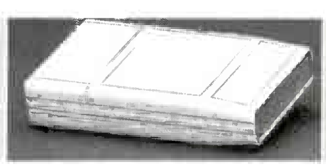

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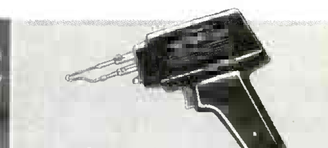

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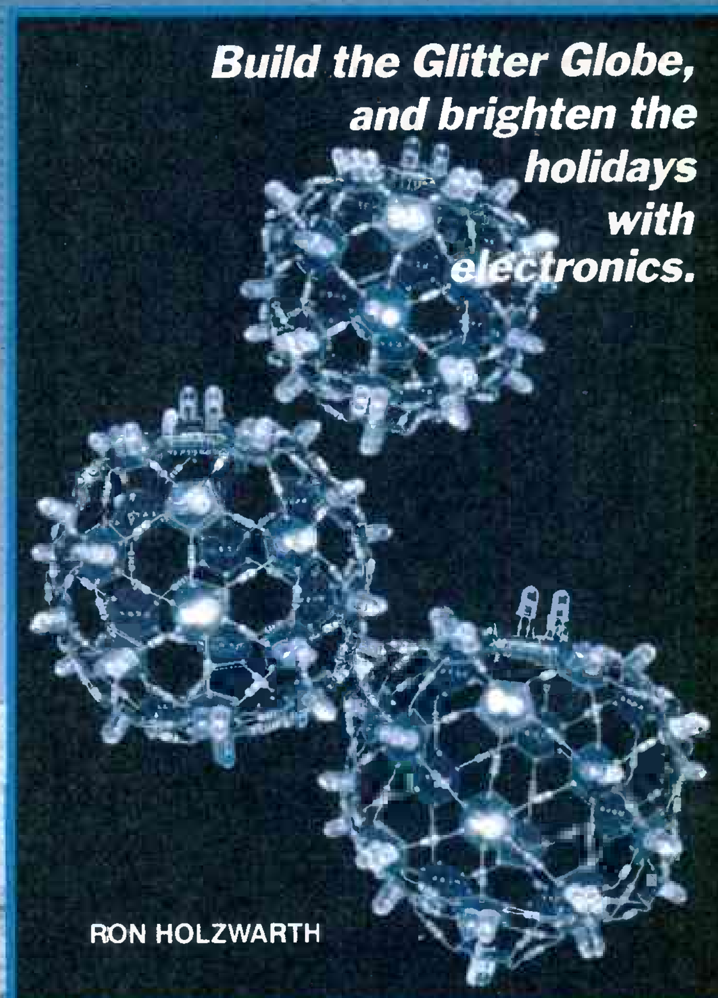
GLITTER GLOBE



Build the Glitter Globe, and brighten the holidays with electronics.

RON HOLZWARTH

WE'D LIKE TO PRESENT ONE OF THE most unusual construction projects you're likely to build. Calling the Glitter Globe simply a construction project does not do it justice—calling it an *electronic sculpture* is more accurate. This is a challenging project, and not for the inexperienced builder. Building the Glitter Globe is a lot like building a model airplane or car, because the quality of your workmanship will be very evident in the finished appearance of the circuit. You can't hide sloppy construction inside a case!

The Glitter Globe is perhaps the world's most sophisticated Christmas ornament: it's constructed entirely of electronic components and very small circuit boards. Each circuit board holds a pair of LED's that chase each other around the globe, creating the illusion that the globe is spinning. The LED's can be the same or different colors, and at least 12 LED's light up at each step. One diagonal line of LED's is always one step ahead of another, creating the illusion that the Glitter Globe is spinning.

Two different animations are possible depending on the value of a resistor (R2): the globe can appear to accelerate and decelerate smoothly over a time period of about 20 seconds, or it can slow gently until almost stopping, and then accelerate quickly. The cycle then repeats. The globe can hang from its power cord in a Christmas tree or lie on any flat surface.

The small PC boards used to make the Glitter Globe can also be hidden in various places (other than as part of the Glitter Globe), such as in clothing or behind photographs to add lights at strategic places. Art forms of this kind are rather popular.

The Glitter Globe is a geodesic sphere; the particular shape is a star-dodecahedron with twenty vertices, which is one of two star-dodecahedra known as the star polyhedra of Kepler. The other star polyhedra has twelve vertices, and could also be constructed from the Glitter Globe's board set.

Circuit description

Figure 1 is the schematic for the Glitter Globe, which is powered from a 12-volt DC supply. (It can therefore be powered from a car's cigarette lighter.) The first stage of the circuit is a triangle/sawtooth waveform generator made from IC1-a and -b, which are part of an LM3900 quad-amplifier chip. This stage varies the acceleration of the globe's apparent rotation by integrating a DC voltage to the trip point of a Schmitt trigger (IC1-b). After IC1-b trips, IC1-a integrates in the opposite direction until the other trigger point is reached. Increasing the value of C1 will lengthen the time period between accelerations. Resistor R2 is set at 2 megohms for a triangle wave output and 200 kilohms for a negative-ramp sawtooth output.

The output of the waveform generator goes to the input of IC1-c, a voltage-controlled os-

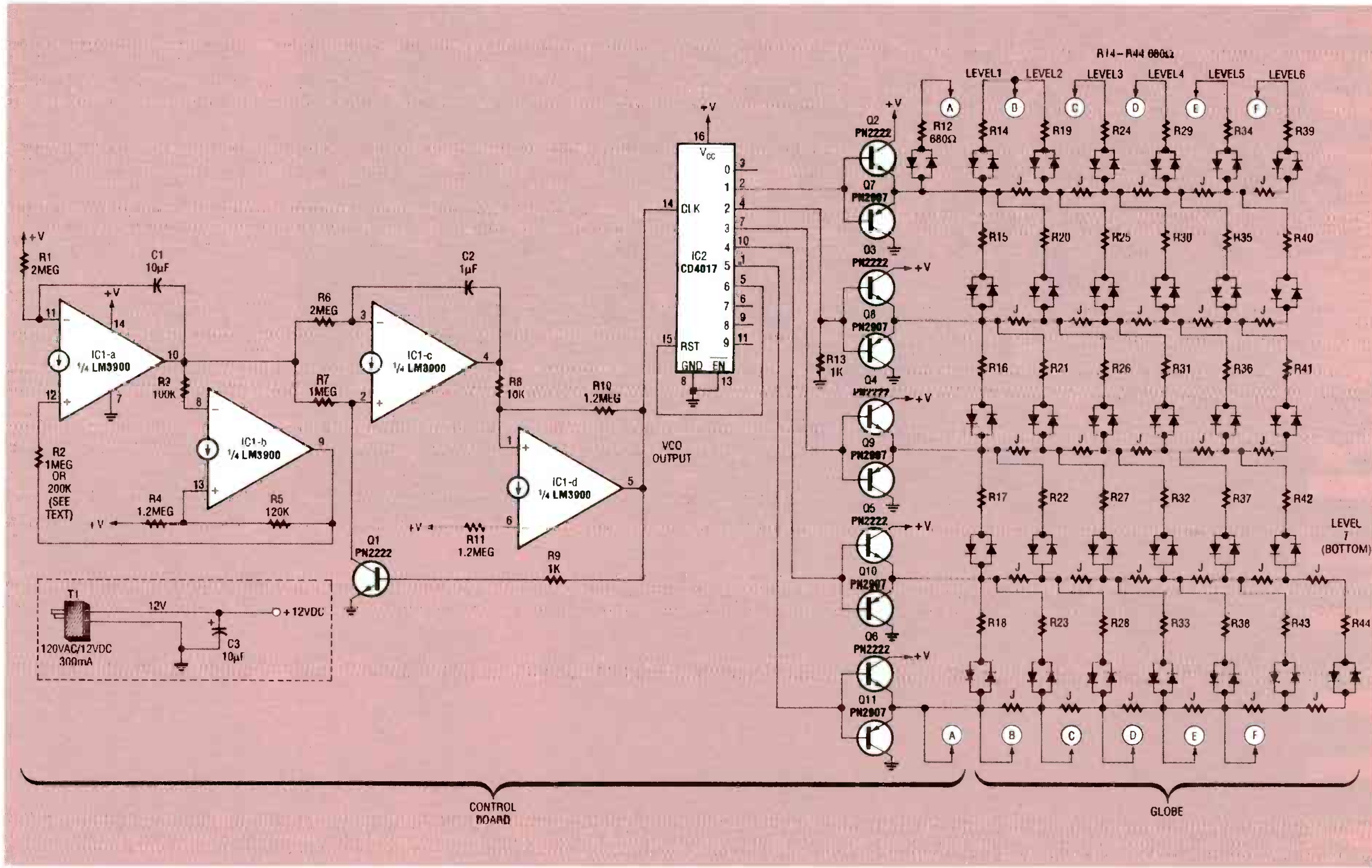


FIG. 1—GLITTER GLOBE SCHEMATIC. The first stage of the circuit, a triangle/sawtooth waveform generator, varies the speed of the Glitter Globe's apparent rotation. All horizontal resistors marked with a "J" are zero-ohm jumpers.

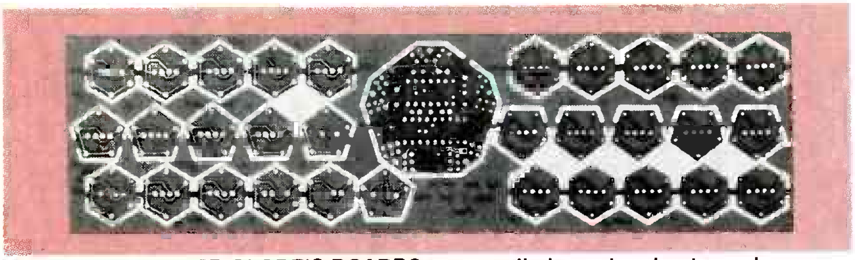


FIG. 2—THE GLITTER GLOBE'S BOARDS are supplied on a breakout panel.

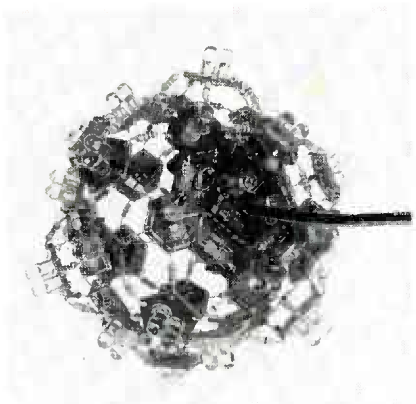


FIG. 5—YOU CAN MAKE a hardball-size star dodechehedra by keeping all the structural resistors and jumpers approximately ½-inch long.

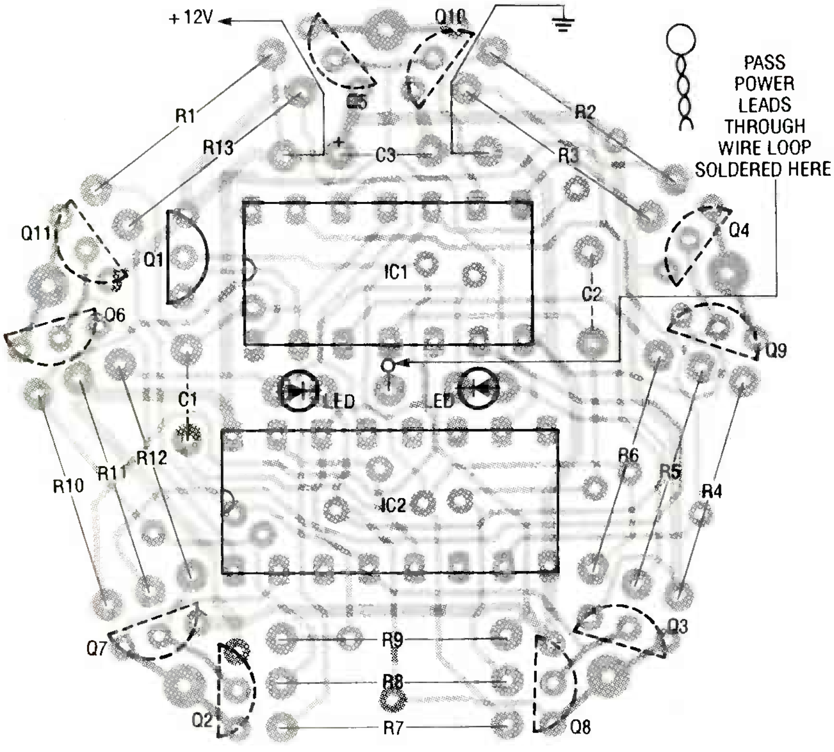


FIG. 3—CONTROL BOARD PARTS PLACEMENT. Capacitors C1 and C2, and all of the transistors, except Q1, are installed on the solder side of the board. The "c" silkscreened on the board indicates the collector lead of each transistor.

FIG. 4—YOU CAN MAKE a softball-sized star dodechehedra by forming all the structural resistors and jumpers approximately ¾-inch long. The pentagon boards stick out a little more than the hexagon boards.

cillator (VCO). The VCO operates very much like the waveform generator except that its voltage reference is the output of the waveform generator instead of the power supply. When transistor Q1 conducts, it grounds pin 2 of IC1-c and the output voltage of the integrator decreases. When the trip point is reached, Q1 ceases conduction, and the output then rises again. The value of C2 (as well as the voltage from the function generator) determines the speed of rotation. To decrease the speed of the spin action, simply increase the value of C2.

The output of Schmitt trigger IC1-d is the input for IC2, a CD4017 decade counter. Only five outputs of the counter are used; after a count of five, the counter resets, resulting in continuous "motion" around the globe.

Since the outputs of IC2 cannot provide enough current to drive a dozen or more LED's, transistor pairs (a PN2222 and a PN2907) are used to drive them. A high output from IC2 turns on the NPN transistors (the PN2222's) and a low output turns on the PNP transistors (the PN2907's). The output of IC2 that is high will turn on the PN2222 transistor connected to it, which sources the LED current. The current is then drained through the two PN2907 transistors on the adjacent outputs.

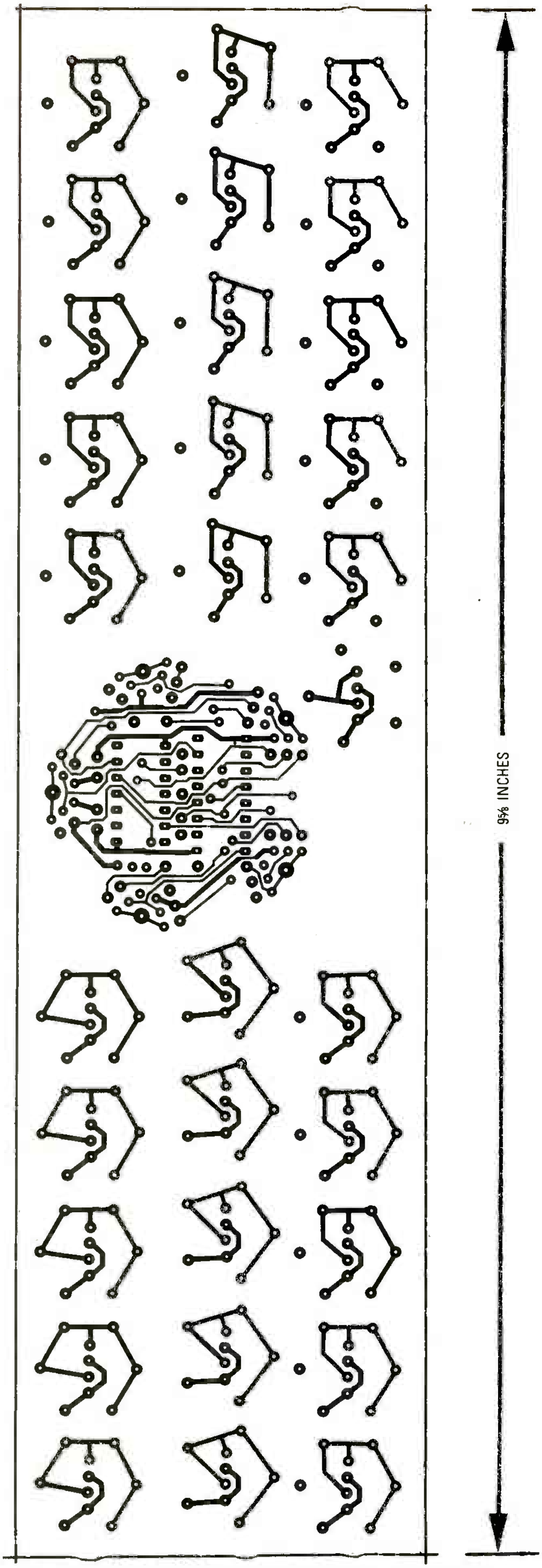
Zero-ohm resistors (jumpers) distribute power around the globe. Plain wire jumpers could be used, but the zero-ohm resistors look much better. Current-limiting 680-ohm resistors (one for each LED pair) ensure that less than 20 milliamperes passes through each forward-biased LED during conduction.

The LED's are all connected back to back so that current flow in one direction lights one, and current flow in the other direction lights the other. That way a color orientation is maintained as the Glitter Globe steps around its five outputs.

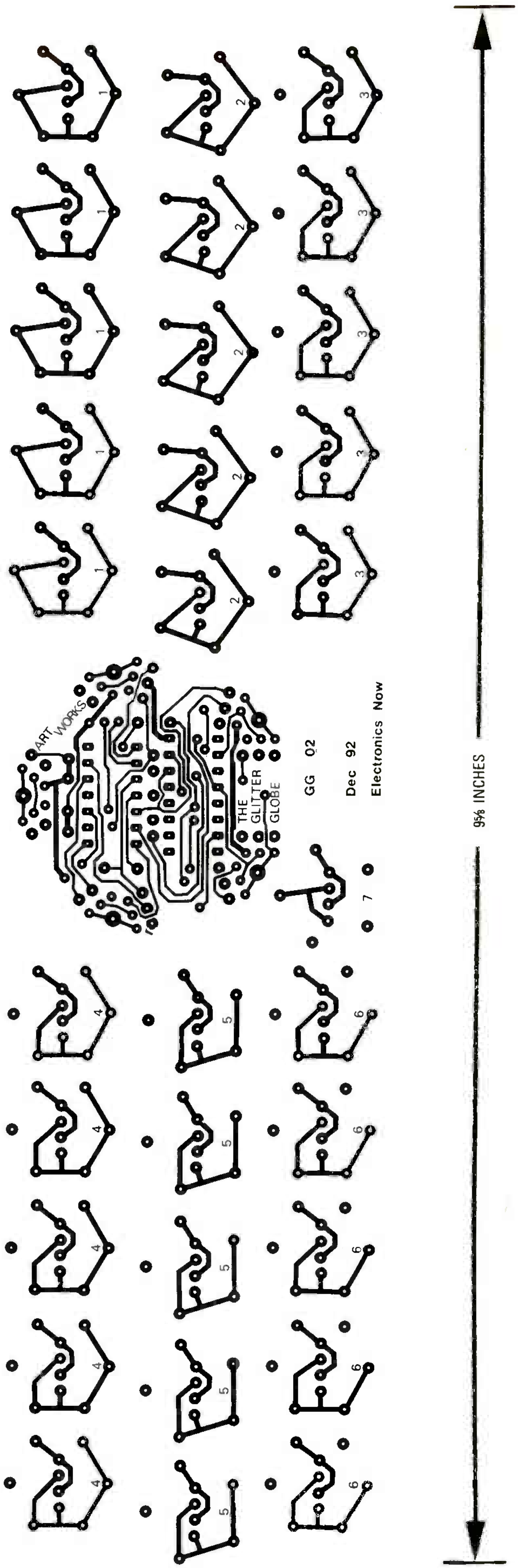
Conduction through one LED limits the reverse voltage across the opposite LED. That's not a concern, except with blue LED's which have a reverse-voltage limit of only 5 volts.

Assembly

Before beginning assembly, have the following tools on hand: a small vise or clamp to hold the globe steady as you work, a pair of needle-nose



COMPONENT SIDE of the Glitter Globe's breakout panel.



SOLDER SIDE of the Glitter Globe's breakout panel.

PARTS LIST

All resistors are ¼-watt, 5%.
R1, R6—2 megohms
R2—1 megohm for triangle wave, 200,000 ohms for sawtooth wave
R3—100,000 ohms
R4, R10, R11—1.2 megohms
R5—120,000 ohms
R7—1 megohm
R8—10,000 ohms
R9, R13—1000 ohms
R12, R14–R44—680 ohms

Capacitors
C1—10 µF, 16 volts, nonpolarized electrolytic
C2—1 µF, 16 volts, nonpolarized electrolytic
C3—10 µF, 25 volts, tantalum electrolytic

Semiconductors
IC1—LM3900 quad amplifier
IC2—CD4017 decade counter
Q1–Q6—PN2222 NPN transistor
Q7–Q11—PN2907 PNP transistor

Miscellaneous: 64 LED's (any color), 28 structural resistors (680-ohm units will match the rest of the resistors), 25 zero-ohm jumpers, 12-volt DC 300-mA wall transformer, PC board set, solder, etc.

Note: The following items are available from Art Works, 415 E. Emerson Street, Saint Francis, Kansas 67756:
- **Set of 32 PC boards, supplied on a breakout panel—$30.00 each, three or more are $25.00 each**
- **Complete Glitter Globe kit (includes PC board, 300-mA wall transformer, 64 LED's, and all components)—$65.00 each, three or more are $55.00 each**

All prices include taxes, shipping, and handling. Please state LED color preference (red, green, or yellow); colors can be mixed. Visa/Mastercard orders (800) 486-6862. For technical assistance call (913) 332-2726. Blue LED's are not available with the kit.

pliers, a small file, a pair of clippers, and a desoldering tool or desoldering braid.

All of the Glitter Globe's boards are supplied on a breakout panel (see Fig. 2). The control board should be assembled first; its parts-placement diagram is shown in Fig. 3. Remove the control board from the breakout panel and file off the excess material.

Insert the components into the control board, making sure that the IC's are inserted correctly and that the tantalum capacitor (C3) is inserted with the proper polarity. Capacitors C1 and C2, and all of the transistors, except Q1, are installed on the solder side of the board. The "c" silkscreened on the board indicates the collector lead of each transistor. Looking at the flat side of the transistors with the leads pointed down, the leads are, from left to right, emitter, base, and collector.

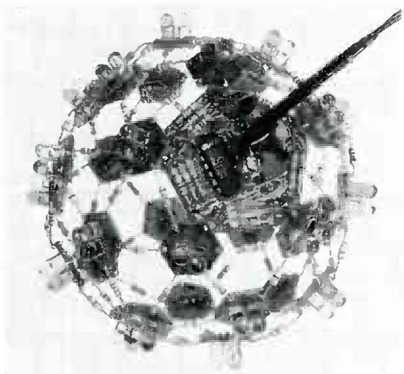


FIG. 6—TO MAKE A SPHERICAL GLOBE, all of the resistors and jumpers that connect to any five-point board (levels 2, 5, and 7) must be preformed to ⅝-inch, with the rest remaining ¾-inch.

In the center of the control board there is a hole for soldering a loop of wire that acts as a strain relief for the power leads. Strip and tin the ground and power wires from the transformer, and then insert them through the center support loop before soldering them into the PC board. The transformer included with the kit (see the Parts List) has the positive lead marked with a white stripe—other transformers can be marked with the opposite convention, so be sure to check the polarity before soldering!

Test the control board to make sure that it works correctly before building the rest of the globe. When powered up, the two LED's on the control board should light sequentially, and then stay off for a brief time. The flash rate change will be

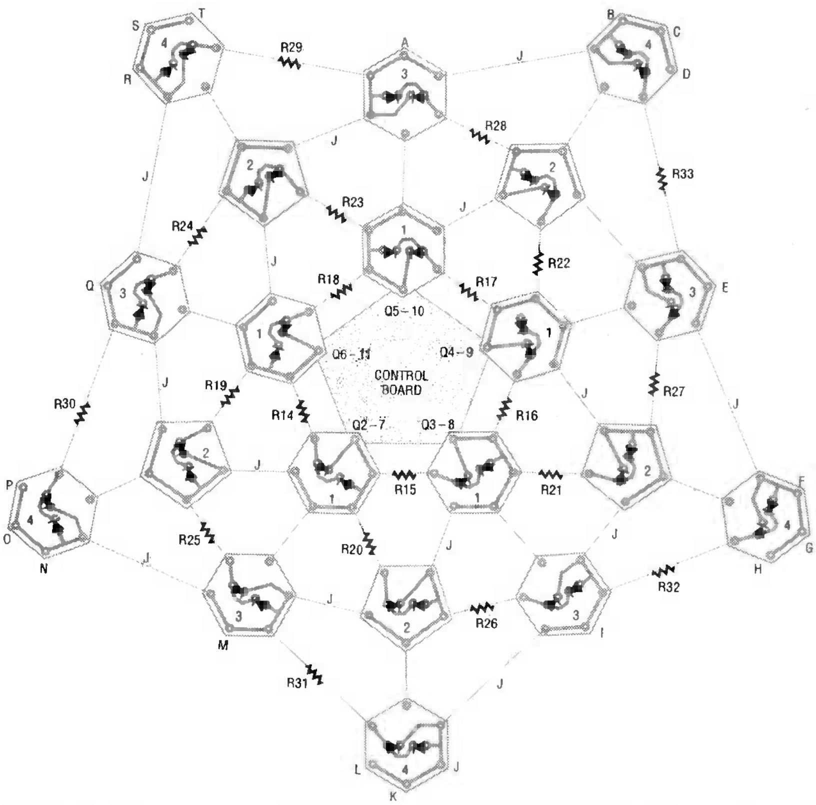


FIG. 7—THIS "COMPONENT MAP" shows how the level 1–4 pieces connect together. All connections marked "J" are zero-ohm jumpers, all connections showing a resistor symbol must be 680 ohms, and all unmarked connections can be made using any material you like.

very obvious. Unplug the transformer before continuing.

The LED boards are numbered on one side in groups from 1 to 7. Groups 1–6 contain five boards each; group 7 is just a single board. The numbers represent the levels away from the controller board in which the LED boards are installed. For example, level-1 boards are installed immediately around the controller board, level 2 surrounds level 1, 3 surrounds 2, and so on. All boards in each level are identical. Locate the numbered side of each board on the inside of the globe, with the LED's on the outside. Putting the numbers on the outside of the globe will result in the diagonal power busses (and thus the lighting pattern) running the other way, although the spin direction will remain unchanged. Also, always position the LED boards so that the numbers on their inside surfaces are pointing away from the control board.

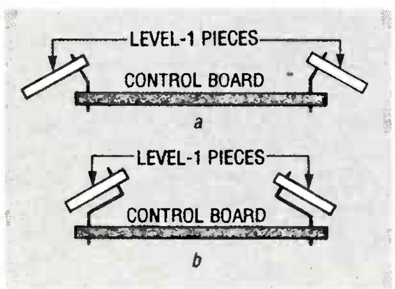


FIG. 8—IF YOU USE ¾-inch spacing, level 1 mounts as shown in *a*; for ½-inch spacing, level 1 mounts as shown in *b*.

Solder the LED's into the small PC boards before removing them from the breakout panel. If you are making a globe with two colors, one color should always be on the left, and the other on the right. Because changing a defective LED can be very difficult after the globe is assembled, test all LED's before soldering. Some multimeters can quickly check LED's; otherwise set up a DC power supply and current-limiting resistor to make sure all the LED's work. The LED's are installed in the boards with their cathodes facing each other (with the flat sides toward each other). Clip excess leads after soldering.

It's much easier to keep the small boards oriented correctly while adding them to the globe if you remove them from the panel only as needed. When you remove the boards from the breakout panel, use a small file to remove any excess material.

Shapes

The least difficult shape to complete is the star dodechehedra. That's the shape that results if all the structural resistors and jumpers are preformed to the same length—approximately ¾-inch. Their actual lengths are not critical, as long as they are all equal. That results in the pentagon (five point) boards sticking out a little more than the hexagon (six point) boards (see Fig. 4). With ¾-inch spacing, the globe will be about the size of a softball.

It is possible to construct a globe with a uniform resistor spacing of ½-inch, but this should be attempted by only the most skilled assemblers. That results in globe the size of a baseball (see Fig. 5). Once you decide on the proper lead spacing for the globe you wish to build, use a bending jig to make all components the same length. If you don't have a real bending jig, cut a piece of wood to the proper width (½-inch, ¾-inch, etc.), and make a depression in it for the body of the component. You can do that by pressing an unneeded resistor into the wood to leave an impression. (Try to center the impression within the width of the wood.)

Although it might seem to be easier to loop the resistors and jumpers through the boards, it is not recommended because they are difficult to remove later, in case of an error. It's best to put the lead straight through the PC board, and then snip it off after soldering. If a repair is necessary, the lead can then be lifted straight out after remelting the solder.

To make the globe into a spherical shape about the size of a softball, all of the resistors and jumpers that connect to any five-point board (levels 2, 5, and 7) must be preformed to ⅝-inch, with the rest remaining ¾-inch (see Fig. 6).

Continued on page 85

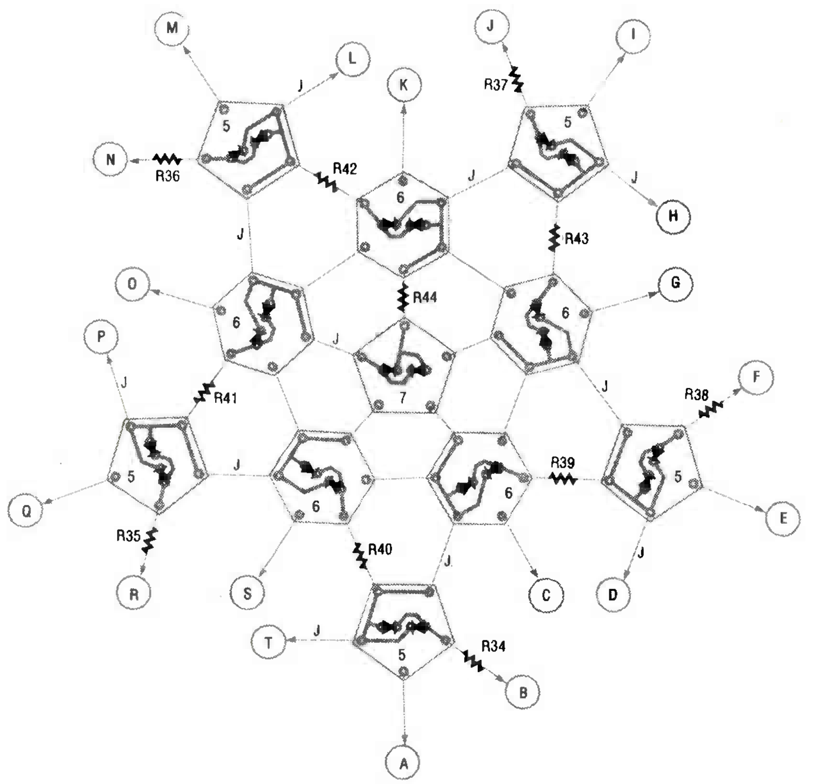
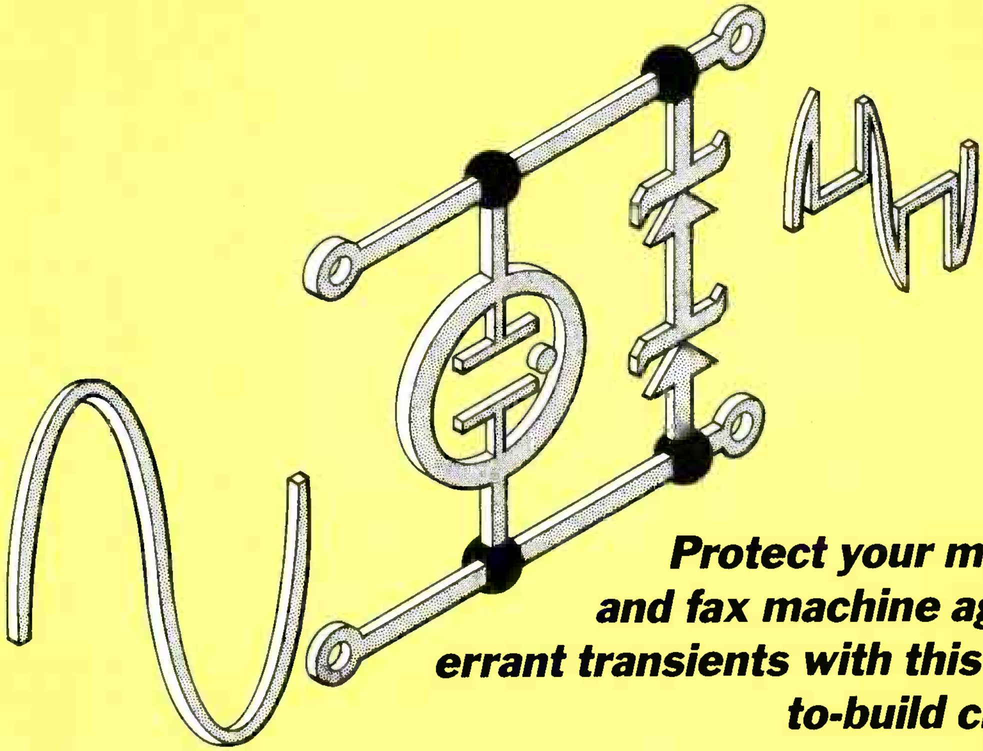


FIG. 9—LEVEL 5–7 COMPONENT MAP. The letters surrounding the two halves in Figs. 7 and 9 indicate the connections between them. Install each level in order from 1 to 7.



Protect your modem and fax machine against errant transients with this easy-to-build circuit.

FAX/MODEM PROTECTOR

TOM PETRUZZELLIS

SHIELD YOUR MODEM, FAX, OR ANswering machine against harmful transients arriving over the phone line by building this fast-acting Modem/Fax Protector. Then you'll be able to relax when electric storms bear down on your home or office. It's an easy, inexpensive project, and low-cost insurance for your expensive telephone-dependent equipment.

Even people who plug their computers and entertainment electronics into power-line surge protectors (and wouldn't dream of leaving them unprotected) are likely to forget about protecting modems, faxes and answering machines from transients arriving over the phone line. Then comes the first thunder storm of the season. Before they remember to do anything about it, the innards of that equipment could disappear in a puff of smoke.

You could, of course, disconnect your telephone gadgets with a switch when they're not in use. But will you remember to do it in time? Needless to say, the switch won't help much if the devices are running when the lightning starts to flash.

Telephone electrical values

When a telephone handset is "on the hook"there is 48 volts DC is across the two wires designated "tip" and "ring." The green tip wire is at ground potential, or zero volts, and the red ring wire is at negative 48 volts. Approximately 21 to 35 milliamperes of current flows in this condition.

When the handset is picked up, phone-line voltage drops to 6 volts DC. The 20- or 30- Hz telephone-ringing signal can be from about 100 volts to about 120 volts AC. It is superimposed across the normal 48-volt DC signal. That "ringing" voltage determines the voltage ratings of the protective devices.

Telephone protection

Although the effects of lightning are well known, many people believe that only a direct strike on a nearby phone or power line will cause damage. However, most damage to electronic equipment is caused by voltages *induced* in those conductors by direct stikes elsewhere. Harmful voltages can be caused by strikes as far as 15 miles away!

Telephone circuits generally have resistive elements in each wire to protect the telephone handsets from transient spikes in excess of about 500 volts. However, this rather crude passive protection is inadequate for protecting more vulnerable electronics.

Spark-gap tubes or surge voltage protectors (SVP) have been used for many years to protect electronic circuits from manmade and natural surges arriving over either power or phone lines. They provide low-resistance paths for excessive voltage transients but appear open to normal voltages. The devices are hermetically sealed gas-discharge tubes. Typically made of ceramic with properly spaced electrodes, they are filled with a rare gas.

The main purpose of the SVP is to provide a conductive path for unwanted and excessive transients, thereby preventing the transient energy and associated voltages from damaging equipment and components—and harming people. They are designed to switch current at a pre-established breakdown voltage.

The breakdown voltage causes the internal gas to ionize and change from a non-conducting to a conducting state, thus permitting an arc to form and short the connected wires to ground. During conduction, the SVP can monmentarily carry high currents. After the voltage transient has been discharged, the gas deionizes and the SVP is ready for another voltage transient.

The SVP is bipolar and has a symmetrical characteristic. In the restored or extinguished condition, it causes very little loss because of its high impedance. This characteristic contrasts with those of transient absorbtion Zener diodes and metal-oxide varistors that exhibit leakage. However, both of those devices have faster response times than SVP's.

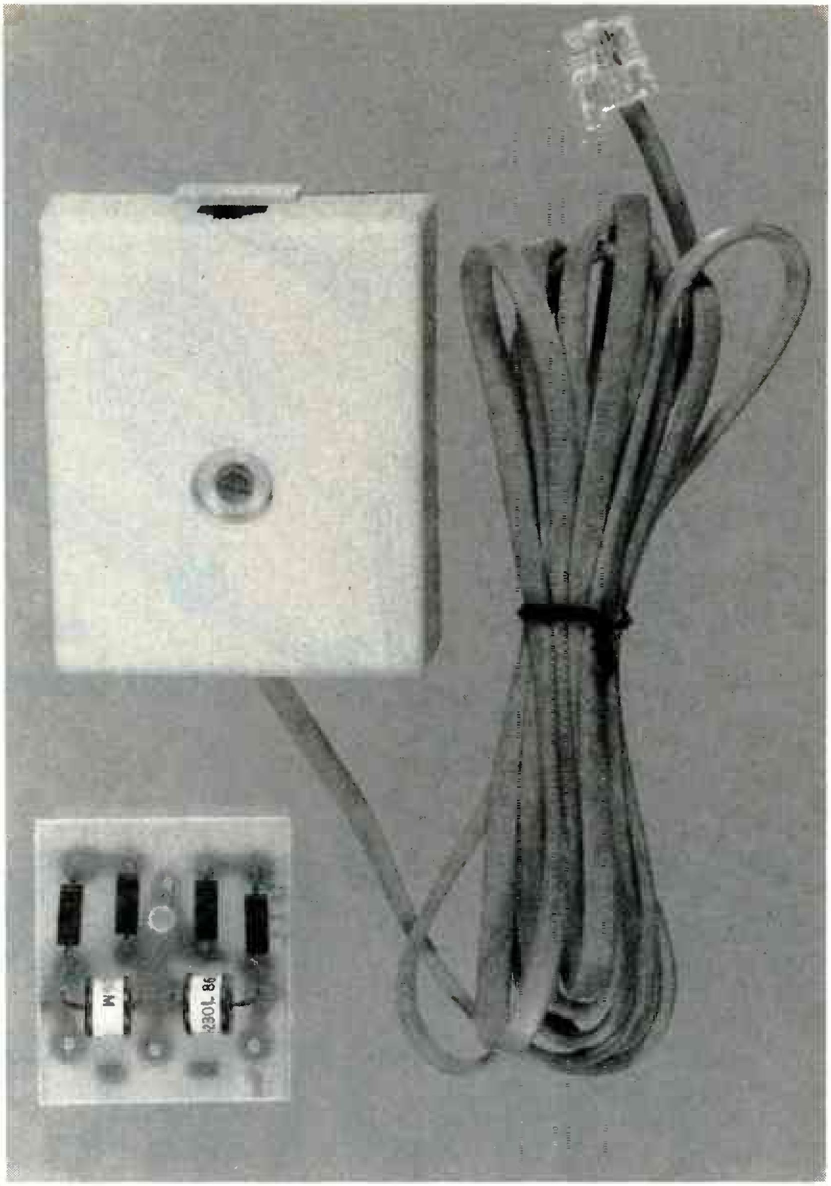


FIG. 1—MODEM/FAX PROTECTOR packaged in a standard telephone jack box.

The metal-oxide varistor (MOV or SIOV) has also been used to protect electronics connected to telephone lines. It is made from finely powdered zinc oxide mixed with binders and pressed into a disk. After firing, the disk becomes a matrix of conductive zinc-oxide grains separated by highly resistive boundaries. This property gives them a symmetrical electrical characteristic similar to the SVP (or two back-to-back Zener diodes).

However, the MOV's breakdown time is too slow to protect connected electronics against the fastest voltage spikes caused by lightning. As a result, faster Zener diodes and SVP's have been combined in our Modem/Fax Protector.

How the protector works

The Modem/Fax Protector (Fig. 1) is shown schematically in Fig. 2. It has a typical response time of about 10 nanoseconds—fast enough to protect your equipment against the speediest voltage spikes. Zener diodes D1 and D2 are connected back-to-back in parallel with surge-voltage protector SVP1 between the ring and the PC board earth ground connection. Similarly, Zener diodes D3 and D4 are connected in parallel with SVP2 between the tip wire and the PC board earth ground. The SVP's are rated for a nominal DC voltage of 230 volts with breakdown voltage from 195 to 265 volts DC.

The Zener diodes break down at 180 volts DC within about 10 nanoseconds to protect the telephone circuits from the fastest initial voltage spikes, and then the SVP's ionize to ground the overcurrent. Note that the circuit has no batteries; all it really needs to protect your equipment is an effective ground.

Construction

The prototype Modem/Fax Protector was built on a small square PC board measuring 1½ inches on a side (see Fig. 3). However, point-to-point wiring techniques can also be used. Note that the board has a hole drilled through it for the screw that clamps the enclosure together and provides the ground connection.

Refer to parts-placement diagram, Fig. 4. Install all of the components as shown, observing the polarities of the Zener diodes. Solder all components in position and trim excess leads.

Obtain a small modular plastic phone jack cover with an included jack. The jack should have a short section of 4-wire telephone cable attached. Cut off the black and yellow wires and connect the red ring and green tip wire pigtails within the box as shown in Fig. 5. Cut a bottom plate from sheet micarta, phenolic or other suitable thin but rigid insulating material slightly larger (about 1/16-inch) than the outer dimensions of the jack box. Carefully mark the location on the cover plate for a hole to accommodate the central screw so that it is opposite the hole in the jack box, and drill a hole of the same diameter through the cover.

Determine a suitable length for the four-wire telephone cable between your telephone outlet

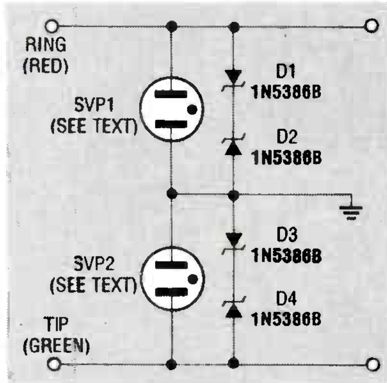


FIG. 2—MODEM/FAX PROTECTOR schematic showing Zener diodes in parallel with surge voltage protectors.

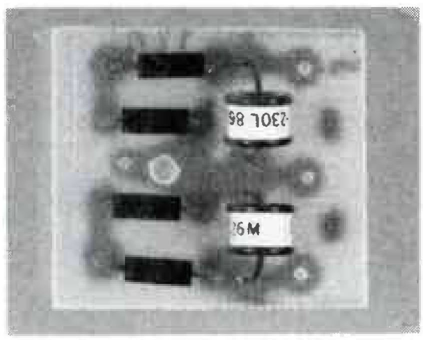


FIG. 3—MODEM/FAX PROTECTOR circuit board assembly shown actual size.

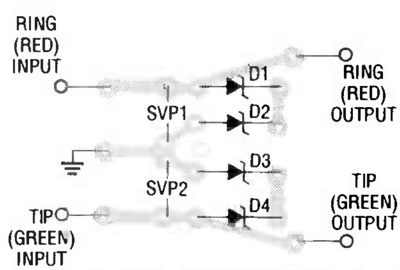
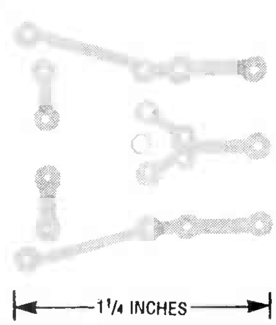


FIG. 4—PARTS-ASSEMBLY DIAGRAM for the the Modem/Fax Protector circuit board.



FOIL PATTERN for the modem/fax protector.

or junction box and the Modem/Fax Protector, and attach a plug to one end of that cable. Carefully form a hole in the side wall of the jack box, as shown in Fig. 5, large enough to permit the bare end of the telephone cable to be pulled through a distance of 3 to 4 inches. Clamp the cable with a plastic cable tie.

Strip the cable jacket back to about ⅛ inch from the cable tie, select out the red ring wire and green tip wire and strip their ends, and cut off the yellow and black wires close to the cable tie. Then strip the ends of the red and green wires from the jack. Solder both red and green wires to the circuit board, as shown in Fig. 4. Cut a short length of insulated 14 or 16 AWG wire, strip both ends, and solder one end to the ground pad on the PC board.

Apply four drops of silicone RTV adhesive to the inside of the jack box as shown, align the hole in the circuit board over the hole in the jack box, and bed the board down in the adhesive. Allow sufficient time for the adhesive to set up before proceeding. Determine a suitable length for a 14 to 16 AWG solid-copper ground wire based on the proximity of your telephone apparatus to a suitable location for a ground rod (to be discussed later).

Form a loop in one end of the heavy ground wire to accommodate the central screw in the Modem/Fax Protector. Then insert the screw through the loop in the ground wire, jack box, and circuit board. Tightly wrap the bare copper end of the ground wire on the circuit board several times around the screw to complete the ground connection. Then apply solder to the outside of the turns.

Plug your modem or fax into the jack, and plug the length of cable into your telephone wall outlet. The ring and tip wires of the telephone line must remain consistant throughout. The tip lead must be positive with respect to the ring lead.

After making sure that all connections have been made correctly, apply a thin layer of RTV adhesive to the rim of the jack box, assemble the cover over the screw, and clamp it in position with a washer and two nuts, as shown in Fig. 5.

Good grounding

The necessity for a good

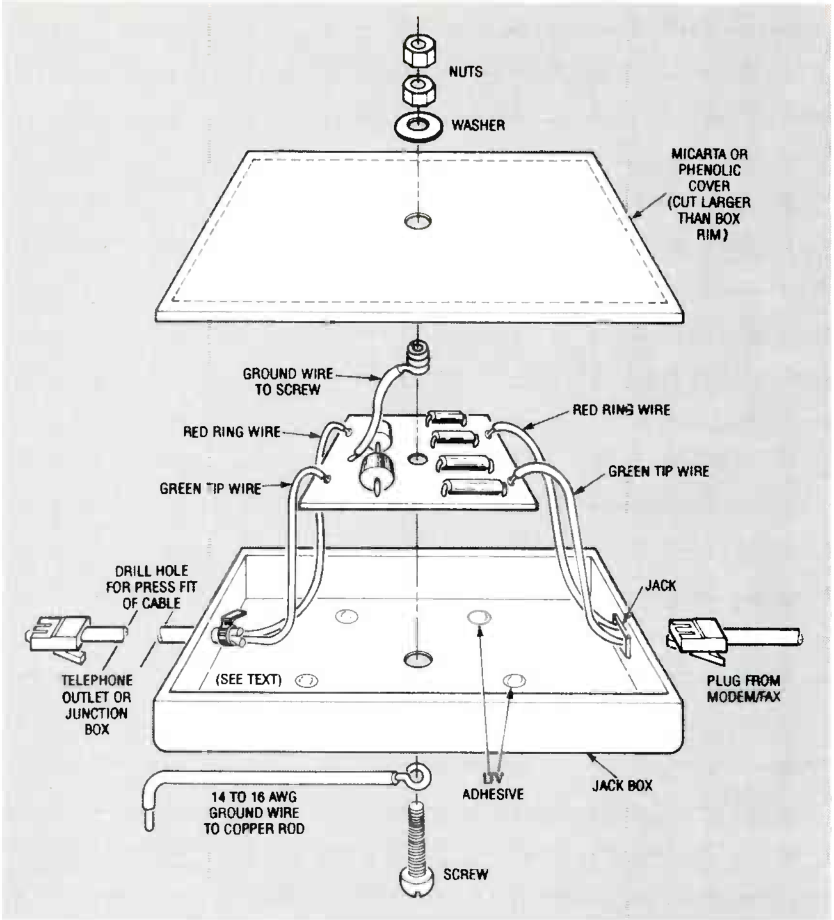


FIG. 5—MODEM/FAX PROTECTOR ASSEMBLY. Note the location of the hole formed for the 4-wire telephone cable. Only the red and green wires are used; the others are cut off near the cable clamp. The assembly is set on four spots of RTV adhesive, and the cover is held on with the central screw, nuts and washer.

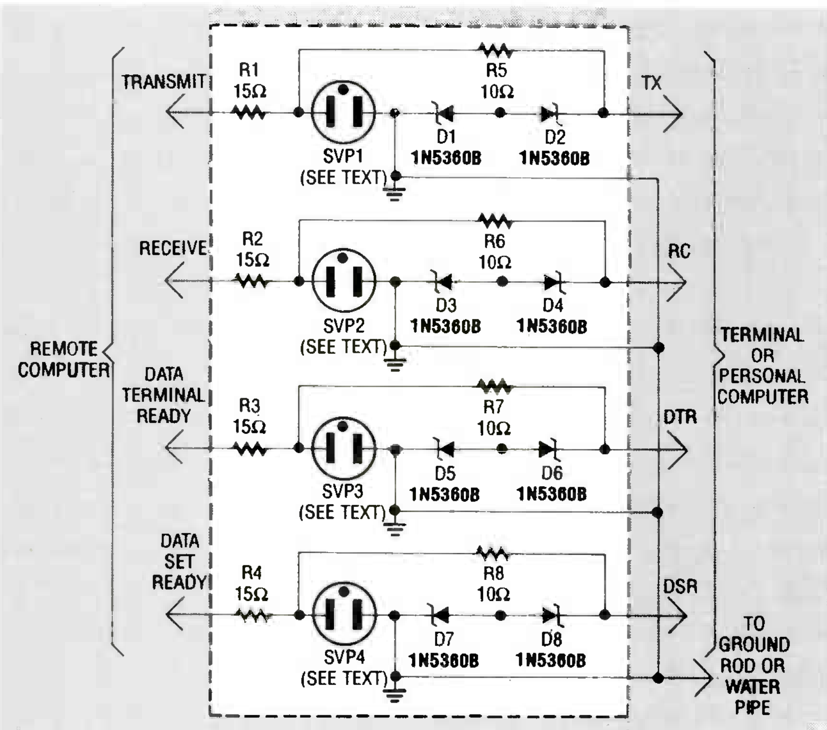


FIG. 6—VARIATION OF THE MODEM/FAX PROTECTOR for use in telephone line connections between PC or terminal and larger distant computer.

ground in protective circuits cannot be overstated: a bad ground is no ground at all! The most effective ground is achieved with a metal rod, preferably copper, at least four feet long, driven into moist soil. Connect the ground rod to the Modem/Fax Protector with the other end of the insulated solid copper ground wire. It can be led to the ground strap through a window opening or a hole drilled through the wall. Suitable grounding rods with wire-connecting clamps are available from electronics supply stores.

The next best grounding method is to connect the 14 to 16 AWG wire to a cold-water pipe. The third, and least satisfactory method (not recommended), is to connect the ground wire to the ground of the 120-volt AC outlet. (This ground can actually be at a higher potential than true earth ground by many millivolts!)

PARTS LIST

Surge voltage protector

SVP1, SVP2—gas surge arrestor, 250-volt, CG-230L (C.P. Claire) or equivalent

Semiconductors

D1–D4—1N5386B Zener diode, 180-volt, 5-watt.

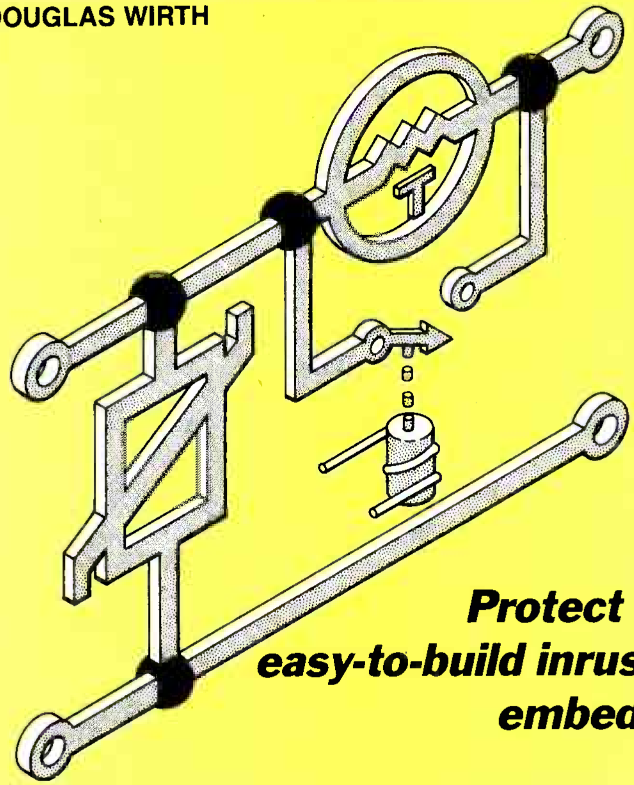
Miscellaneous: PC board, modular plastic phone jack box with jack, phenolic or micarta cover, length of 4-wire telephone cable, modular phone jack, length of insulated 14 to 16 AWG solid copper wire, copper ground rod (at least 4 feet long), nuts, bolt, washer, silicone RTV adhesive, solder.

Variations on a theme

Figure 6 shows the Modem/Fax Protector concept applied to the protection of remote computer terminals or personal computers connected to a larger computer over long-distance phone lines. The schematic shows a typical four-channel protective circuit.

The SVP's and transient absorbtion Zener diodes in Fig. 6 differ from those in the Modem/Fax Protector. The SVP's are C.P. Clare C675L's or equivalent, and the Zener diodes are 1N5360B units. Resistors R1 through R4 are 2-watt wirewound units, and resistors R5 through R8 are 1/2-watt. R-E

DOUGLAS WIRTH



INRUSH CURRENT LIMITER

Protect sensitive electronics with an easy-to-build inrush-current limiter that can be embedded in host equipment or be a stand-alone unit.

THE INRUSH-CURRENT LIMITER DEscribed here can protect sensitive line-powered electronics against normal current surges that occur when that circuitry is powered up. The limiter gives a "soft start," to any product or system it protects, and it can be expected to lengthen the operating life and improve the reliability of the host. A thermistor and relay protect against normal "turn-on" overcurrent, and a metal-oxide varistor protects against unwanted overvoltages and overcurrents occuring after startup.

Our inrush-current limiter, shown packaged in an enclosure in Fig. 1, can protect any equipment operated from 120-volt, 60-Hz AC. It can also protect non-electronic circuits such as lighting networks and appliances, provided that they do not include motors. (Many appliance motors depend on surge current for starting.) The circuit can be modified for protection at higher or lower AC voltages or DC voltages.

FIG. 1—INRUSH-CURRENT LIMITER circuit as a stand-alone component.

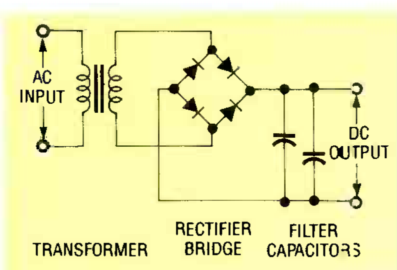


FIG. 2—SIMPLIFIED SCHEMATIC for a linear power supply with a full-wave rectifier and capacitor filter.

Current limiting

Most power supplies for electronic equipment that are embedded within the enclosure (typically sharing a PC board with other circuitry) are conventional linear circuits. As shown in Fig. 2, they consist of a transformer, bridge rectifier circuit, and one or more filter capacitors. When AC power is applied to such equipment, there is no charge on its capacitors, and the circuit components present an extremely low impedance to the line voltage.

As a result, a large inrush current surge with a fast rise time occurs, and it decays exponentially only as the filter capacitors charge. The peak inrush current is orders of magnitude greater than the circuit's steady state current. It is limited primarily by the short circuit characteristics of the power transformer and rectifier, which are determined by their internal resistance and inductance values and the wiring, as shown in Fig. 3.

An inrush-current limiter, as its name implies, limits inrush current and allows the voltage to rise gradually across the protected circuit. The limiter was designed for high-power stereo amplifiers to avoid the excessive current surges that occur at turn-on. The current drain of large stereo amplifiers is high enough to dim the lights in an average home when it is turned on.

Electronic-equipment and power-supply manufacturers typically limit inrush current by placing a momentary switching device with a fixed resistance at the power input terminal of the circuitry to be protected. After a predetermined time interval, relay contacts close, shorting out the input resistor so that full voltage is applied to the load.

Our inrush-current limiter circuit takes that conventional approach one step further. The fixed-value protective resistor is replaced by a temperature-variable resistor whose resistance value declines with increasing inrush current. A negative temperature-coefficient (NTC) thermistor optimized for inrush-current protection, its manufacturer refers to it as an *inrush-current limiter.*

A typical temperature vs. resistance curve for an inrush current limiter device is shown in Fig. 4. These devices are widely used in AC/DC switching power supplies. The unit specified for this project has a resistance of 120 ohms ± 25 % at 25°.C, a maximum steady state current of 2 amperes, and an approximate resistance of 1.18 ohms at maximum current.

Inrush-current limiting

Refer to the simplified block diagram, Fig. 5. The hot side of the AC line is fed through the inrush-current limiter (shown as a resistor with the letter "T.") Actual resistance change depends on the magnitude and duration of the current drawn. With a nominal resistance of 120 ohms, the maximum instantaneous current through any connected circuit will be limited to 120 volts/120 ohms = 1.0 ampere. (The current drawn will be less than the theoretical value because of the impedance of other components.)

At the end of a preset elapsed time after power is applied, a relay is actuated and it shorts out thermistor R9; that applies full power to the protected circuitry. The time delay is adjustable and determined by the value of a single resistor or potentiometer; it can range from less that a second to more than a minute.

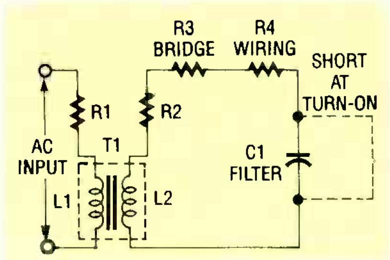


FIG. 3—EFFECTIVE RESISTANCE and inductance of transformer primary and secondary are represented by R1, L1 and R2, L2, respectively; R3 and R4 are the effective resistances of the rectifier bridge and circuit wiring, respectively. The dotted line across filter capacitor C1 represents zero resistance at power turn-on.

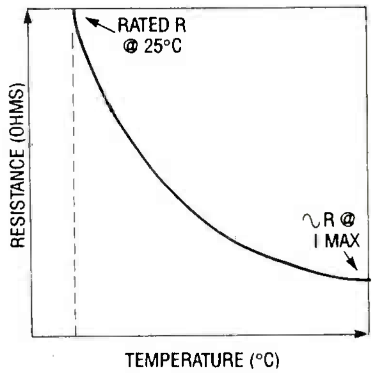


FIG. 4—INRUSH-CURRENT LIMITER device shows negative-temperature coefficient (NTC) characteristics. A thermistor optimized for circuit protection, its resistance declines as temperature increases due to current flow.

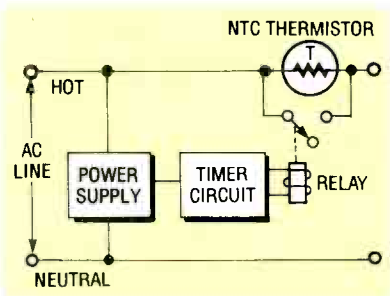


FIG. 5—BLOCK DIAGRAM OF INRUSH-current limiter circuit shows relay power supply and an inrush-current limiter component to protect against current surges at turn-on.

How the limiter works

The schematic of the inrush-current limiter circuit is given in Fig. 6. The 24-volt DC for the timer circuitry and relay are derived from a regulated power supply made up of resistor R1, capacitors C1 and C2, and diodes D1 to D3. The 120-volt input voltage is dropped primarily by C1, and applied to the two series-connected Zener diodes, D1 and D2.

When the polarity of the hot (upper) AC line is positive with respect to the neutral (bottom) AC line, a positive voltage is developed across the Zener diodes. That voltage charges filter capacitor C2 through diode D3. Resistor R1 and parallel metal-oxide varistor MOV1 limit the peak current in the circuit. Resistor R2 discharges C1 and resistor R3 discharges the filter and timing capacitors when power is removed, readying the circuit for immediate restart.

The relay power supply in Fig. 6 is popular in isolated electronics products where only small DC currents are needed to power circuitry. It eliminates the bulk and expense of a power transformer. However, appropriate safeguards must be taken because the supply is not isolated from the AC line. The timing circuit consists of resistors R4 to R7, capacitors C3, diode D4, transistors Q1 and Q2, and relay RY1. Timing capacitor C3 charges through timing resistor R4. (With a value of 150 K, the time delay will be 11 seconds.)

The PC board provides three holes for 1 megohm board-mounted potentiometer R9. Its adjustment will give a continuous range of time delays from about 1 second to 60 seconds. As an alternative, Table 1 lists the values of resistor R4 needed to obtain time delays from 1.5 to 180 seconds in discrete increments. The time delays given in the table can vary because of the wide tolerances of electrolytic capacitors.

When the voltage on C3 reaches the 12-volt breakdown threshold of Zener diode D4, it conducts and applies base drive to turn on NPN Darlington transistor Q1. When Q1 conducts, its collector voltage decreases, turning on PNP Darlington transistor Q2, whose collector current actuates relay RY1. The

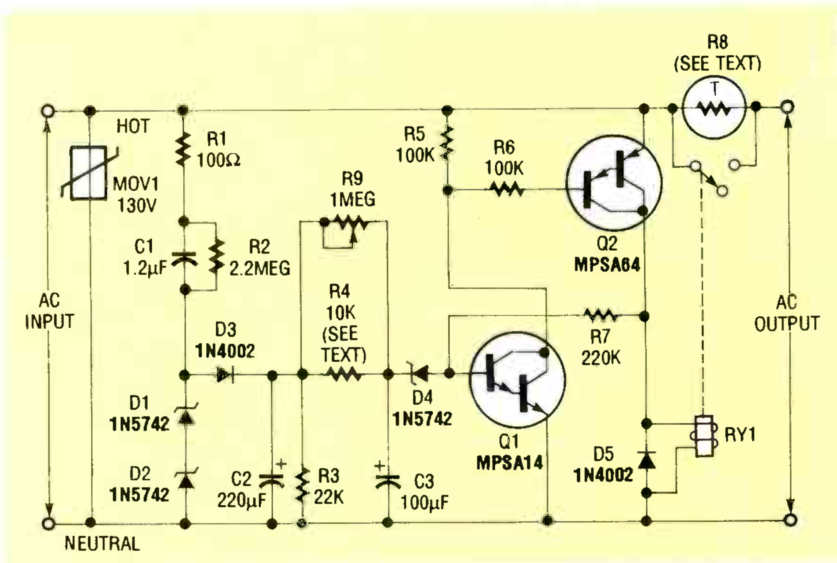


FIG. 6—SCHEMATIC OF INRUSH CURRENT LIMITER. Note that Q1 is a an NPN Darlington and Q2 is a PNP Darlington. MOV1 is a metal-oxide varistor and R8 is an NTC thermistor for limiting inrush current.

relay's normally open contacts are connected across the inrush current limiting device. When closed, the contacts apply full power to any connected load. Resistor R7 provides positive feedback to Q1's base, ensuring positive turn-on of the relay.

Diode D5 protects the circuit from the inductive "kickback" of the relay coil when it is de-energized. The resistance of the relay's coil must be at least 1.3 K for effective relay operation. The metal-oxide varistor MOV1 will protect the load against voltage spikes and transients, but it is not a requirement for the operation of this circuit. It has symmetrical bidirectional "breakdown" characteristics similar to those of back-to-back-connected Zener diodes.

Construction

All of the circuitry fits on a PC board measuring 2.5 x 2.5 inches. However, you might want to make the PC board's outer dimensions larger or smaller. If you plan to mount the circuit in a case, the board size and the hold-down screw spacing will depend on the case selected. The complete circuit assembly can also be mounted within the enclosure of its host equipment with mounting holes and insulating standoffs, if desired.

The PC board for this project

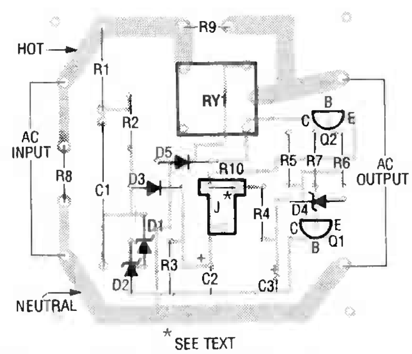
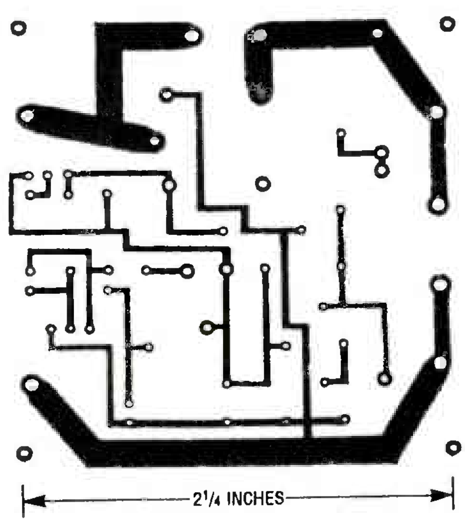


FIG. 7—PARTS-PLACEMENT DIAGRAM for the inrush-current limiter circuit.



FOIL FOR INRUSH-CURRENT LIMITER PC board.

is simple enough for an amateur to make, so its foil pattern is included here. However, because there are no critical components on the board, the components can be assembled on prepunched insulating board and connected by point-to-point wiring. Before doing any assembly work, drill the four corner holes in the board for the screws to mount the board to the case or inside the host's enclosure with standoffs.

Figure 7 is the parts-placement diagram. Install the resistors, capacitors and diodes first, observing the proper polarities for the capacitors and diodes. If you elect not to use the 1 megohm potentiometer R9, the value of R4 should be 150 K ohms rather than the 10 K shown on Fig. 6, and a jumper should be installed across two of the holes as shown. (Table 1 gives values of R4 for specific time delays.) After all the components are assembled on the board (see Fig. 8), solder them, and trim all excess leads. Recheck your work, carefully examining the circuit for shorts before continuing with the checkout.

Checkout procedure

Warning: This is a line-operated device, so perform all testing and troubleshooting with a line-isolation transformer. *Never* operate the circuit outside of an insulating housing and *never* make adjustments or any kind of modifications to it when it is directly connected to the AC line.

An isolation transformer is recommended for testing this circuit. If you cannot obtain a commercial unit, you can build one by connecting the secondaries of two identical transformers back-to-back as shown in

TABLE 1
TIME DELAY VS. RESISTANCE

Resistance (R4) (ohms)	Time delay (seconds)
22 K	1.5
47 K	3.0
68 K	5.0
100 K	7.0
150 K	11.0
220 K	17.0
470 K	40.0
1.0 MEG	80.0
2.2 MEG	180.0

Fig. 9. (It can also be used to test other transformerless electronic circuits.) The 120-volt line is stepped down, and then stepped back up to 120 volts. Use only transformers with the same secondary voltages, and do not exceed the current or power ratings of each of the transformers.

With no power applied to the circuit, perform the following resistance checks:

- Measure the resistance between the AC inputs, the hot AC line connected to R1, and the neutral AC line connected to the anode of D2. The readings should be greater than 10 megohms—anything less could indicate a problem.

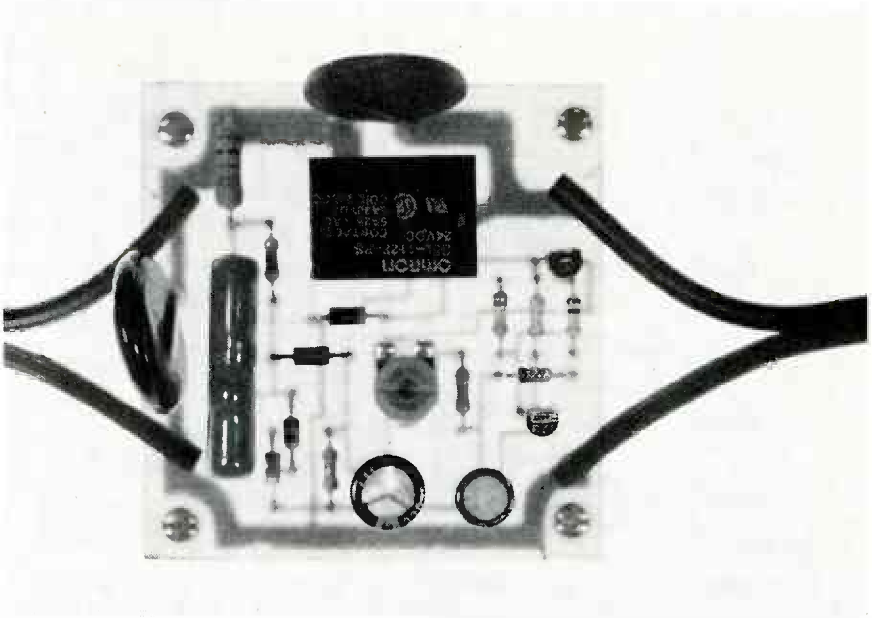


FIG. 8—ASSEMBLED INRUSH-CURRENT LIMITER circuit.

PARTS LIST

All resistors are ¼-watt, 5%, unless otherwise stated
R1—100 ohms, 2 watt, 5%, metal-oxide
R2—2,200,000 ohms
R3—22,000 ohms
R4—10,000 ohms (see text)
R5, R6—100,000 ohms
R7—220,000 ohms
R8—120 ohms inrush-current limiter (NTC thermistor) 2-ampere (Keystone) CL-90 or equivalent
R9—1,000,000 ohms potentiometer, 3-pin, PC board-mount, insulated knob.
Capacitors
C1—1.2 µF, 250-volt, polyester-film
C2—220 µF, 35-volt, aluminum electrolytic
C3—100 µF, 16-volt, aluminum electrolytic
Semiconductors
D1, D2, D4—1N5742, Zener diode, 12-volt, 1-watt
D3, D5—1N4002, 1 ampere, 100 peak volts
Q1—MPSA14, NPN Darlington transistor, (National Semiconductor) or equivalent
Q2—MPSA64 PNP Darlington transistor, (National Semiconductor) or equivalent
Other components
MOV1—metal-oxide varistor, 130-volt AC, (Panasonic) 20K201U, or equivalent
RY1—SPST relay, coil: 24-V, contact: 5 A, 250-V AC, 30-V DC, coil resistance 1300 ohms, PC-mount, (Omron) G5L-112P-Ps or equivalent
S1—toggle or rocker switch, panel-mounted, 350-volt, 3 amp
Miscellaneous: circuit board, panel-mounted receptacle (three-prong), length of 3-conductor power cord 18 AWG with 3-prong plug, four 1/4-inch insulated standoffs (see text), insulated case with cover, cable grommet, screws as needed, and solder.

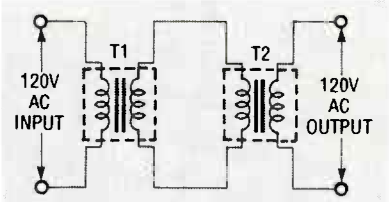


FIG. 9—SCHEMATIC FOR AN ISOLATION transformer to be used in testing the circuit. All turns ratios must be equal.

- Measure the resistance between the same end of R1 and the end of R2 connected to D1. The readings should be 2.2 megohms. Those measurements assure that there are no shorts or low resistances across the AC line.
- Connect the circuit to the isolation transformer and apply power. If the circuit is operating properly, you should hear the faint click of the relay contacts closing after the appropriate time delay.
- Check for proper operation of the power supply by measuring the voltage across filter capacitor C2. The reading should be about 22 volts DC when the relay is energized.

When testing and experimenting with loads connected to the inrush-current limiter, allow several minutes for the circuit to cool down to room temperatures and the nominal resistance values to be restored. The allowed time should depend on the magnitude and duration of the current drawn through the device. In normal operation, allow about a minute after power is removed for timing capacitor C3 to discharge before initiating a new time delay sequence.

Installation

The inrush current limiter can be installed within the enclosure of the host equipment. Connect the circuit to the AC line after the host equipment power switch and preferably after the line fuse or circuit breaker. Install the circuit so that the hot leg of the AC line is connected to the surge limiter, as shown in Fig. 6. Cut the AC line to the host and install the circuit in series, as shown in Fig. 8. Be sure the circuit board for the inrush-current limiter and all components are insulated from the equipment's chassis and all other components with insulated standoffs.

As an alternative, install the inrush-current limiter in a suitable insulated case with a line cord, power receptacle, and ON-OFF power switch as shown in Fig. 9. The prototype case measured 4⅜ × 3¼ × 1½ inches deep.

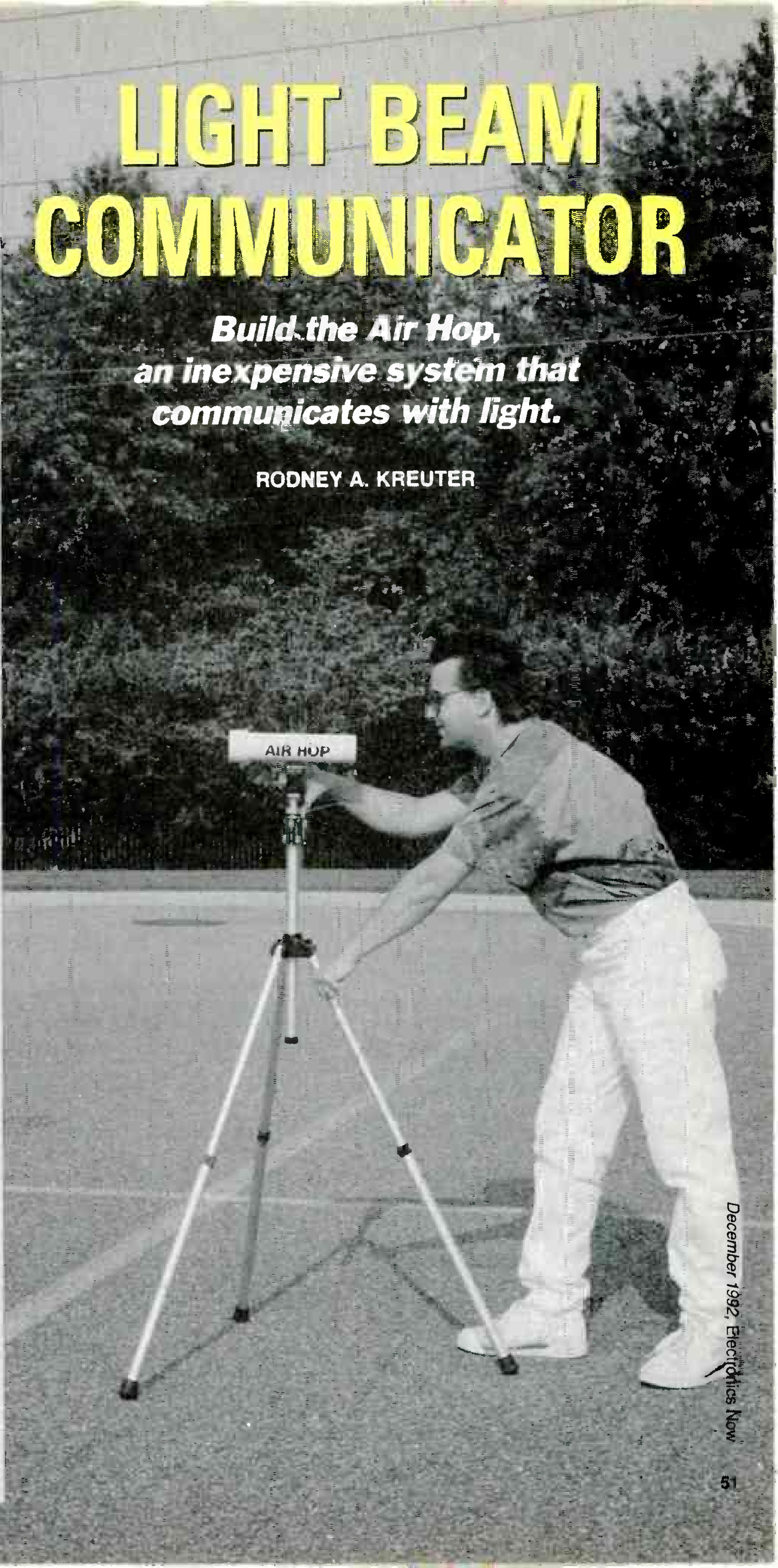
It might be necessary to cut down the four standoff posts within the case to accommodate

continued on page 76

LIGHT BEAM COMMUNICATOR

Build the Air Hop, an inexpensive system that communicates with light.

RODNEY A. KREUTER



IMAGINE YOU WERE CHALLENGED TO build a device that could send an optical audio signal—with a bandwidth of 300 to 3000 Hertz—as far as possible. To make the contest as fair as possible, the rules would require that only commonly available parts could be used. Also, because optics would play a large role in determining the range of such a device, no optics with a collection area greater than seven square inches could be used.

A dozen years ago, the author lost just such a contest by achieving a communications distance of a little over two and a half miles. The winning entry achieved a distance of 6 miles!

The optical communications system presented here is a somewhat modified version of the author's original Air Hop. The circuits have been redesigned in order to use common parts and provide a decent link at a reasonable cost. The unit has an output power of about 10 milliwatts peak and 5 milliwatts average. It uses frequency modulation on a 50-kilohertz carrier and has a bandwidth of 300–3000 Hertz. Without optics, the Air Hop can communicate about 40 feet—with 3-inch diameter optics (a magnifying glass), the range is increased to over a mile.

Air Hop can be used as a simple point-to-point audio communications system or to transmit digital data. Since its bandwidth is the same as a phone line, modems can be used to send and receive digital data. It can also be used as a link for a remote control such as that used in a TV receiver, perhaps with a tone encoder/decoder combination. A remote link to a repeater or a long-distance "broken beam" security system can also be made. Whether you need a link from a house to a barn or a short jump across the commotion of Wall Street, Air Hop can do it.

Electro optics

Before we get into the design and construction of the Air Hop, let's explain some optical terms.

PIN Diode. A photosensitive diode with a response time of a few nanoseconds. It can be used in a photoconductive mode where the current through it is a function of light, or in a photovoltaic mode where the voltage across it is a function of light (see Fig. 1).

Phototransistor. A transistor whose base current is a function of light. The collector current is the base current times the gain of the device. Response time is a few microseconds.

Photodarlington. Two transistors in the same package connected in a Darlington configuration. The first transistor is a phototransistor and the second is an ordinary transistor. Response time is tens to hundreds of microseconds.

Detector area. The area (in square inches or millimeters) of the light-gathering detector. Most PIN diodes have a plastic case that acts as a simple lens and provides a collection area of 0.01 to 0.025 square inches. This area is important when you're calculating lens gain.

Inverse square law. This is the "killer" in nearly all communications systems. Very simply stated, it means that if you increase the distance between the transmitter and the receiver, the signal strength will drop in proportion to the square of the distance. For example, if you receive 9 microwatts of power when the distance between the transmitter and receiver is ten feet, you will receive only 1 microwatt of power if you increase the distance to thirty feet.

Transimpedance amplifier. An amplifier with a very low input impedance. Sometimes called current-to-voltage converters, these special amplifiers are often used in optical systems because their low impedance load will ensure maximum current from a photodiode. They can provide a bandwidth up to a few hundred megahertz.

Lens gain. The ratio of the lens area to the detector area. Since the area of a lens is larger than the area of the detector, more light is gathered by the lens. Lens losses and focusing errors (which together should be about 15%) must be included in a rigorous calculation of lens gain.

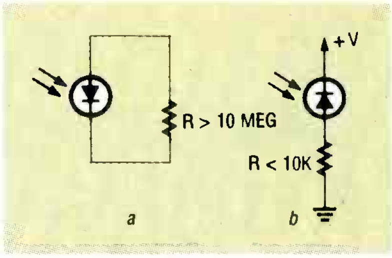


FIG. 1—A PHOTOSENSITIVE PIN diode has a response time of just a few nanoseconds.

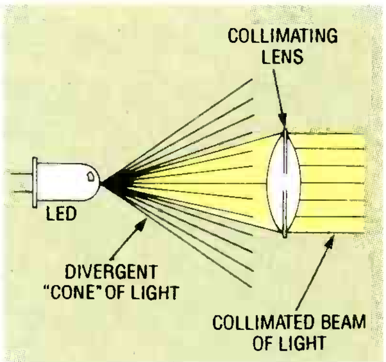


FIG. 2—THE LIGHT FROM AN LED diverges or spreads out as it leaves the LED. A lens will then collimate the light so that it travels in parallel beams.

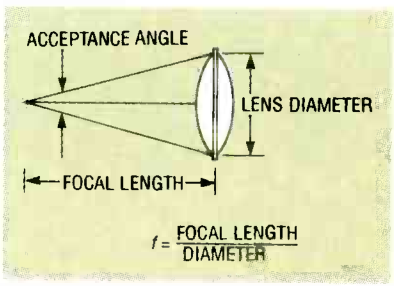


FIG. 3—THE f NUMBER or lens speed is the ratio of the focal length to the diameter. You can think of this as an optical acceptance angle.

Infrared. The region of the light spectrum next to the color red (about 800 nanometers). Most infrared LED's emit at either 880 nanometers or 940 nanometers. Most silicon detectors have their maximum response at about 900 nanometers. Infrared is used because most red (visible light) LED's have trouble producing a half a milliwatt of power, while many IR LED's have an output of 10 milliwatts or more.

Collimate. To direct in a straight line. When light from a source travels in parallel beams instead of a divergent cone, it is said to be collimated. Although you can't form a truly collimated beam, the lens on the transmitter attempts to do that (see Fig. 2).

Divergence. The "spreading out" of an optical beam. In other words, a divergent beam is the opposite of a collimated beam. All optical beams diverge, some more than others. If you could form a beam with zero divergence (you can't), it would not obey the inverse square law. In other words, you could send your beam an infinite distance because the energy wouldn't spread out. Laser beams have small divergence compared with other light sources. Spot lights are built to have a small amount of divergence, whereas flood lights are built to have a great deal of divergence (see Fig. 2).

Responsivity. A measure of the relationship between the optical and the electrical signal of a detector. A rule of thumb for PIN diodes is 0.4 to 0.6 amps per watt. This means that if 1 milliwatt of light strikes a PIN diode, a current of 0.4 to 0.6 milliamps will flow through the diode. To put that in perspective, Air Hop will work at levels of about 100 picoamps of current or about 200 picowatts of optical power.

AC and DC light. If you pulse an LED on and off it becomes an AC-light source. If you simply apply DC though it, it becomes a DC-light source. This concept is important because most light sources contain some AC and some DC light. Normal tungsten-filament light bulbs contain a lot of DC and some AC light (because of the thermal time constant of a hot filament). The sun contains a lot of DC *and* a lot of AC. Fluorescent lights contain some DC and a lot of AC. The only reason that this is important is that if you build a DC-coupled optical receiver and operate it outdoors where there is a lot of sunlight, the receiver can easily "saturate" and your AC signal will not be amplified correctly. Some kind of "light shield," such as those that are used on some camera lenses, will help. That's why the Air Hop uses an AC-coupled detector.

f number or lens speed. In lenses, the ratio of the focal length to the diameter is called the "f" number (f = fl/d). The smaller the number, the "faster" and more expensive the lens. It is convenient to think of this as an optical "acceptance" angle (see Fig. 3). This will be important in choosing the transmitter's collimating lens. In cameras, where the focal length is fixed, a lens with a larger diameter than another lens has a smaller "f" number, and is said to be faster. That's because the larger lens gathers more light and the shutter can be set to a faster speed than the smaller lens. Table 1 shows f numbers vs. acceptance angles.

Thermal noise. Although thermal noise is not applicable to optical devices such as lenses, the electronic performance of your optical system will be limited by thermal noise. Thermal noise is caused in an electrical device by the random movement of molecules. The thermal current noise (i_N) of a resistor is given by:

$(i_N)^2 = 4KTB/R$

where

K = Boltzmann's constant (1.38×10^{-23})

T = temperature in Kelvin (300)

B = bandwidth in Hertz

R = resistance in ohms

A 300K resistor operated at near room temperature in a receiver with a bandwidth of 20 kilohertz will have a thermal noise current of 33 picoamps

Although 33 picoamps might not sound like a lot of current, the noise it will cause at the output of the transimpedance amplifier will be about 10 microvolts (RMS). Converting to peak-to-peak noise gives about 60 microvolts peak-to-peak.

In the Air Hop, the only amplifier between the transimpedance amplifier and the comparator is a differential amplifier with a gain of about 50. That amplifies the 60 microvolts of noise and produces about 3 millivolts of noise at the output of the optical amplifier. Actual measurements showed 5 millivolts of noise. That is reasonable because there are other noise-producing devices in the system such as the current noise of the first transistor. Although every transistor produces some noise, the first one produces more because of its higher signal amplification.

One reason it's important to present equations like this is that they give us insight into system improvement. If there were no noise, virtually unlimited distances could be achieved. However, when the strength of the signal is less than the noise, we're out of luck. We can control temperature to some extent, and the equation shows that at a lower temperature, the noise is lower. But lowering the temperature of the transimpedance resistor even by 100 degrees Kelvin will decrease the noise power only by a factor of about 1.2.

If a system requires only a small amount of bandwidth, say a few hertz, as in a television remote control, we could decrease the bandwidth from 20 kilohertz to 20 Hertz and decrease the noise by a factor of about 30. Even with the inverse square law working against us, that would improve the range by a factor of about 5. Such a bandwidth reduction would require a good tunable filter, but it certainly can be done. Of course, audio signals sent over a link with a 20-Hertz bandwidth wouldn't be recognizable as audio. It would, however, permit Morse-code communication.

Photodetector. Any device that can convert light into an electrical signal. Phototransistors, photo SCR's, phototriacs photocells, solar cells, and photodiodes are all examples. Even photoresistors and thermocouples can be loosely considered as forms of photodetectors.

Phototransistors and photodarlington detectors are often used to detect light. Both work well if you don't require high speed. Typical phototransistor rise and falls times are 1 to 5 microseconds; for Darlingtons they are hundreds of microseconds. In electronics that is equivalent to measuring bandwidth with a stop watch and a calendar, respectively.

The author prefers to use PIN diodes in the photoconductive mode as detectors. Rather than being limited by the gain and bandwidth of a phototransistor, PIN's give us the choice of both by allowing us to design our own amplifiers. PIN diodes are also very "quiet." Their noise is almost unmeasureable.

LED's. A light-emitting diode is a semiconductor device that emits light when forward biased. You would think that choosing an LED for a system such as this would be a simple matter, but it's not. Characteristics such as power output,

TABLE 1
f NUMBER VERSUS ACCEPTANCE ANGLE

f	Angle (in degrees)
0.5	90
0.75	67.4
1.0	53.2
1.5	36.8
2.0	28
2.5	22.6
3.0	19
3.5	16.2
4.0	14.2

FM TRANSMITTER PARTS LIST

All resistors are ¼-watt, 5%.
R1, R5, R9, R15, R16—1000 ohms
R2—22,000 ohms
R3—10,000 ohms
R4—1000 ohms, potentiometer
R6—100 ohms
R7—5600 ohms
R8, R13—2200 ohms
R10—470 ohms
R11—50,000 ohms, potentiometer
R12—33,000 ohms
R14—15,000 ohms
R17, R18—22 ohms (see text)
Capacitors
C1–C3, C6—1 µF, 16 volts, electrolytic
C4—100 µF, 16 volts, electrolytic
C5, C9—10 µF, 16 volts, electrolytic
C7—0.001 µF, ceramic
C8, C10, C11—0.01 µF, ceramic
Semiconductors
IC1—NE555 timer
Q1–Q4—2N3904 NPN transistor
LED1–LED4—IR LED (Optek OP293A 880nm, Optek OP295A 880nm narrow beam, Lytron 940nm, see text)
Other components
MIC1—electret microphone
Miscellaneous: 4 "AA" batteries and holder, PC board, PVC pipe and plastic disks, hardware, wire, solder, etc.

wavelength, speed, and beam angle all come into play.

The first consideration is usually the power output. However, if you can't get the power into your lens, it's simply wasted, and if it's at the wrong wavelength, your detector won't see it.

Wavelength is important. The most widely used wavelengths for infrared devices are 880 nanometers and 940 nanometers. The first choice is to find a detector and emitter that match. We used 940 nanometers, which is further into the infrared than 880. Many detectors made for 940 nanometers have a built-in visible-light filter. Filters are not often put on the 880-nanometer devices because that wavelength is near the visible spectrum and such a narrow filter would be difficult to produce in large quantities.

If you wish to produce a hundred thousand Air Hop systems with optics, you would want to buy emitters with wide but uniform beams. Then you would have a custom lens designed and produced at a small cost in plastic material. That would produce the most uniform beam and would be reproducible in large quantities. In applications such as remote control, you might want to use an emitter or many emitters to "flood" an area. In that case, you would want an emitter with a wide beam.

If, on the other hand, you're just trying to see how far you can "air hop" a signal, you will want something totally different. Narrow beam angles are necessary for efficient coupling to an off-the-shelf lens. As a matter of fact, choosing the smallest beam angle available will save money when it comes to buying a lens. The smallest easily obtainable beam angle for an LED is about 20 degrees. When a manufacturer specifies that angle, he really means a "half angle" of 20 degrees, or a solid cone of 40 degrees.

The angle also specifies the half-power point. For example, if a manufacturer specifies 5 milliwatts and a beam angle of 20 degrees, that means that if you can capture all of the power contained in a 40-degree cone, you will get 2.5 milliwatts of optical power. In any case, purchase an LED with a small beam angle, as much power as possible, and a reasonable speed.

Lenses. Lenses are to the optical world what antennas are the world of RF. The importance of even simple lenses cannot be over emphasized. If any high-frequency RF engineer could build an antenna with 60 dB of gain for less than ten dollars, we would see a lot of happy RF engineers! Since the optical world deals with very small wavelengths, 60 dB (a gain of 1000) is certainly possible.

Although at first it might be hard to believe, the size of the lens on the receiver is very important, but on the transmitter it isn't. That's because at the receiver you are trying to intercept as much light as possible, so the larger the lens, the better. The purpose of the lens at the transmitter is to collimate the beam, so any lens with the right "f" number will work.

The "speed" of a lens, also called the "f" number, should be familiar to anyone with photography as a hobby. It's a measure of the angle of acceptance of a lens. On the transmitting end, any light from the LED that

OPTICAL AMPLIFIER PARTS LIST

All resistors are ¼-watt, 5%.
R1—100,000 ohms
R2—10,000 ohms
R3, R9, R10, R16, R23—15,000 ohms
R4, R5—150,000 ohms
R6, R17, R24—3300 ohms
R7, R12—100 ohms
R8—3900 ohms
R13, R14—5600 ohms
R11, R15, R18, R21—4700 ohms
R19, R22—22 ohms (see text)
R20—360 ohms

Capacitors
C1, C4, C8—10 µF, 16 volts, electrolytic
C2, C5, C9—0.1 µF, ceramic
C3, C12, C14–C16—0.01 µF, ceramic
C6, C7, C11—470 pF, ceramic, 10%
C10—0.001 µF, ceramic, 10%
C13—100 µF, 16 volts, electrolytic

Semiconductors
Q1—MPS918 NPN transistor (Motorola)
Q2–Q6—2N3904 NPN transistor (Q5 and Q6 must be a matched pair, see text)
D1—PIN diode (Siemens SFH205 940nm usable at 880nm, Panasonic PN323BPA 940 nm, Panasonic PN334PA 880 or 940 nm, see text)

Other components
SPKR1—8- to 45-ohm speaker

Miscellaneous: PC board, wire, solder, etc.

TABLE 2—LENS GAIN

Lens Diameter/Area (inch/sq. inch)	Power Gain (at 0.01 sq. inch)	Distance Improvement (85% lens efficiency)
2/3.14	314	×16
3/7.07	707	×24
4/12.6	1260	×33
6/28.3	2830	×49

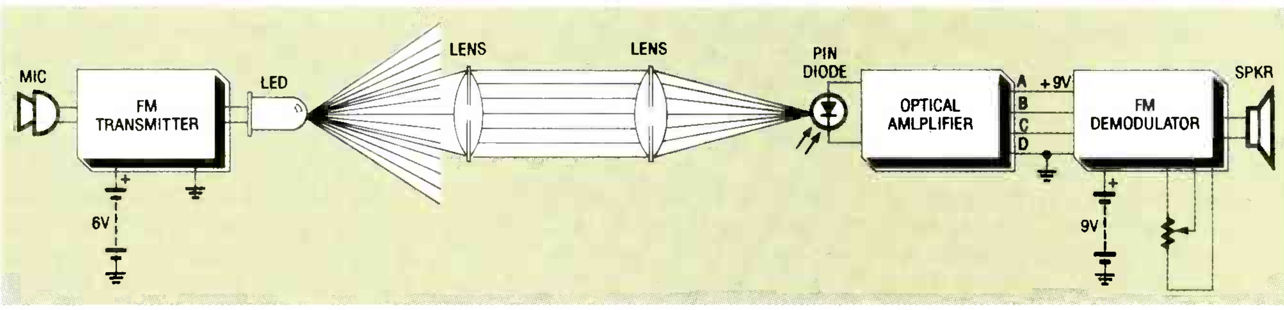


FIG. 4—THE AIR HOP IS BUILT FROM THREE MODULES: an FM transmitter, an optical amplifier, and an FM demodulator.

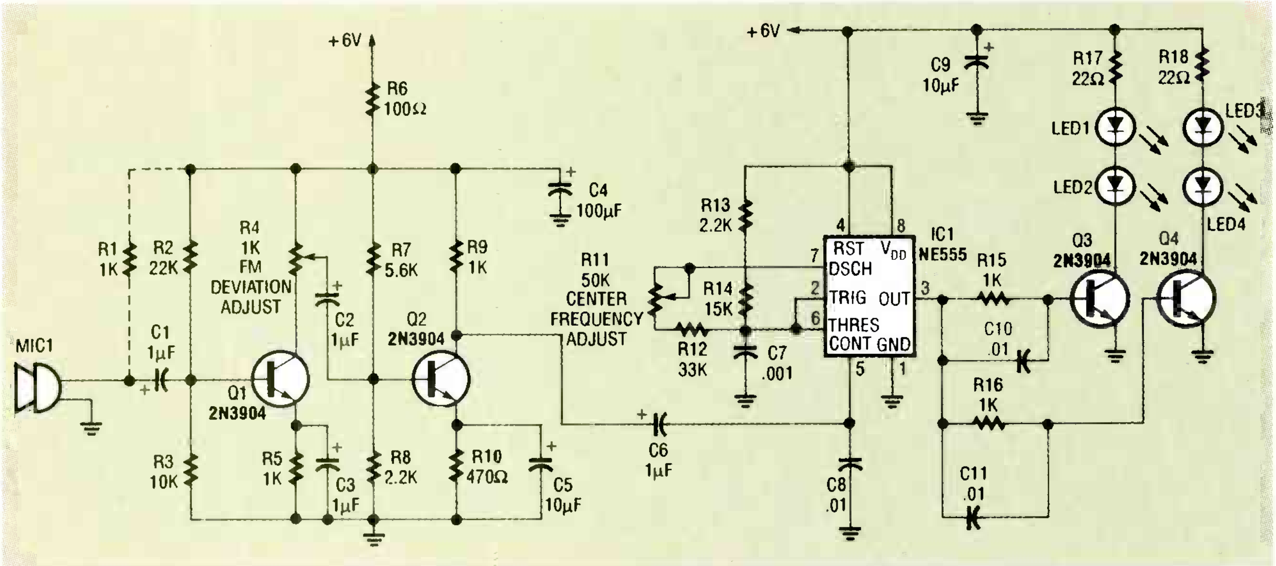


FIG. 5—FM TRANSMITTER MODULE. It provides a microphone amplifier and FM modulator.

FM DEMODULATOR PARTS LIST

All resistors are ¼-watt, 5%.
R1—100 ohms
R2, R3, R6, R11–R13, R16—10,000 ohms
R4, R5—100,000 ohms
R7—33,000 ohms
R8—50,000 ohms, potentiometer
R9, R14, R15—68,000 ohms
R17—4700 ohms
R18—10,000 ohms, potentiometer
R19—22,000 ohms
R20—470,000 ohms
R21—10 ohms
Capacitors
C1, C6, C10, C16—1 μF, 16 volts, electrolytic
C2, C5, C9, C12—0.1 μF, ceramic
C3—100 μF, 16 volts, electrolytic
C4, C7—0.001 μF, ceramic, 10%
C8—470 pF, ceramic, 10%
C11—0.01 μF, ceramic
C13—100 pF, ceramic
C14—4.7 μF, 16 volts, electrolytic
C15—470 μF, 16 volts, electrolytic
Semiconductors
IC1—LM311 or LT1011 comparator
IC2—CD4046 phase locked loop
IC3—MC34119 audio amplifier (Motorola)
Q1—2N3904 NPN transistor
Miscellaneous: 9-volt battery and clip, PC board, blank PC-board material and solder-wick straps for shield (see text), PVC pipe, plastic disks, hardware, wire, solder, etc.

Note: The following items are available from Q-Sat, P.O. Box 110, Boalsburg, PA 16827:

- **Complete Air Hop kit including all three PC boards (does not include speaker, 10K volume control, lenses, PVC pipe and batteries), AIRHOP-KIT—$30.00**
- **Transmitter kit including one IR LED and PC board, AHTX-KIT—$11.00**
- **Transmitter PC board only, AHTX-PCB—$5.00**
- **Optical amplifier kit including PIN diode and PC board, AHOPTAMP-KIT—$12.00**
- **Optical amplifier PC board only, AHOPTAMP-PCB—$6.00**
- **FM demodulator kit including PC board (no speaker or 10K volume control), AHFMDEMOD-KIT—$12.00**
- **FM demodulator PC board only, AHFMDEMOD-PCB—$6.00**

Add $3.00 shipping and handling to all orders. Pennsylvania residents must add 6% sales tax. Please allow 3 to 4 weeks for delivery.

doesn't stay within that cone is lost. A 50-milliwatt LED will be of no value if the light "sprays" out at 90 degrees—any light that can't be coupled into the lens is lost.

The gain of a lens is basically the ratio of the area of the lens to the area of the detector. For example, the area of most PIN diodes is about 0.01 square inch. The area of a 2-inch diameter lens is 3.14 square inches. Therefore, the gain of a 2-inch lens is about 3.14/0.01 or 314. Remember that this amplifier (the lens) consumes no power, has (for our purposes) infinite bandwidth, and adds no noise to the signal. A device of this kind in the electrical world would be nothing short of a miracle.

Table 2 shows the gain for some different size lenses. The calculations assume that no light is absorbed or reflected by the lens, and the detector is at the exact focal point of the lens. Those asumptions are certainly not true. Even fine-quality camera lenses, which are coated with anti-reflective coatings, do not pass 100 percent of the light. There's plenty of room here for experimentation. Some crude experiments showed about 85% of the theoretical gain.

FM transmitter

The Air Hop is built from three modules. The first module is the FM transmitter. Two other modules (the optical amplifier and FM demodulator) comprise the receiver. A block diagram of the system is shown in Fig. 4.

The FM transmitter module, shown in Fig. 5, provides a microphone amplifier (Q1 and Q2) and an FM modulator built from a 555 timer (IC1). There are two adjustments, one for the FM center frequency (R11) and one for the amount of deviation (R4). Resistor R1 is for microphones that require an external power source, such as an electret type. For an external audio source, the input must be limited to a few millivolts.

The output of IC1 (pin 3) is adjusted via R11 so that the frequency is 50 kHz (20 microseconds). The output of the 555 can be frequency modulated by applying the upper trip-point

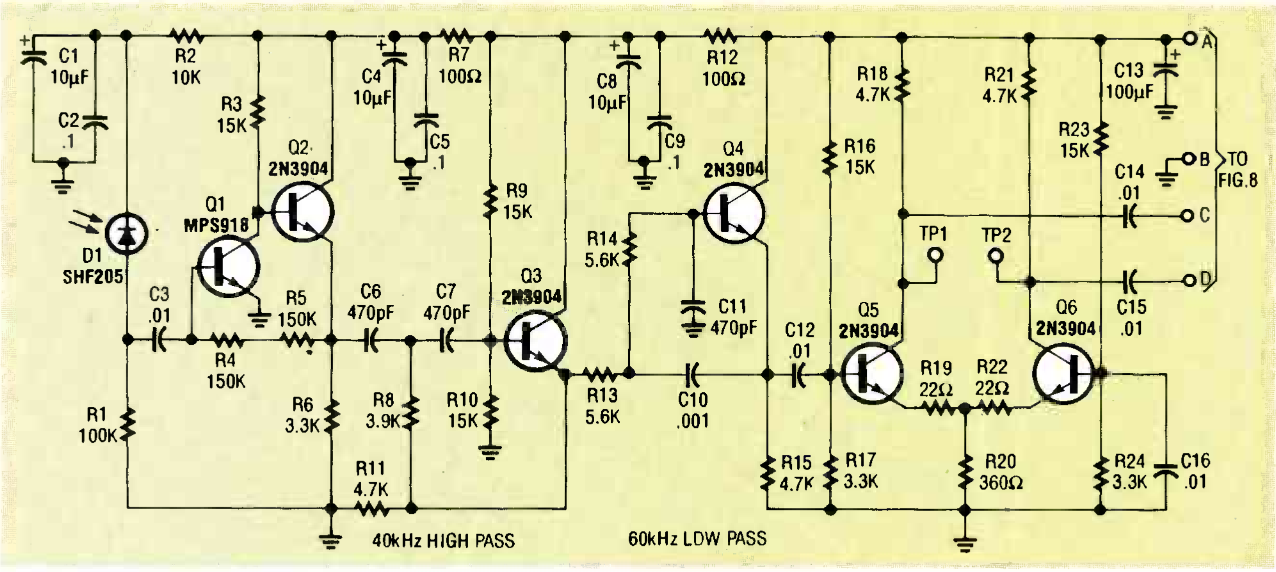


FIG. 6—THE OPTICAL AMPLIFIER MODULE converts the optical signal into an electrical signal, limits its bandwidth, and provides a differential drive to the comparator.

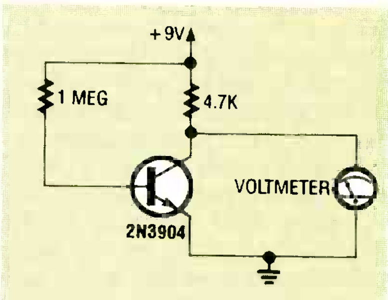


FIG. 7—YOU CAN MATCH transistors Q5 and Q6 using this circuit. Any transistor having less than about a volt between the collector and emitter has too much gain. Choose two transistors that have the closest match between collector-to-emitter voltages.

voltage reference to pin 5. Although you cannot sweep the frequency very far, deviations of 10 percent or so can be obtained easily. The FM deviation is a function of the amplitude of the signal applied to pin 5. If a DC voltage is applied to pin 5 and switched on and off, FSK (digital) data will result. Although the output of the 555 could drive a modest LED, transistor drivers are provided to drive multiple LED's.

Current-limiting resistors R17 and R18 are adjusted to limit the current for your particular LED. Currents of up to 200 milliamps pose no problem for the LED's, but they will drain your batteries quickly. If you're using one LED, values of about 47 ohms will yield about 45 milliamps, average. Systems using two LED's in series will require about 22 ohms for the same current.

The prototype system uses four AA alkaline type batteries for the transmitter power supply. Although they give reasonable life, you may want to use something a little larger, perhaps four D cells.

Optical amplifier

The purpose of the optical amplifier module, shown in Fig. 6, is to convert the optical signal into an electrical signal, limit its bandwidth (to reduce noise), and to provide a differential drive to the comparator.

The PIN diode detector (D1) is AC coupled to a simple transimpedance amplifier consisting of Q1 and Q2. Even though the signal is AC coupled, the bias for the PIN diode must be DC coupled. That is done through resistors R1 and R2. If Air Hop is used in a high ambient light situation, resistor R1 might have to be reduced in value to prevent DC saturation of the PIN diode. If the DC voltage across R1 is greater than about 3 volts in operation, you should lower the value of R1.

The transimpedance resistors (R4 and R5) set the overall gain of the amplifier. Two resistors in series were used instead of just one because every resistor has some capacitance across it. Using two resistors decreases the capacitance by a factor of two. All you have to do is join the two resistors above the PC board.

The output of the transimpedance amplifier is simply its input current times the transimpedance resistance. That's why it's sometimes called a current-to-voltage converter. As you increase the resistance, the signal increases, but the bandwidth decreases. Since the signal increases directly with the value of the resistance and the noise increases with the square root of the resistance, it makes sense to have the resistance as large as possible—it would, if you still had enough bandwidth. That's why Q1 is a VHF transistor.

Since the center frequency of the signal is at 50 kilohertz, it's desirable to limit the bandwidth of the optical amplifier to reduce the total noise. Transistor Q3 and the surrounding components form a two-pole high-pass filter at about 40 kilohertz. That eliminates such low-frequency noise as the 60-hertz optical noise given off by room lights.

Transistor Q4 and its associated circuitry form a 60-kilohertz low-pass filter. That eliminates high-frequency electrical noise such as that from AM radio stations.

When the low-pass and high-pass filters are cascaded, they form a bandpass filter centered

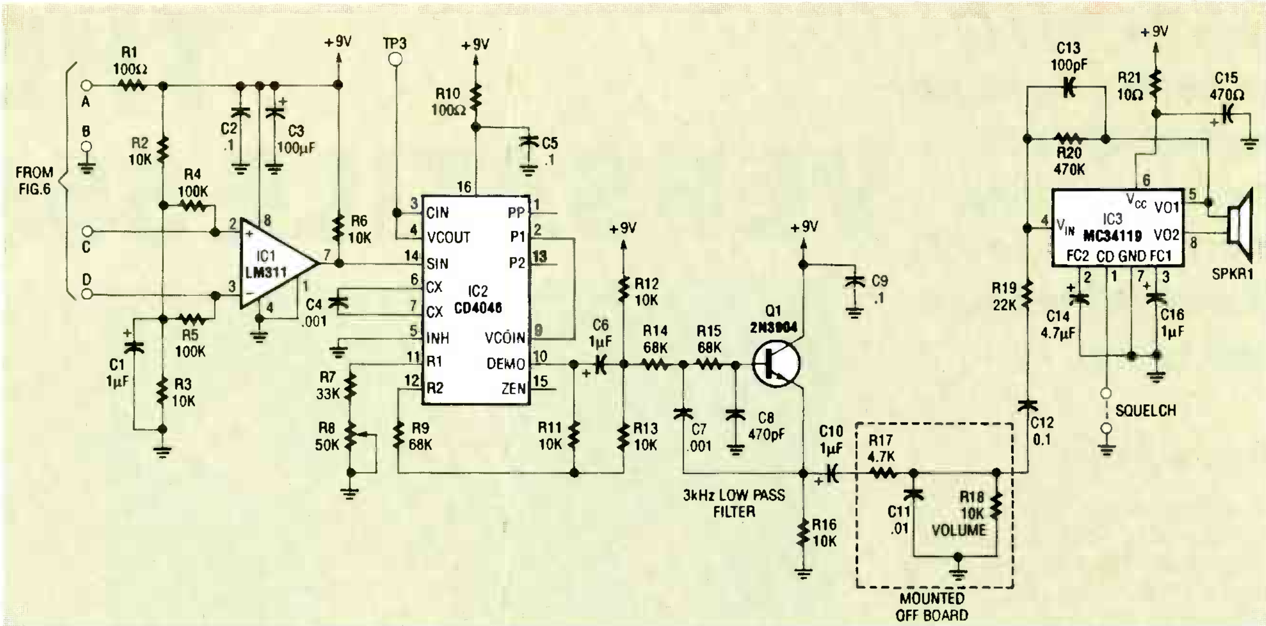


FIG. 8—FM DEMODULATOR. An LM311 comparator converts the small analog signal to a digital level for the CD4046 phase-locked loop, which is configured as a first-order FM demodulator.

on 50 kilohertz, with a pass band of about 20 kilohertz. You could reduce the noise by making the filter narrower, or by putting a narrower filter between the output of the optical amplifier and the input of the demodulation board. The disadvantage of doing that is that you would have to make the narrow filter tunable, and use a scope to adjust it.

Transistors Q5 and Q6 form a differential amplifier that is the only real gain stage in the optical amplifier besides Q1. The purpose of using a differential amplifier is so that a differential signal will be available to drive the voltage comparator. It's nice to drive a comparator differentially because you get twice the signal but not twice the noise. There is one problem with a differential amplifier: if you want a reasonable amount of gain, the transistors must be well matched. That prevents one transistor from "current hogging" and saturating.

The matching of transistors can be done a number of different ways—a curve tracer is best but most people don't have access to one. Next best is a meter that actually measures gain at a given base or collector current. As a last resort, the circuit in Fig. 7 can be used. Some kind of socket, such as an IC socket with only three pins can be used to hold the transistor. Simply measure the voltage from the collector to emitter, and choose two transistors that have the closest match between the collector-to-emitter voltage. Any transistor having less than about a volt has too much gain.

It's also a good idea to use bias resistors that have nearly the same values. Try to match the values of R16 and R23 and R17 and R24 as close as possible. If the final amplifier isn't matched within a volt, you might want to adjust the values of R19 and R22. Those resistors were purposely put there to allow some "balancing" of the differential amplifier. Values from 10 to 33 ohms should be fine. (Potentiometers were not used because they are expensive.)

FM demodulator

The schematic for the FM demodulator is shown in Fig. 8. An LM311 comparator (IC1) converts the rather small analog signal to a digital level for the CD4046 phase-locked loop (IC2). Remember that the amplitude of the recovered audio has nothing to do with the amplitude of the received signal. The amplitude of the recovered audio depends only on the amount of frequency deviation set by the transmitter and the amplitude of your voice.

The phase-locked loop (IC2) is configured as a first-order FM demodulator. With no input signal, the center frequency of the loop (pin 3 of IC2, which is also TP3) is adjusted by R8 for a frequency of 50 kilohertz. Because the variation from one CD4046 to another can be quite large, you might have to adjust R7 and, perhaps, R9 as well.

The demodulated output from IC2 is low-pass filtered at 3 kilohertz by Q1 and its associated circuitry, and then sent to audio power amplifier IC3, a Motorola MC34119. A wider bandwidth can be obtained by making the filter higher in frequency. Since the "carrier" frequency is only 50 kilohertz, don't try extending the audio bandwidth to more than 6 or 7 kilohertz. Pin 1 of the MC34119 can be used for squelch or in conjunction with a push-to-talk switch to silence the receiver while transmitting. If you don't need the squelch, simply jumper pin 1 of IC3 to ground.

Although you can use a standard alkaline 9-volt battery to power the receiver, the current draw can be quite high on voice peaks. Six AA cells would be a much better choice.

We'll finish up the project next month with complete construction details. **R-E**

Use the 555 to generate sawtooth waves, detect missing pulses, convert DC to AC, boost DC voltage and more.

THE VERSATILE 555

RAY M. MARSTON

THE POPULAR 555 TIMER IC HAS been the star of three previous **Electronics Now** articles (September 1992, page 58, October 1992, page 69 and November 1992, page 61.) Just when you thought that all possible applications for that versatile 555 had been exhausted—surprise! This article takes the 555 into new territory—a sawtooth generator, a "ramp" generator, a time-base generator, a frequency meter, and even a tachometer for your car.

But that's not all—there is a missing-pulse detector, and DC voltage doubler, tripler and quadrupler. There are also negative and high-voltage generators and a DC to AC inverter!

If you've been following the previous articles and (we hope) building some or all of the circuits presented in them, you'll be all set for the circuits presented here. Who said the microprocessor was the most versatile IC, anyway?

The last three articles on the 555 explained its basic operating principles. You would have learned (or refreshed your memory) about how to place external components so the timer functions either as a monostable or astable multivibrator. You might want to reread the introductory sections of those articles to brush up on the unusual features of the 555. A complete schematic of the circuitry contained in the 555 is given as Fig. 2 on page 64 of the September 1992 issue.

Figure 1 is another functional block diagram and pinout of the bipolar 555 with a different arrangement of functional blocks than the others given earlier, illustrating yet another manufacturer's preferred data book presentation. Neither diagrams nor data sheets on the 555 have been standardized.

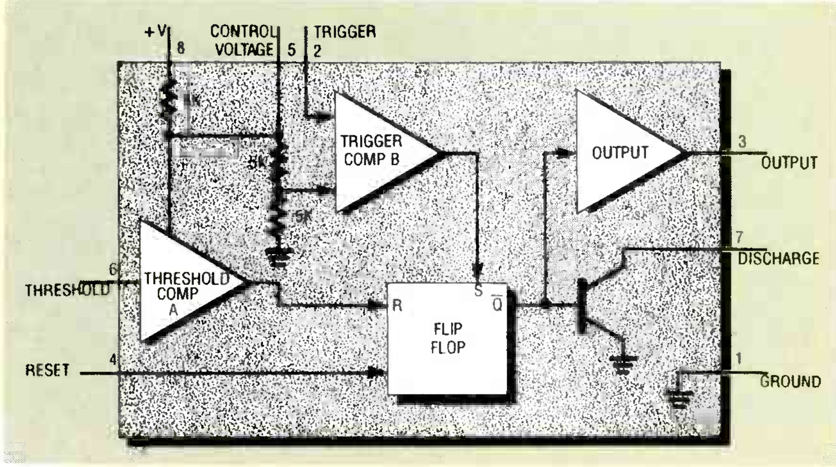


FIG. 1—FUNCTIONAL BLOCK DIAGRAM and pinout for the bipolar 555 timer IC.

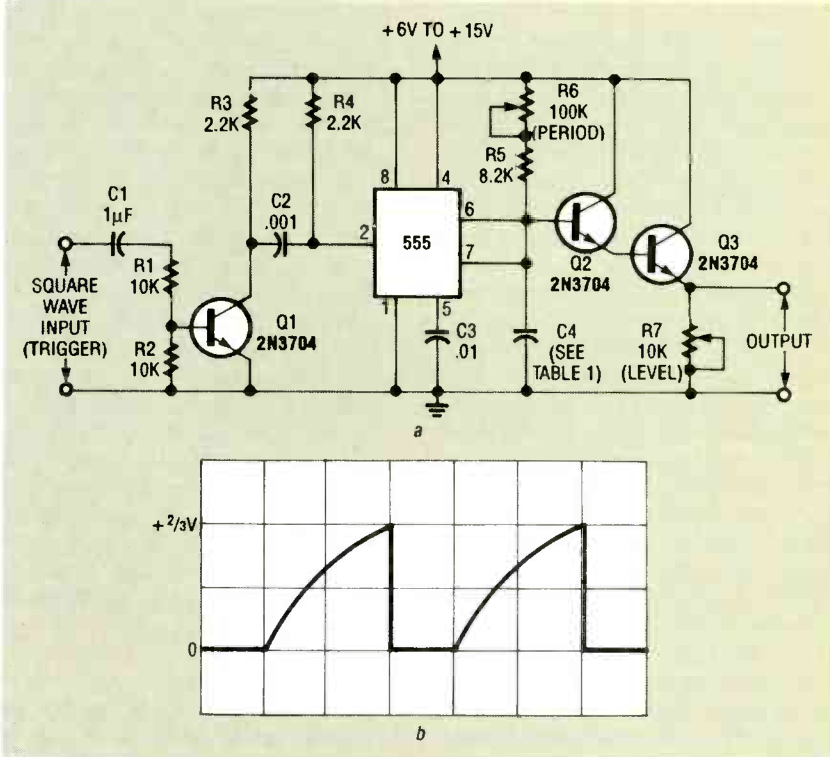


FIG. 2—TRIGGERED SAWTOOTH GENERATOR based on the 555, a, and typical output waveform, b.

Sawtooth-wave generators

The 555 with external components can become a triggered nonlinear (exponential) sawtooth waveform generator, as shown in the schematic Fig. 2-a. The circuit is a modified

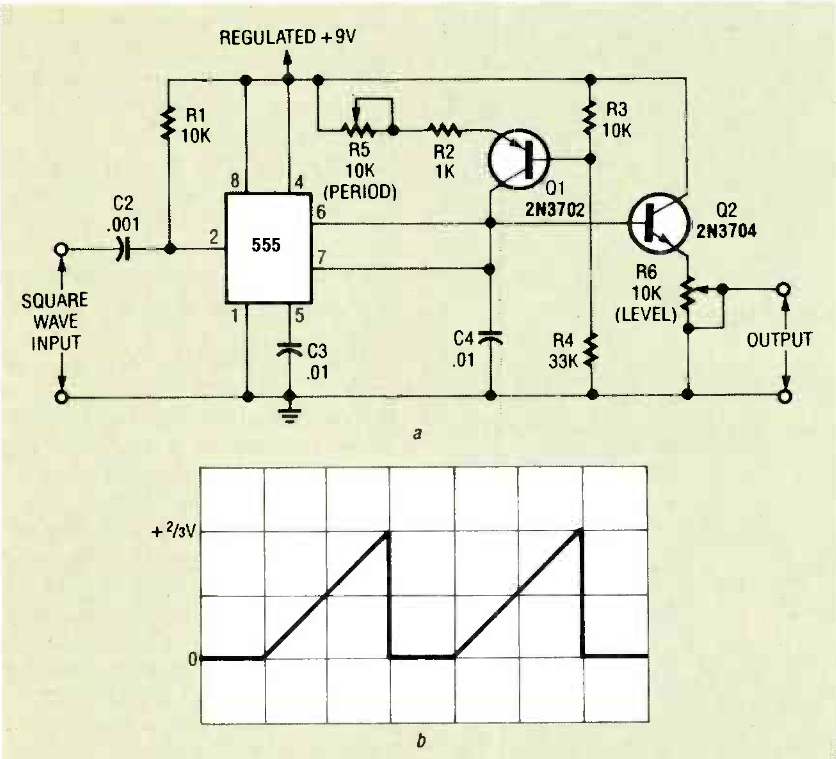


FIG. 3—LINEAR SAWTOOTH OR RAMP waveform generator based on the 555, a, and "ramp" waveform, b.

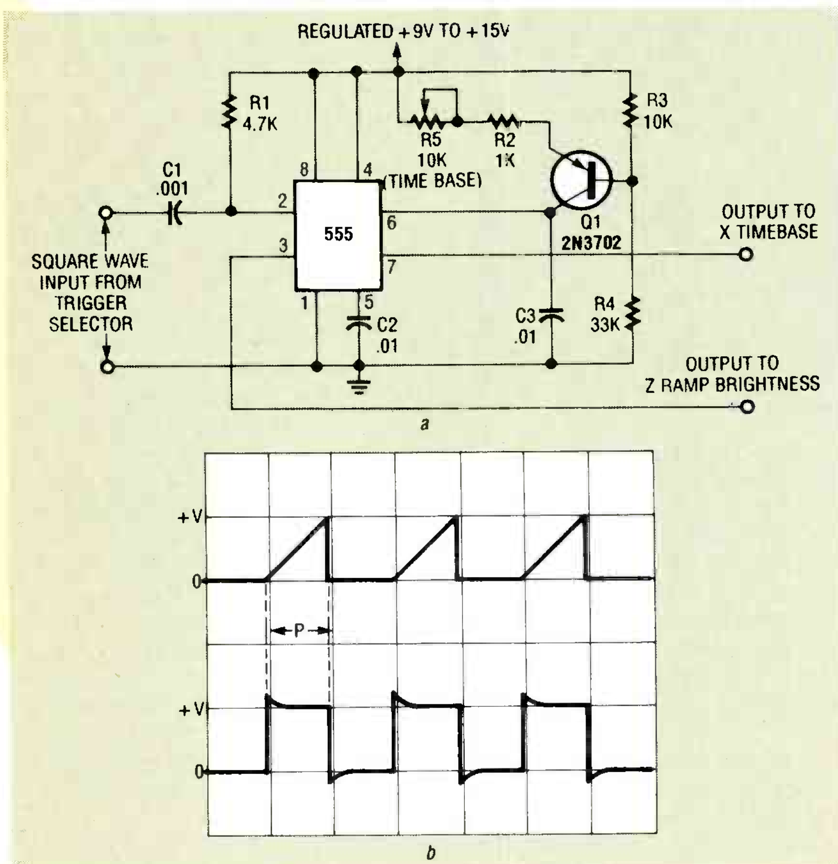


FIG. 4—OSCILLOSCOPE TIME-BASE GENERATOR circuit based on the 555, a, and ramp and ramp brightness pulse waveforms for an oscilloscope's X and Z axes.

monostable multivibrator that is triggered by an external square wave TRIGGER pin 2 obtained through capacitor C2 from the collector of transistor Q1. Note that OUTPUT pin 3 of the 555, used in most of the 555-based circuits presented earlier is unused here.

The voltage across C4 (the timing component) is normally zero, but whenever the circuit is triggered, C4 charges exponentially through resistor R5 and PERIOD potentiometer R6 to two-thirds of the supply voltage. At that time, the monostable period ends and the voltage across C4 drops abruptly to zero. The output sawtooth waveform (Fig. 2-b) is taken across capacitor C4 through buffer transistors Q2 and Q3 and LEVEL potentiometer R7.

The period of the sawtooth or width can be varied from 9 microseconds to 1.2 seconds with the capacitance values for C4 listed in Table 1. The circuit's maximum usable repetition frequency is approximately 100 kHz.

The generator must be triggered by rectangular input waveforms with short rise and fall times. Potentiometer R6 controls the sawtooth period over a decade, and potentiometer R7 controls the amplitude of the output waveform.

Figure 3-a shows a triggered linear sawtooth or *ramp* waveform generator. Capacitor C4 is charged by a constant-current generator that includes Q1. The output waveform (Fig. 3-b) is taken at the wiper of LEVEL potentiometer R6, which is coupled to the voltage across C4 through Q2. Note that the curved ramps of Fig. 2-b have been flattened.

When a capacitor is charged from a constant current source, its voltage rises at a predictable linear rate that can be expressed as:

Volts/second = amperes/farad

By introducing more practical values, alternative expressions for the rate of voltage rise are:

V/μs = A/μF, or

V/ms = mA/μF

Those formulas state that voltage rate-of-rise can be in-

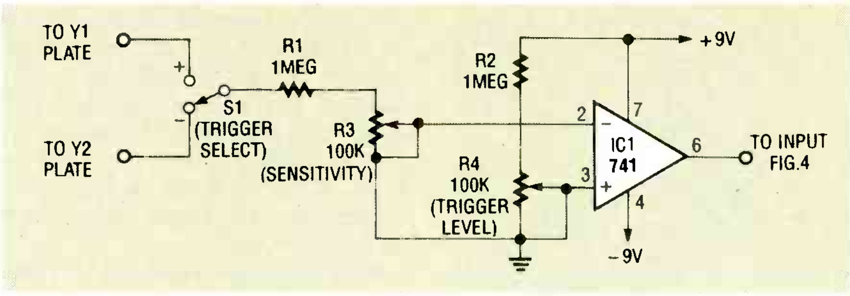


FIG. 5—TRIGGER SELECTION CIRCUIT for the Fig. 4 circuit

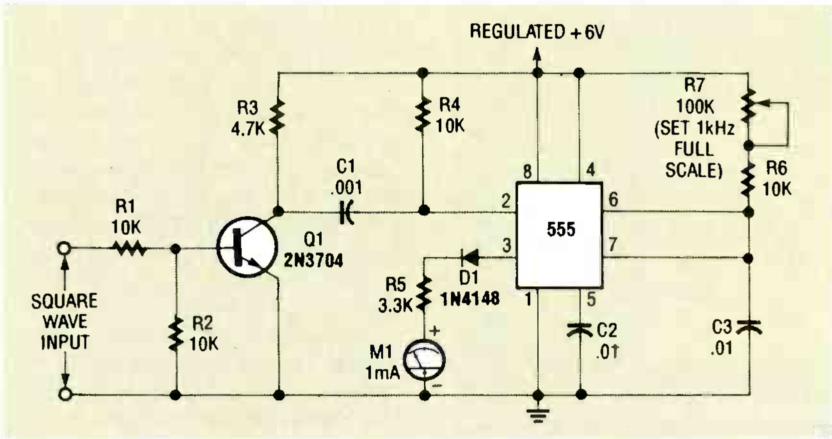


FIG. 6—A 1-kHz LINEAR-SCALE ANALOG FREQUENCY meter circuit based on the 555.

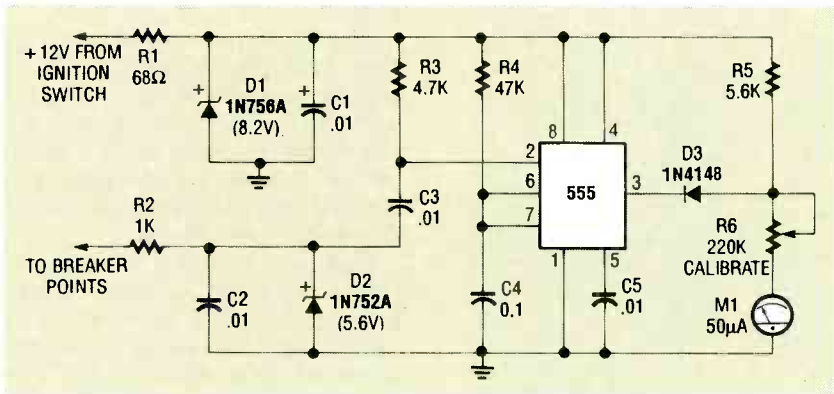


FIG. 7—VEHICULAR TACHOMETER CIRCUIT based on the 555.

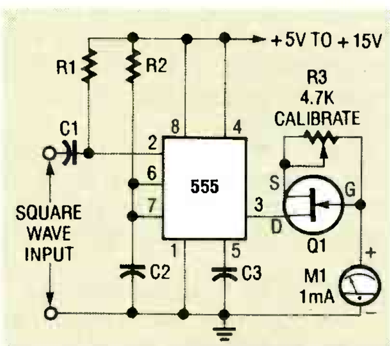


FIG. 8—ALTERNATIVE ANALOG TACHOMETER CIRCUIT to Fig. 6.

creased either by increasing the charging current or by decreasing the capacitance value.

The charging current in the Fig. 3-a circuit can be varied over the range of about 90 microamperes to 1 milliampere with PERIOD potentiometer R5, thus giving the 0.01 microfarad timing capacitor rates-of-rise of 9 volts per millisecond to 100 volts per millisecond.

Each one-shot or monostable cycle of the 555 ends when the voltage across C4 reaches two-thirds of the supply voltage. As shown in Fig. 3-a, the supply is 9 volts, so two-thirds of 9 volts is 6 volts, the amplitude of the ramp waveforms in Fig. 3-b.

The sawtooth cycles of the circuit have periods variable from 666 microseconds (2/3 millisecond) to 60 microseconds (6/100 millisecond).

Periods can be increased beyond those values by increasing the value of C4, or reduced by reducing the value of C4. In this circuit, stable timing periods depend on a stable voltage source.

Fig. 4-a shows how the circuit in Fig. 3-a can be modified to become an oscilloscope timebase generator. It can be triggered by external square waves through a suitable trigger selector circuit. The *ramp* output waveform (top of Fig. 4-b is fed to the X plates of an oscilloscope with a suitable amplifier stage. The pulsed OUTPUT from pin 3 of the 555 (shown in the lower half of Fig. 4-b) is fed to the CRT's Z axis to trace the ramps with higher brightness.

The shortest useful ramp period that can be obtained from the circuit in Fig. 4-a (with a 0.001 microfarad capacitor C3) is about 5 microseconds. That value, when expanded to give full deflection on an oscilloscope with a ten-division graticule, yields a maximum timebase rate of 0.5 microsecond per division.

The timebase circuit of Fig. 4-a can synchronize signals at trigger frequencies up to about 150 KHz. At higher frequencies, the input signals must be divided by a single- or multi-decade frequency divider. With that approach, the timebase can be used to view input signals at megahertz frequencies.

Figure 5 illustrates a simple but versatile trigger selector circuit for the timebase generator in Fig. 4-a. Operational amplifier IC1 (a μA741) has a reference voltage fed to its non-inverting input pin 3 by TRIGGER LEVEL potentiometer R4. The signal voltage is then fed to IC1's inverting pin 2 through switch S1, resistor R1 and SENSITIVY potentiometer R3.

Switch S1 selects either in-phase or out-of-phase input signals from the Y-driving amplifier of the oscilloscope, permitting the selection of either the plus or minus trigger modes. The output of the circuit in Fig. 5 is coupled directly to the C1 input of Fig. 4.

Analog frequency meters

Figure 6 shows the 555 IC organized as a linear-scale analog frequency meter with a full-scale sensitivity of 1 kHz. The circuit's power is obtained from a regulated 6-volt supply, and its input signals can be pulses or square-wave signals with peak-to-peak amplitudes of 2 volts or greater. Transistor Q1 amplifies this input signal enough to trigger the 555. The output from pin 3 is fed to the 1-milliampere full-scale deflection moving-coil meter M1 through offset-canceling diode D1 and multiplier resistor R5.

Each time the monostable multivibrator is triggered, it generates a pulse with a fixed duration and amplitude. If each generated pulse has a peak amplitude of 6 volts and a period of 1 millisecond, and the multivibrator is triggered at an input frequency of 500 Hz, the pulse will be high (at 6 volts) for 500 milliseconds in each 1000 milliseconds. Moreover, the *mean* value of output voltage measured over this period is 500 milliseconds/1000 milliseconds × 6 volts = 3 volts or half of 6 volts.

Similarly, if the input frequency is 250 Hz, the pulse is high for 250 milliseconds in each 1000-millisecond period. Therefore, the mean output voltage equals 250 milliseconds/ 1000 milliseconds × 6 volts = 1.5 volts or one quarter of 6 volts. Thus, the circuit's mean value of output voltage, measured over a reasonable total number of pulses, is directly proportional to the repetition frequency of the monostable multivibrator.

Moving-coil meters give *mean* readings. In the circuit of Fig. 6 a 1-milliampere meter is connected in series with multiplier resistor R5, which sets meter's sensitivity at about 3.4 volts full-scale deflection. The meter is connected to give the mean output value of the multi-

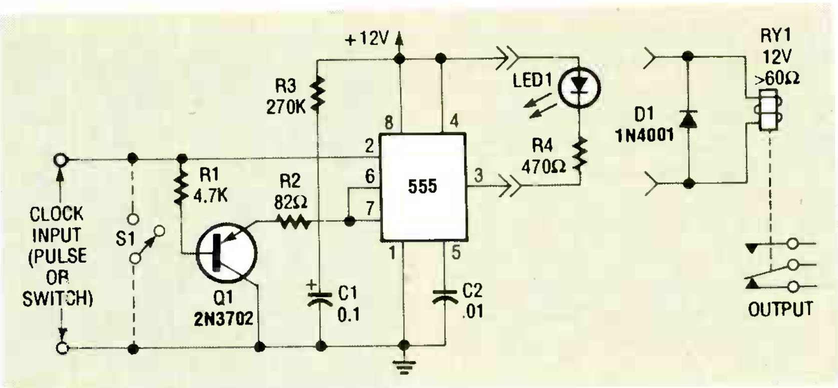


FIG. 9—MISSING-PULSE DETECTOR with LED or relay output.

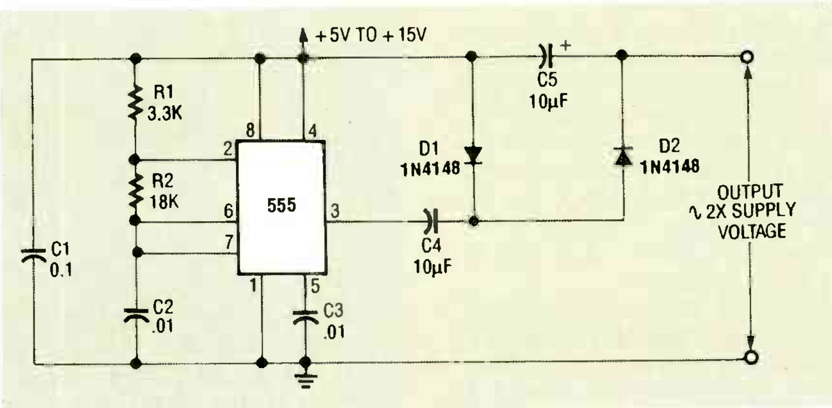


FIG. 10—DC VOLTAGE-DOUBLER based on the 555.

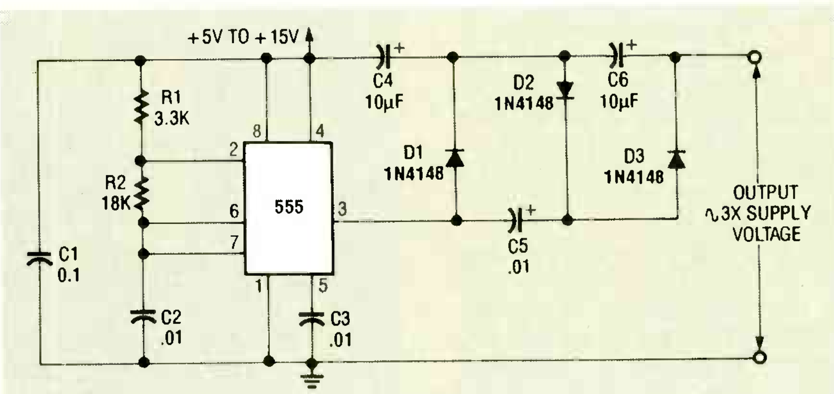


FIG. 11—DC VOLTAGE-TRIPLER based on the 555.

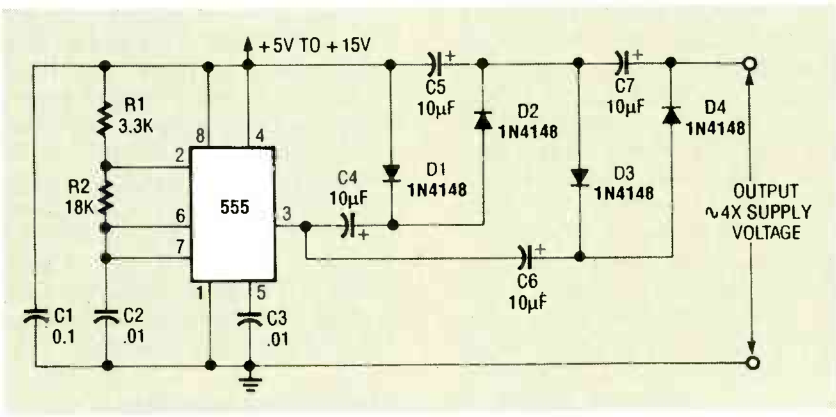


FIG. 12—DC VOLTAGE-QUADRUPLER based on the 555.

vibrator, and its reading is directly proportional to the input frequency.

With the component values shown, the circuit is organized to read full-scale deflection at 1 kHz. To set up the circuit initially, a 1-kHz square-wave signal is fed to its input, and full-scale-adjust potentiometer R7 (it controls pulse length) is set to give a full-scale reading on the meter.

The full-scale frequency of the circuit in Fig. 6 can be varied from about 100 Hz to 100 kHz by selecting the value of C3. The circuit can read frequencies up to tens of megahertz by introducing the input signals to the monostable multivibrator through either a single or multidecade digital divider. The dividers can reduce the input frequencies to values that can be read on the meter.

Figure 7 shows how the circuit in Fig. 6 can be modified to become an analog tachometer or revolutions per minute (rpm) meter for motor vehicles. The circuit is powered by a regulated 8.2 volts derived from the vehicle's 12-volt battery with resistor R1, Zener diode D1, capacitor C1, and the ignition switch. The 555 is triggered by a signal from the vehicle's breaker points conditioned by the network of resistor R2, capacitor C2, and Zener diode D2.

The 50-microampere moving-coil meter M1, the rpm indicator, is activated from OUTPUT pin 3 of the 555 through diode D3. Current is applied to the meter through series-connected resistor R5 and CALIBRATE potentiometer R6 from the power supply when the 555's output is high. But current is dropped nearly to zero by diode D1 when the 555's output is low.

Both the circuits of Figures 6 and 7 are powered from regulated sources to ensure a constant pulse amplitude and provide accurate, repeatable readings from the meter. The meter is actually a current-indicating device, but it is connected as a voltage-reading meter with suitable *multiplying* resistors. They are R6 and R7 in Fig. 6 and R5 and R6 in Fig. 7.

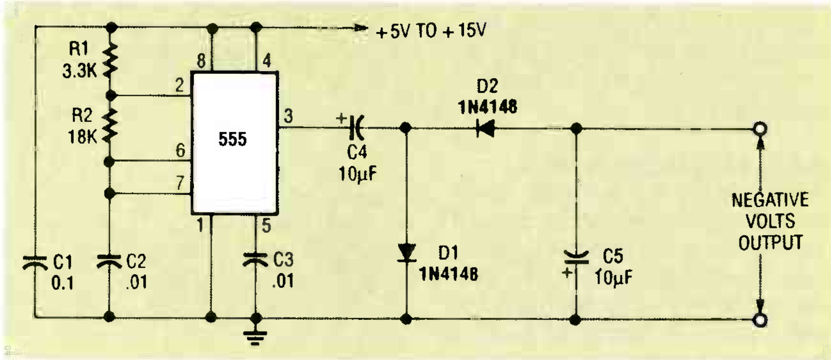


FIG. 13—DC NEGATIVE-VOLTAGE GENERATOR based on the 555.

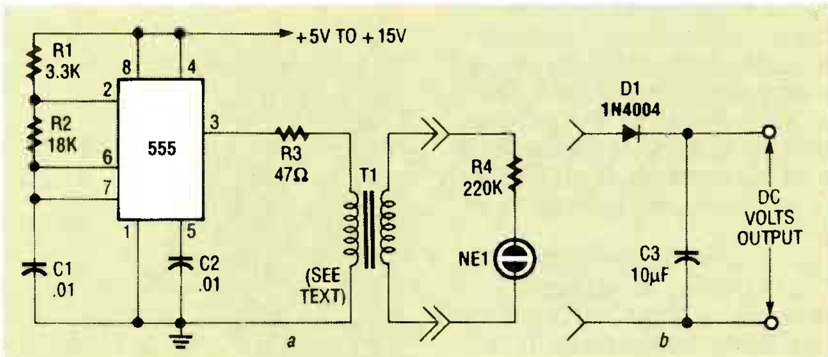


FIG. 14—NEON-LAMP DRIVER based on the 555, a, and DC-to-DC converter with rectifier and filter replacing lamp, b.

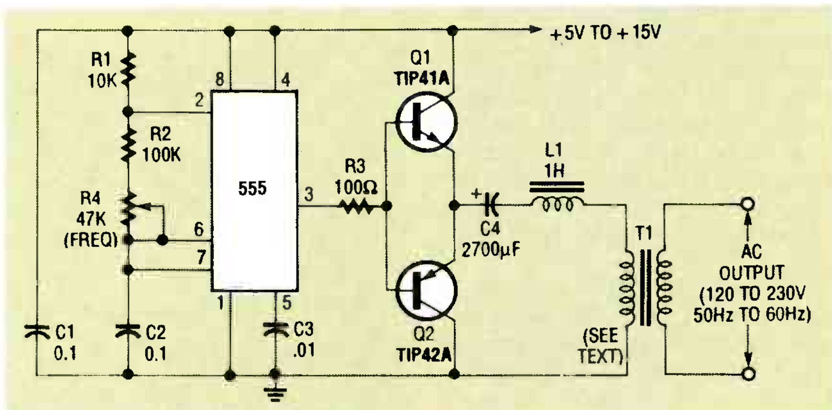


FIG. 15—DC-to-AC INVERTER based on the 555.

The diagram of Fig. 8 shows the outline schematic for an alternative analog frequency meter that requires neither a multiplier resistor nor a regulated power supply. In this circuit, OUTPUT pin 3 of the 555 is connected to the meter through JFET transistor Q1. Configued as a constant-current generator through potentiometer R3, it sends a fixed-amplitude pulse to the meter regardless of variations in the supply voltage.

Missing-pulse detector

Figure 9 illustrates how the 555 can become the key component in a *missing-pulse detector* that closes a relay or illuminates a LED if a normally expected event fails to occur. The 555 is connected as a monostable multivibrator except that Q1 is placed across timing capacitor C1, and its base is connected to TRIGGER pin 2 of the IC through R1.

A series of short pulse- or switch-derived clock input signals from the monitored event is sent to pin 2. The values of R3 and C1 were selected so that the natural monostable period of

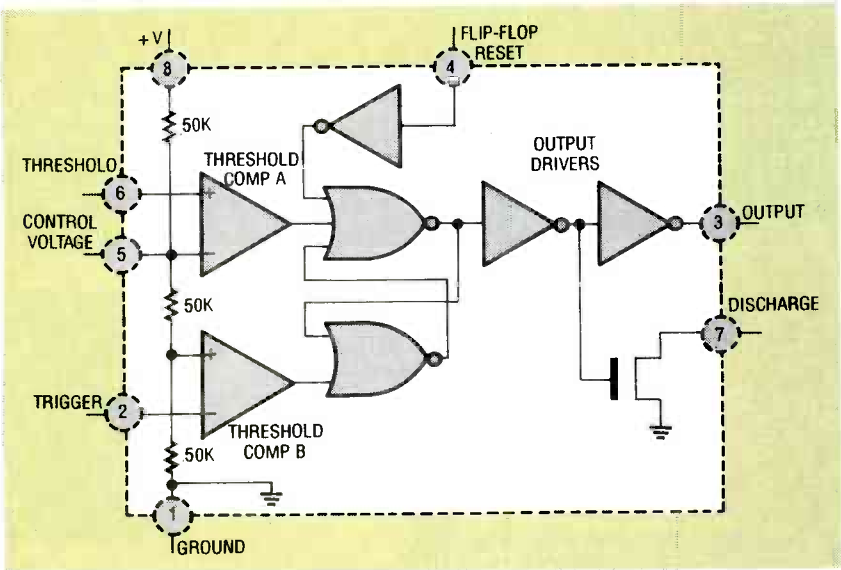


FIG. 16—FUNCTIONAL BLOCK DIAGRAM and pinout of the CMOS 7555.

the IC is slightly longer than the repetition period of the clock input signals.

Thus, each time a short clock pulse arrives, C1 is rapidly discharged through Q1, and simultaneously a one-shot timing period is initiated through TRIGGER pin 2 of the IC, forcing OUTPUT pin 3 high. Before each monostable period can terminate naturally, however, a new clock pulse arrives and starts a new timing period. Therefore OUTPUT pin 3 remains high as long as clock-input pulses continue to arrive within the preset time limits.

If a clock pulse is missing or its period exceeds the pre-set limits, the monostable period will end on its own. If that happens, pin 3 of the IC will go low and drive either the relay or LED "on." As a result, the circuit becomes a missing-pulse detector. It will produce a pulse output when an input pulse fails to occur within the timer delay.

Missing-pulse detectors like this can automatically warn of gaps or one or more missing pulses in a stream of pulses at the input. They are used in communications systems, continuity testers, and security systems. With the component values shown, the timer has a natural period of about 30 seconds. This period can be changed by changing R3 or C1 to satisfy specific needs.

Voltage converters.

The 555 IC can be instrumental in converting a DC voltage to a higher DC voltage, reversing the polarity of a DC voltage or converting it to an AC voltage. Figures 10 to 15 show variations of those circuits.

Figure 10, for example, shows how the 555 functions in a DC voltage doubler. The 555 is organized as a free-running astable multivibrator or square-wave generator that oscillates at about 3 kHz. (The oscillation frequency is set by the values of R1, R2 and C2.) The circuit's output is sent to the capacitor/diode voltage-doubler network made up of C4, D1, C5, and D2. That network produces a voltage that is about twice the supply voltage. Capacitor C1, across the supply, prevents the 3-kHz output of the 555 from being fed back to the IC, and C3 stabilizes the circuit.

The voltage-doubler circuit of Fig. 10 will operate from any DC supply offering from 5 to 15 volts. As a voltage doubler it can provide outputs from about 10 to 30 volts. Higher output voltages can be obtained by adding more multiplier stages to the circuit circuit. Figure 11 is the schematic for a DC-voltage tripler that can supply from 15 to 45 volts, and Fig. 12 is the schematic for a DC voltage quadrupler that supplies from 20 to 60 volts.

The DC negative-voltage generator is a particularly useful 555-based converter circuit. It supplies an output voltage that is almost equal in amplitude but opposite in polarity to that of the IC supply. This circuit can provide both positive and negative voltages for powering op-amps and other IC's with dual power requirements from a positive supply. The DC negative-voltage generator in Fig. 13, like that shown in Fig. 10, is a 3-kHz oscillator that drives a voltage-doubler output stage made up of C4, C5, D1, and D2.

Figures 14-a and 15 show DC to AC inverters that change input DC voltage to output AC voltage by means of transformer coupling. The AC voltage from these inverters needs no further conditioning, and it can be converted back into higher DC voltages with the addition of only a half- wave rectifier and a capacitor filter.

The inverter shown in Fig. 14-a can drive a neon lamp with its AC output. If the lamp and resistor R4 are replaced by the diode and capacitor filter as shown in Fig. 14-b, the AC output can be converted back to a low-current, high-voltage DC output. For example, with a 5- to 15-volt DC input, the inverter can produce an output of several hundred volts DC.

The 555 in Fig. 14-a is configured as a 4-kHz oscillator and its square-wave output from pin 3 is fed back to the input of audio transformer T1 through resistor R3. Transformer T1 has the necessary ratio of primary to secondary turns to produce the desired output voltage. For example, with a 10-volt supply and a 1:20 turns ratio on T1, the unloaded output of T1 will be 200 volts, peak.

The DC-to-AC inverter schematic of Fig. 15 produces an AC output at line frequency and voltage. The 555 is configured as a low-frequency oscillator, tunable over the frequency range of 50 to 60 Hz by FREQUENCY potentiometer R4. The 555 feeds its output (amplified by Q1 and Q2) to the input turns of transformer T1, a reverse-connected filament transformer with the necessary step-up turns ratio. Capacitor C4 and coil L1 filter the input to T1, assuring that it is effectively a sinewave.

A CMOS version of the 555

The standard bipolar 555 timer IC is still one of the most popular and versatile IC's today, but it has some drawbacks that were overcome by a CMOS version. For example, the 555 will not operate from voltages less than about 5 volts. Moreover, it typically draws 10 milliamperes of quiescent current when run from a 15-volt supply. This rather large current drain makes it unsatisfactory for most battery-powered circuits.

In addition to those shortcomings, the 555 produces a massive 400-milliampere current spike from the supply as its output is switched from one state to the other. A spike, lasting only a fraction of a microsecond, can cause lost bits in digital circuits near the 555 or powered from the same supply.

The CMOS version of the 555 timer, also able to operate in both monostable and astable modes, is known generically as the 7555. Figure 16 shows the functional block diagram and pinout of the 7555. This can be compared with the functional block diagram of Fig 1. Note that the pinout is identical.

Harris Semiconductor's version of the 7555, for example, is designated the ICM7555. In common with all other 7555's, it will run from a +2- to +18-volt DC supply. Notice that the resistors in its internal voltage divider are 50 K rather than the 5K of the 555. Other sources of the 7555 are Maxim (ICM7555) and Sanyo (LC7555).

Supply current to the 7555 is typically only 60 microamperes when run from an 18-volt supply. In addition, typical TRIGGER, THRESHOLD, and RESET currents are 20 picoamps, orders of magnitude lower than those of the bipolar 555. Those low currents permit the use of higher impedance timing elements for longer RC time constants. The 7555 can be organized to time out in periods from microseconds to hours.

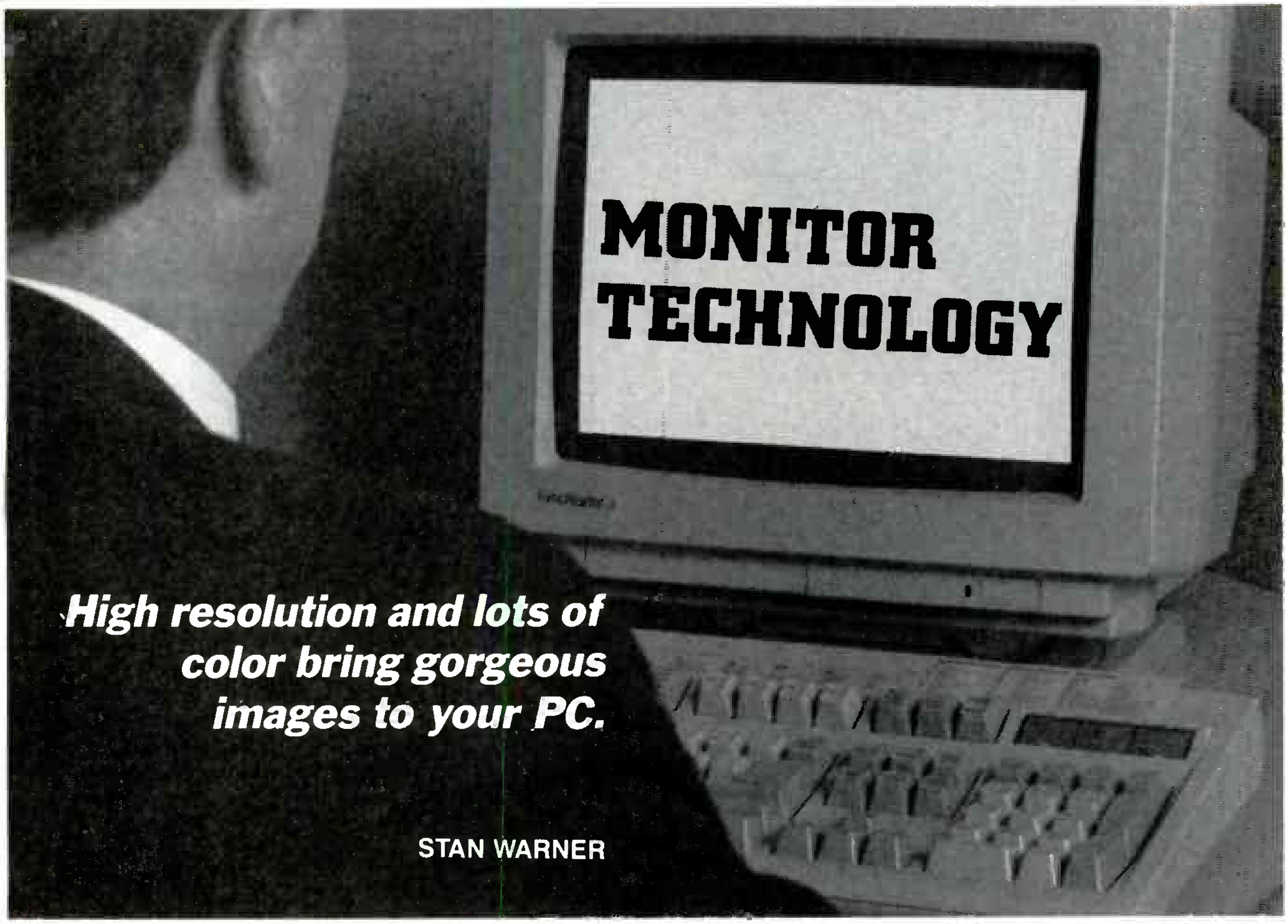
Table 2 compares the characteristics of the 7555 to those of the 555. The 7555 permits:

- Lower supply current
- Wider supply voltage range
- Lower power dissipation
- Lower current spikes in output transitions
- Higher switching frequency performance

These improvements must be balanced against the higher cost of the 7555. The 7555 should be specified only if:

- It is to be used in a battery-powered circuit where power economy is critical
- Available power is 5 volts or less (too low for the 555)
- It is to be in digital circuitry whose signal output could be degraded by noise.

The 7556 is the dual CMOS counterpart of the bipolar 556. The 7555 can directly replace any 555 in all the circuits presented in this series. R-E



MONITOR TECHNOLOGY

High resolution and lots of color bring gorgeous images to your PC.

STAN WARNER

TUMBLING PRICES AND SURGING power have brought computers into nearly every facet of our lives. Gone forever are the days when only large companies could afford computers. No longer does it take a mainframe that nearly fills an entire room to sort business records or do mind-bending arithmetic. Today's powerful yet affordable desktop machines are taking on exciting new chores in every phase of business—and the home.

According to the Electronic Industries Association (EIA), the computer and peripheral market more than doubled during the 1980's, from $24.3 billion in 1980 to $56.1 billion in 1990, as shown in Fig. 1. According to the EIA, the home computer market grew 50% in one three-year period, from $4.5 billion in 1988 to $6.4 billion in 1991. In addition, personal computers can be found in 33% of the homes in the United States.

Today's computers can crunch reams of data at blinding speeds, but improvements in monitor technology have also increased the number of computer applications. Desktop publishing systems that combine text and graphics are bringing print-shop quality to financial reports, company newsletters, and sales presentations. Surgeons create computer-generated, 3-D images of their patients' insides long before they pick up a scalpel. Landscape artists design lifelike layouts with trees, shrubs, and flowers before turning a single spade of dirt.

Monitor manufacturers are continually working to improve graphics clarity and resolution, and large strides have occurred during the past decade. The monitors of the early eighties had poor resolution and fuzzy graphics compared to those on the market today. Today's mainstream monitors are capable of displaying crisp graphics and text. High-end monitors produce fabulous pictures with crystal-clear resolution.

Monitor improvements

These improvements have come about as a result of enhancing four primary performance-defining characteristics: horizontal frequency, horizontal resolution, vertical frequency, and vertical resolution, as shown in Fig. 2. Each is defined below:

Horizontal Frequency The number of times per second the electronic beam travels horizontally across the CRT and back. Horizontal scan time is the inverse of horizontal frequency ($1/f_h$).

Horizontal Resolution The number of dots or picture elements ("pixels") that can be displayed horizontally. A pixel is the smallest dot the monitor can display.

Vertical Frequency The number of times per second the electron beam travels from the

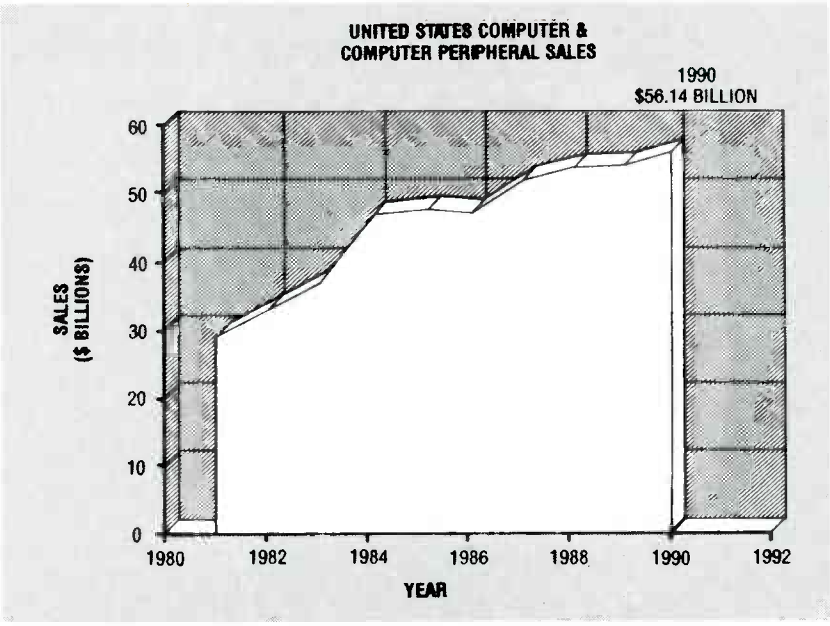


FIG. 1—SALES OF COMPUTERS AND PERIPHERALS surged in the 1980's, and continue to grow in the 1990's.

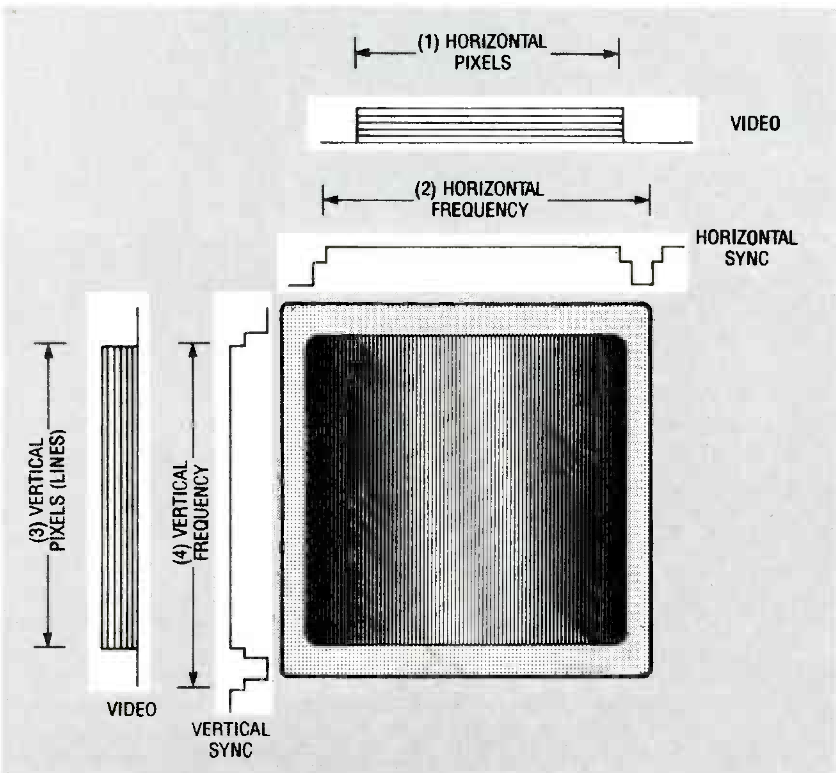


FIG. 2—COMPUTER MONITOR PERFORMANCE can be defined by four characteristics: horizontal frequency and resolution, and vertical frequency and resolution.

top of the CRT to the bottom and back. Vertical scan time is the inverse of vertical frequency ($1/f_v$).

Vertical Resolution The number of picture elements displayed vertically on the CRT. Vertical resolution is comparable to the number of "lines" in television terminology.

A fifth characteristic, dot pitch, also plays a role in determining the resolution of a monitor. Dot pitch is the distance between like colors in the shadow mask. Dot pitch determines the size of the smallest pixel a color CRT can display. The smaller the dot pitch, the sharper the image. Typical values of dot pitch are between 0.26 and 0.50 mm. Figure 3 shows the distance between the centers of two red dots.

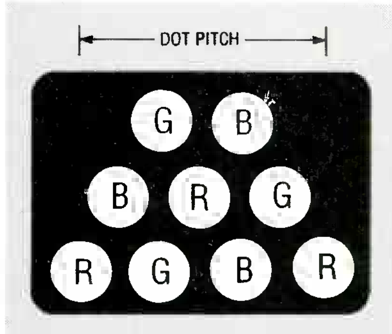


FIG. 3—DOT PITCH is the distance between like colors in a CRT shadow mask.

Today's high-resolution monitors represent improvements over their predecessors in several ways, including increased horizontal and vertical frequency and resolution, and decreased dot pitch. On early monitors, the electron beam typically took 63.7 μs(corresponding to a frequency of 15.7 kHz) to scan one line. Today it is not uncommon for the beam to complete its trip in 13.0 μs(76.9 kHz) or even less, as shown in Fig. 4.

In addition, more pixels are being displayed per horizontal line, and more lines are displayed per frame. Whereas early computer monitors had 640 horizontal pixels and 200 lines, common monitors today have 1,024 horizontal pixels and 768 lines—or more. A faster scan rate gives the monitor extra time to display additional lines and pixels.

Video bandwidth

Video bandwidth is the highest frequency the monitor's video circuits can pass. In general, higher resolution requires higher bandwidth. A visual indication of sufficient bandwidth comes from displaying a pattern that produces a single-pixel line, as shown in Fig. 5.

To get a basic understanding of the bandwidths required by high- and low-resolution monitors, let's calculate the bandwidth required by each.

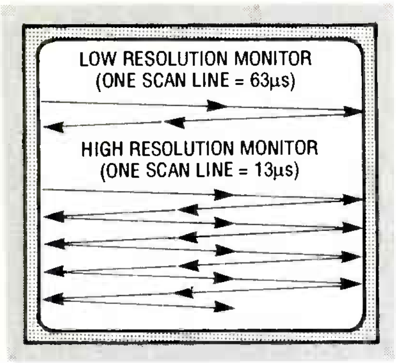


FIG. 4—A HIGH-RESOLUTION MONITOR scans across the screen more than four times, while a low-resolution monitor does so once.

We'll analyze a high-resolution monitor that scans at 64 kHz and displays 1024 pixels per line, and a low-resolution monitor that scans at 15.7 kHz and displays 640 pixels per line.

High-Resolution Bandwidth Inverting the horizontal scanning frequency (64 kHz) gives a total horizontal scan time of 15.6 µs. As shown in Fig. 6, about 80% of that time is for active video (what's seen on the monitor) and about 20% is for blanking. Using the 80/20 ratio in the example translates into 12.5/3.1 µs active/blanking. If it takes 12.5 µs to display 1024 pixels, it therefore takes 12.5/1024 = 12.2 ns to display a single pixel. Inverting that figure gives a bandwidth of 81.9 MHz. So, to see a crisp, distinct line, one pixel wide, the bandwidth of the video amplifiers in a high-resolution monitor must be 81.9 MHz or greater.

Low-Resolution Bandwidth A horizontal scan rate of 15.7 kHz gives a horizontal scan time of 63.7 µs. Eighty percent of that is 51.0 µs, during which 640 pixels will be displayed. Thus the time per pixel = 51/640 = 79.6 ns. Inverting that figure gives a low-resolution bandwidth of 12.6 MHz.

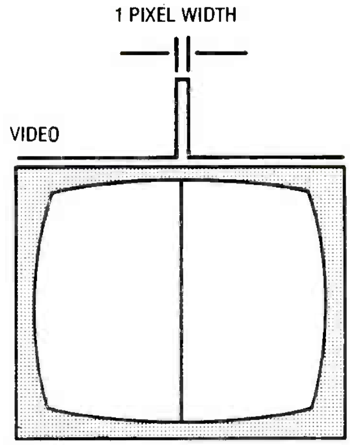


FIG. 5—A ONE-PIXEL VERTICAL LINE is a good indicator of a monitor's maximum bandwidth. A crisp, distinct line shows that the monitor has sufficient bandwidth.

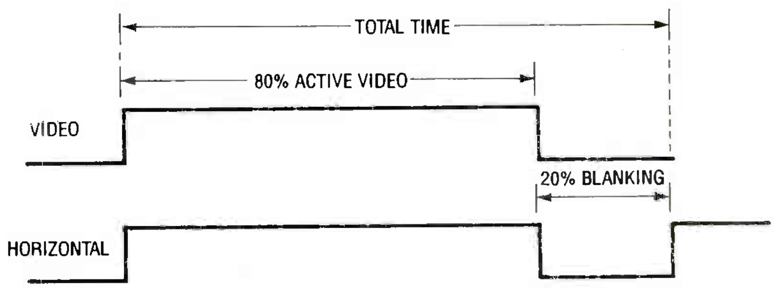


FIG. 6—A TYPICAL VIDEO SCAN LINE consists of 80% active video and 20% blanking.

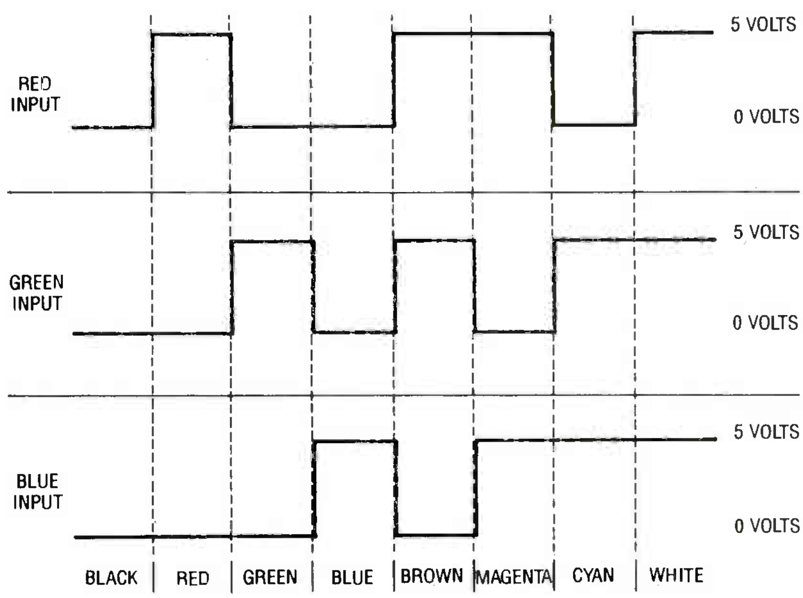


FIG. 7—A DIGITAL-INPUT MONITOR PRODUCES COLORS based on various combinations of signals. For example, the monitor displays magenta when red and blue are high and green is low.

Computer monitors

Monitors can be divided into three basic categories: digital, analog, and ECL (emitter-coupled logic). Digital and analog monitors can be either monochrome or color. ECL monitors are always monochrome.

The video input signals to a digital monitor are TTL logic levels that are either high (greater than 2 volts) or low (less than 0.8 volts). A color digital monitor has red, green, blue and (usually) intensity inputs, and it can display as many as 64 colors, depending on the binary code on the RGBI inputs. Figure 7 shows how different combinations of 1's and 0's translate into different colors on a digital color monitor. A digital monochrome monitor can display as many as 64 shades of gray (or green or amber, depending on the phosphor), also by using combinations of logic levels.

An analog monitor can display an infinite number of colors (or shades of gray). The video signal fed to an analog monitor is usually 0.7 volts peak-to-peak (black to white). Figure 8 illustrates the correspondence between analog input voltage and gray level.

To achieve fast switching time and higher resolution, some high-end monitors use ECL IC's. ECL monitors are monochrome, can display only a limited number of shades of gray, typically have a 19-inch or larger screen, and horizontal resolutions greater than 1024 pixels.

Video adapters

Most IBM-compatible personal computers have a video adapter card that is responsible for generating the video and sync signals used by the monitor. There are many standards for the different video formats, as shown in Table 1. Each format has a different resolution and scan rate. Fixed-frequency monitors are built to handle just one format; multi-frequency monitors can handle several. Digital monochrome monitors are least expensive, followed by analog monochrome monitors, followed by fixed-frequency color monitors, followed by multi-frequency color monitors.

TABLE 1—COMMON COMPUTER MONITOR FORMATS

System/Mode	Horizontal Frequency (kHz)	Vertical Frequency (Hz)	Horizontal Resolution (Pixels)	Vertical Resolution (Lines)
Color/Graphics Array (CGA)	15.7	60	640	200
Monochrome Display Adapter (MDA)	18.4	50	720	350
Hercules Graphics Adapter (HGC)	18.4	50	720	350
Enhanced Graphics Adapter (EGA)	21.8	60	640	350
Professional Graphics Adapter (PGA)	30.5	60	640	480
Video Graphics Array (VGA) Mode 1	31.5	70	640	350
Video Graphics (VGA) Mode 2	31.5	60	640	480
Video Graphics (VGA (Mode 3)	31.5	70	720	400
Super VGA	35.2	56	800	600
8514A	35.2	87	1024	768
Extended Graphics Adapter (XGA)	35.2	87	1024	768
Apple Macintosh II	35.5	67	640	480

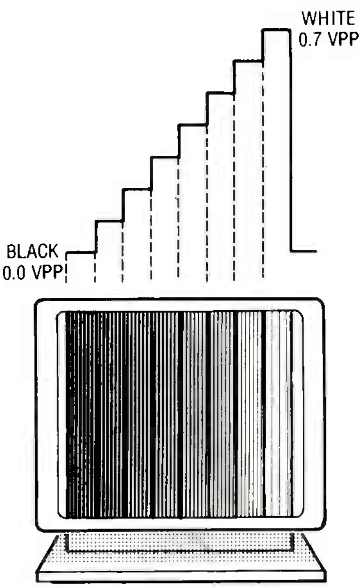


FIG. 8—AN ANALOG MONITOR can display an infinite number of colors or shades of gray.

IBM introduced the CGA and MDA formats in the early 1980's. Both are digital formats. CGA provides 16 colors and can display bit-mapped graphics at a resolution of 640 × 200. MDA provides only two shades of a single color and cannot display graphics. The Hercules card met a need by providing total compatibility with the MDA and also providing the ability to display bit-mapped graphics, e.g., graphs in Lotus 1-2-3.

IBM introduced the EGA standard in 1984. EGA's increased scanning frequency allowed a significant improvement in resolution over CGA, from 200 to 350 lines (horizontal resolution remained the same). EGA is a digital standard that can simultaneously display 16 of a total of 64 colors.

Next came IBM's PGA standard, in 1985. It was the first PC-based analog format, with TTL composite sync. The scanning frequency increased EGA's 21.8 kHz by about 50% to 30.5 kHz. The PGA standard displays 256 colors out of 4096.

IBM introduced the VGA standard in 1987. VGA produces analog video with separate TTL sync, and a horizontal scan frequency of 31.5 kHz. VGA can display 256 colors out of 256,000 in a low-resolution mode, and 16 colors in a text mode. VGA increased vertical resolution from 350 to 480 lines, again keeping horizontal resolution the same at 640.

After VGA started to become popular, the market demanded even more resolution and color. IBM introduced the 8514, but prices were high, and at first only a model for the PS/2 was available. So video-card vendors introduced a variety of Super VGA formats that typically-max-out at 1024 × 768, with 256 colors. IBM later introduced XGA, the current version of which supports 1024 × 768 × 256. There are rumors that an upcoming 80x86 microprocessor from Intel will have a built-in XGA video processor.

The Macintosh II standard produces an analog video signal with separate composite TTL sync. Other MAC standards place the composite sync on the green video line. Some Macintosh video cards are capable of producing 256 colors from more than 16 million. These cards are also available for PC's.

The video formats shown in Table 1 illustrate the vast changes that have occurred in the PC side of the computer market during the past ten years. But the chart doesn't tell the entire story; these are only the monitors sold for mainstream applications (e.g. word processing, spreadsheets, and home finance). In other areas (e.g., engineering workstations, medical imaging devices, high-end publishing equipment), it is not uncommon for monitors to have resolutions of 2,048 pixels or more, and horizontal scan frequencies three to four times greater than that of VGA. Wouldn't it be great to have one of those monitors sitting on your desk? If current market trends continue, there's a good chance that you will—and soon. **R-E**

WHAT'S NEWS

continued from page 6

the development of table-top, laser-powered particle accelerators, as opposed to today's massive, expensive accelerators. Another potential use for supercharged laser beams is the development of an X-ray laser capable of observing the molecular and atomic action of living cells.

The secret to the record-breaking power levels is a technique called *chirped-pulse amplification*, in which laser pulses are first produced in short bursts of a fraction of a picosecond (about one trillionth of a second). The duration of the pulses is then stretched out about a thousand times before the pulses enter the laser's amplifier. After amplification, the pulse is compressed back to the original fraction of a picosecond burst.

The research teams' "ultimate goal," according to Jacques Coutant, department head at the Centre, "is to push the power of the beam to 1000 terawatts." **R-E**

VIDEO NEWS

continued from page 8

HDTV service, since most major cable systems have channels to spare. It's easy to see the possibility of a pay channel carrying movies in widescreen near-theater definition, the way they were intended to be seen. In fact, HBO and other pay cable operators are excited over the prospect. The same is true of the proposed multi-channel direct satellite-to-home systems, such as Hughes Aircraft's DirecTV, which seem certain to earmark some channels for HDTV.

The real key to the equation lies with consumers. Will they be willing to pay $2000 and up—perhaps way up—for the first HDTV sets when there is little or no programming? Test after test shows average viewers regard program content as more important than picture quality. A massive education job and some significant program pump-priming seem indicated if HDTV is to catch on in a faster time frame than color TV's 10 years. **R-E**

INRUSH CURRENT LIMITED

continued from page 50

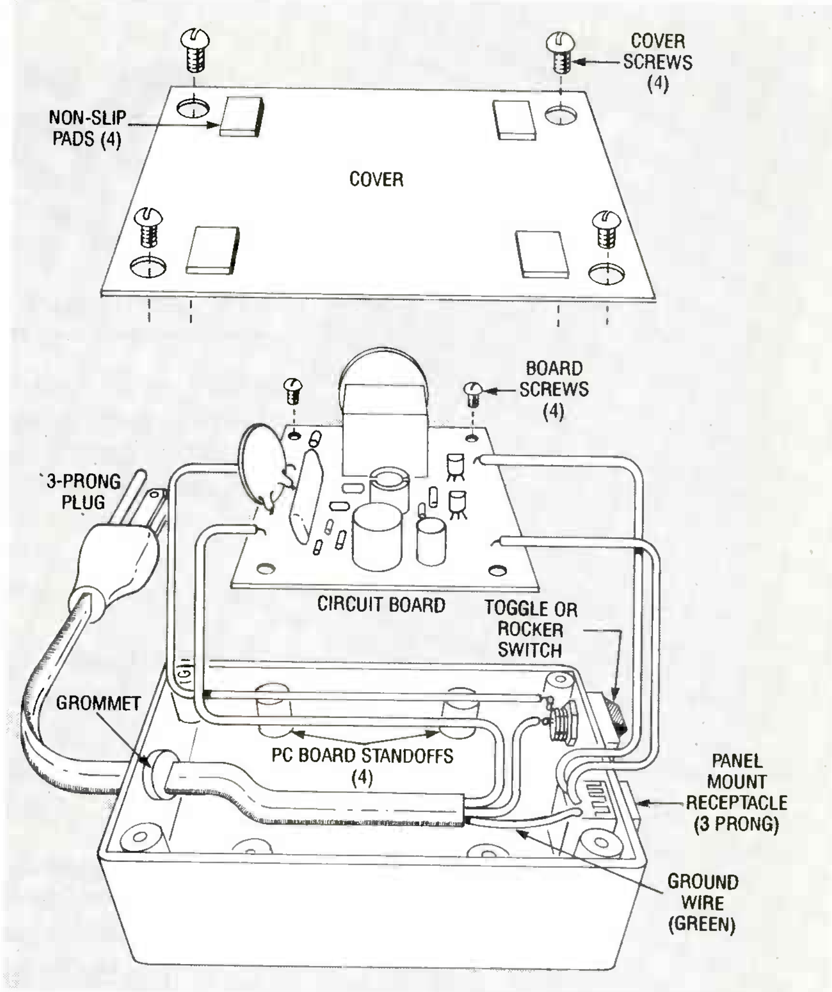


FIG. 10—EXPLODED VIEW OF INRUSH-CURRENT limiter circuit in enclosure. Note the completion of ground within the case with a 3-wire power cord.

the completed circuit. Pull the three-wire cable through a grommet in the case sidewall as shown. Strip the jacket from the cable in the case, strip the end of the green ground wire, and connect it to the ground terminal of the three-prong receptacle. Solder one of the cable's conductors to the PC board, as shown, and solder the other conductor to one terminal of the switch.

Using short insulated lengths of the same cable conductor, solder a connection from the switch to the other side of the PC board, as shown. Solder two more short lengths of conductor to the output pads on the PC board, and connect their other ends to the panel-mount receptacle.

Fasten the circuit assembly in in the case with hold-down screws and close the cover. Fasten the cover in position with the four screws included. The inrush-current limiter then becomes a plug-in accessory and the host equipment need not be altered. The equipment's power switch should be clamped in the "on" position so that power to the equipment is then applied with the limiter's ON-OFF toggle or rocker switch.

Although the surge protector is in the circuit only for short time intervals, be sure that any protected equipment does not draw more than 2 amperes. **R-E**

HARDWARE HACKER

Conventional currents, assorted wonderments, navigation and navicubes, FM Yagi antenna design, and two new piezo rate gyros.

DON LANCASTER

So many exciting new hacker opportunities have come down this month that I do not even know where to start. We seem to be moving into a boundless new era of hardware hacking.

Before we begin, though, there have been a few recent helpline calls over some really ancient history which we should go over one final time...

Follow that current!

Which way does the current travel in any electrical or electronic circuit? Many years ago, one of the electrical pioneers ventured his wild *guess* that *electrical current always goes from the negative to the positive terminal in an energy source and from positive to negative in an energy sink.*

It took over a century to verify, but the guess turned out to be correct. At least for certain solid-state circuits, at least some of the time.

To this day, this guess is called the *conventional* electrical current, and appears in Fig. 1. Conventional current is the *only* standard taught in *all* university- and *all* graduate-level engineering courses, is used by *all* physicists, and is accepted by *all* large electronic firms worldwide.

Conventional current is shown in the direction of the arrows on *all* the standard electronic symbols. Even the IEEE tie clasp and cuff links strongly restates conventional current. So does the right-hand generator rule and left-hand motor rule.

Yeah, but just which way does the current *really* go? Well, a glib answer for the new age nineties is "any way you want it to."

In semiconductor loads, the current direction is decided by the majority carriers. In any PNP transistor or any P-channel MOSFET, conduction is by hole carriers, and the current does in fact go in exactly the same direction as the conventional current. In N-type devices, the current is the opposite of the conventional current direction.

So what is the problem? And why am I standing here whipping this long-dead horse?

Way back during World War II, PNP vacuum tubes were very few and far between. Come to think of it, they still are. Because of that, the military introduced the concept of the *electron current* to explain how a vacuum tube works. And many trade schools and lower-level textbooks continued the practice into the fifties and sixties.

That led to the absurd result that a few hackers, technicians, and much of the hobby press had their currents heading in one way, while all of the engineers, physicists, and the rest of industry had their currents heading in the exact opposite direction.

The bottom line: If any individual or any textbook still tries to teach you electron current, they are ripping you off. They are also doing you a serious disservice that will lead you to untold confusion and latter day hassles.

Neither electron nor conventional current is correct all of the time. The overwhelming majority of industry and professional-level training *always* goes with the conventional current. Among the other reasons, because there is no compelling reason not to.

NEED HELP?

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

Just what would it take to convert industry over to electron current? For openers, extremely frigid conditions in a distinctly unpleasant locale. Or some words to that effect. Even then, I would not expect to see this happen until a few weeks after the Ayatolla's Bar Mitzvah.

Navicube update

Way back in a July 1988 *Hardware Hacker*, we looked at the *Navicube*, a 3-inch, $10 cube that always knew where it was and which way it was pointed. Well, we still don't have $10 Navicubes, although I do expect some Korean toy manufacturer or two kids in an Iowa basement to come up with a really good one shortly.

A lot is happening with Navicubes, both evolutionary and revolutionary. An update summary of Navicube info appears as our resource sidebar.

Today's popular approaches to the Navicubes include the GPS satellite system, fluxgates, real gyros, laser gyros, accelerometers, and a pair of brand new piezo gyros.

The GPS global positioning system is going great guns. Their eighteenth satellite is now in orbit, and Russian and ECC competing systems are now being established. Receiver prices are in free fall, and the $500 barrier has recently been broken.

GPS World is your foremost trade journal. Its publisher also just started up a new *GPS World Showcase* shopper. As before, the *Journal of the Institute of Navigation* is the finest Navicube technical resource.

Although *Rockwell* is still the most obvious source for the GPS chip sets, *Hewlett Packard* has just developed a new single-chip GPS front end. While it's too early for a part number, several details now appear in *Microwaves & RF* for August

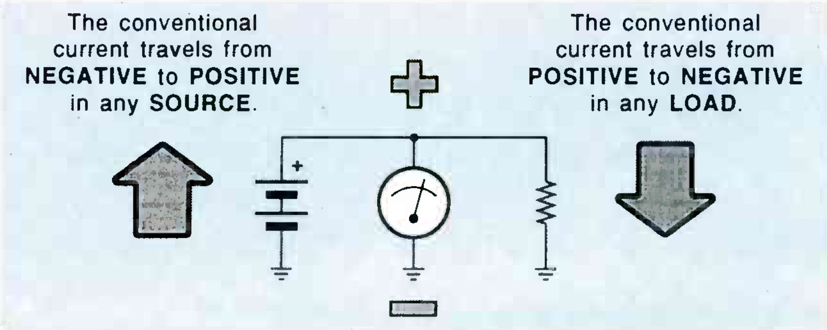


FIG. 1—CONVENTIONAL ELECTRIC CURRENT goes from negative to positive in any energy source and from positive to negative in any energy sink. This is *the* standard used by all graduate engineers and physicists, and in electronic symbols, and the industry worldwide. It even appears on the IEEE cufflinks.

1992. I expect cheap new GPS parts real soon now, from several obvious sources.

North sensing isbest done using fluxgate magnetometers. Radio Shack has a cheap one in its car compass, and *KVH* sells expensive commercial units. We have seen several fluxgate construction projects, and references to them in those *Hardware Hacker II* reprints. Naturally, any magnetic sensor gets confused by nearby iron.

Many hackers still labor under the delusion that Hall-effect devices can be used as compasses. Well, possibly they can, but fluxgates are *thousands* of times more sensitive.

One exception is the very low cost *Dinsmore* magnetic compass sensor. Sadly, its best possible accuracy is a crude 22.5 degrees.

Solid-state accelerometers continue to drop in price, spurred on by newer automotive uses, especially airbags. While *Motorola* and *Micro Switch* are the largest suppliers, the better priced and more innovative sensors are now provided by *Analog Devices*, *SenSym*, *IC Sensors*, and *NovaSensor*.

Your two best accelerometer trade journals are *Measurement & Control* and *Sensors*.

Note that you could integrate (sum through time) any acceleration to get velocity, and then integrate velocity to get the position. There is one huge technical hassle with accelerometers, though—it's called the "t-squared" problem. Any bias or similar error in acceleration ultimately piles up as a position error that is proportional to time *squared*.

That means if you wait around long enough for your position, it is certain to be wrong. Accelerometers work best for short-term uses, when they can be repeatedly recalibrated or reset from some other standard every now and then.

Classic navigation is usually done by using mechanical gyros. They are nothing but rapidly spinning masses, comparable to a toy gyroscope. They can be costly, cumbersome, and often involve precision elements rotating at very high speeds. Gyros are available as surplus from *Fair Radio Sales*, *Radio Research Instruments*, and *AST Servo Systems*. One current manufacturer is *Humphrey Products*.

Yes, there are laser gyroscopes. A coil of fiber-optic cable has coherent laser light beams routed through it in opposite directions which then can be phase compared. But not much seems to be happening here to drop the costs by the 1000:1 needed to make them a practical hacker tool. Good information on laser gyroscopes is available from the *IEEE Press* and from *SPIE*.

But our really big Navicube gyro news for this month involves a pair of brand new...

Solid-state rate gyros

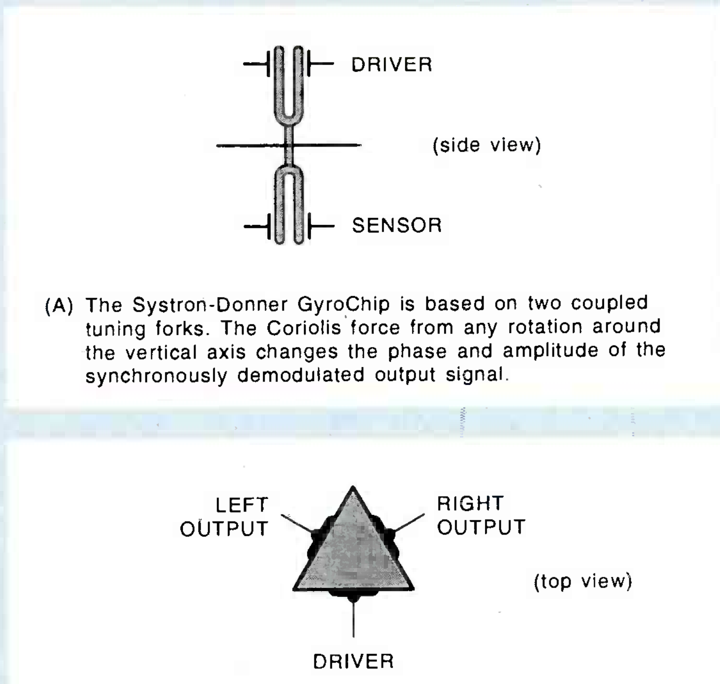
A *rate gyro* is a special gyroscope that can tell you how fast you are *turning*. By integrating your rate of turn, you can get your direction. By combining that with some separately measured velocity, you can find your present position. And there will be no t-squared problem, since no double integration is involved.

Traditional rate gyros are available from the sources of regular gyros we just looked at. A hackable and a low-cost fluidic rate gyro was made a few years back by Doug Garner at *NASA*. It used an airstream differential cooling a pair of thermistors. But not too much seems to have come of that approach either.

A pair of new solid-state rate gyros are now available. At least one of them promises to end up as a $5 component. Because they both use vibrating piezo structures, it is not quite correct to say that they have no moving parts. But they certainly are simple and rugged single-piece units with no rotating parts or precision mechanisms.

The first unit is the *GyroChip* by *Systron Donner*, shown in Fig. 2-*a*. This is a pair of back-to-back tuning forks machined from a single piece of silicon. The phase of the output signal it determined by the *Coriolis* force caused by turning.

The second piezo gyro is that new *Gyrostar* by *Murata-Erie*, shown in Fig. 2-*b*. This is just a triangular piezo oscillator. The Coriolis force of rotation again changes the phase of the output signal in propor-



(A) The Systron-Donner GyroChip is based on two coupled tuning forks. The Coriolis force from any rotation around the vertical axis changes the phase and amplitude of the synchronously demodulated output signal.

(B) The Murata-Erie GyroStar is based on carefully controlled vibration modes in a triangular piezo element. Any relative clockwise or counterclockwise rotation changes the phase and amplitude of the output signals.

FIG. 2—NEW DEVELOPMENTS IN PIEZO RATE GYROS should eventually lead to low cost Navicube solutions. A rate gyro tells you how fast you are now turning. Integrating the turn rate (summing through time) gives the present direction.

tion to the rotation rate. This new scheme looks ridiculously simpler and vastly more elegant than the GyroChip design.

While both of those breakthrough devices have the potential to become low-cost parts, samples today cost $300 for Murata's GyroStar, and a ludicrous $2000 for the GyroChip. Their support literature so far is also utterly dismal. But a new $5 Hong Kong knockoff is just about certain to become quickly available.

Assorted wonderments

Continuing this month's stunning new developments, here is a double handful of great new stuff...

• Image Striking—Be sure to check out *Motion Imaging Processing: Striking Possibilities* in the August 1992 issue of *Advanced Imaging*. What we apparently have here is a unique new concept and toolset for video, movie, and multimedia editing.

Put one frame of a small image in the upper left of your monitor screen. Next, move down one pixel and one pixel to the right, and then repeat the process for the next frame in the sequence. Continue until you have a diagonal smirp on down your screen, ending with a final full small image. While you are at it, show your sound amplitude for each frame along the top diagonal of the smirp.

What do you have? In one place and at one time, a display that lets you view the *temporal content* of a *time sequence* of multimedia or other video. In short, you can instantly look *forward or backward through time*, seeing the relationship between your current frame, its recent history, and its near future!

Looking at this "striking" concept in a slightly different way, say you had a few feet of movie film. Cut the individual images apart so they have no borders. Stack them up and look *sideways* at their top and left edges. Once again, in one place and at one time, you can see what has happened and what is going to happen. An instant and real-time plot of images versus time.

Naturally, the edges will only show you wildly abstract colors or patterns. But, with practice, those patterns can easily be read for the scene, camera angle, panning, duration, sound sync, and much more.

A non-obvious application: Quickly finding a buried sequence in a humongous video data base. It is sort of the video equivalent to that ISAM, or *indexed sequential access method* long used in data bases.

The editing, tweening, scanning, high-speed access, and all the visual flow possibilities of this new scheme seem boundless.

• Wavelets—The onslaught continues. A second book is now available and titled *Ten Lectures on Wavelets* by Ingrid Daubechies and published by *SIAM*, shorthand for the *Society for Industrial and Applied Mathematics*. While it's a first-rate text, this is a very advanced math book that makes for rough reading by mere mortals.

A brief story on optical wavelet uses appears in the August 1992 issue of *Photonics Spectra*. All those optics folks sure do have it easy. They just dump a pile of crockery on the table, squirt some light through it, and they get instant real-time 2-dimensional *Fourier* or wavelet transforms. None of the old point-by-point computation nonsense for them.

An entire issue on optical wavelet transforms appears as the September 1992 issue of *Optical Engineering*. I have added #494 EMERGOP2.PS and #456 WAVELETS.PS to *GEnie* PSRT to go along with all the rest of our wavelet downloads. A complete list appears in Fig. 3.

• Multilayer PC breakthrough—I am still looking for a hacker solution that makes printed-circuit plated-through holes cheaply possible at home. Or some workaround that flat out does away with the need for through holes.

A major step in this direction has been taken by *Sheldahl*, whose new special adhesive lets you build ultra expensive multilayer boards out of the cheaper double-sided ones. Sadly, you still need some plate-throughs.

Their *Zlink 1900* is basically a new adhesive that conducts only in its thickness direction. Just take a pair of double-sided boards and selectively apply the adhesive to one of them. You then add heat and pressure to bond the pair together. You can end up with either a three- or a four-layer board at a tiny fraction of the going price. And, yes, you can do six layers, eight layers, or as many as you want. You can even have buried plated-through holes! Far simpler, cheaper, and with a much lower scrap rate than before.

Carefully isolated solder particles make the adhesive conduct in only one direction with conductivity about the same as real multilayer conductors.

A small free sample is available from Sheldahl on request.

• Buckyballs—The price of Buckyballs continues to drop dramatically, and they are now hacker-affordable. The leading supplier remains *MER Inc.*, and their pricing starts as low as $5.50 a gram raw, and $90 per gram fully refined. Minimum order is $50.

Meanwhile, a *fourth* carbon form has been discovered that is called the *Buckytube*: hollow cylindrical pipes of carbon that have both the hardness of diamond and the surface area of graphite. Possible new uses include their use as lubricants, and unique materials that conduct heavily in only one direction. Check out the August 17 issue of *E.E. Times* for a summary update.

More on FM antennas

Last month, we checked into the fundamentals of distant FM reception. We have had some requests for still more information, so here goes...

The noise situation at 100 MHz is a tad further complicated than I first made out. If you do have any remote rural site, then your first-stage KTB thermal agitation noise does, in fact, dominate. And the best noise figure you can get is super important.

Atmospheric noise is negligible at FM frequencies. Galactic noise runs ten decibels or so above KTB, around 100 MHz. But you do not normally point an FM antenna straight up on a clear day, so this is also no problem. The potential killer is the manmade noise, which can be 25 decibels above KTB in suburban locations, and 40 decibels or more in urban locations. Nearby dimmers or computers could also induce those noise levels.

Most of the manmade noise comes from car ignitions. It sure would be interesting to watch the FCC try to enforce the same Part 15 rules and regulations on Detroit iron that they do on Hardware Hackers. Talk about potential noise levels! The howl over this would probably

NAMES AND NUMBERS

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CIRCLE 318 ON FREE INFORMATION CARD

Cushcraft
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(603) 627-7877
CIRCLE 319 ON FREE INFORMATION CARD

EE Times
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Manhassat, NY 11030
(516) 365-4600
CIRCLE 320 ON FREE INFORMATION CARD

GEnie
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Rockville, MD 20850
(800) 638-9636
CIRCLE 321 ON FREE INFORMATION CARD

Heartland America
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Eden Prairie, MN 55344
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CIRCLE 322 ON FREE INFORMATION CARD

MER, Inc
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Tucson, AZ 85706
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CIRCLE 323 ON FREE INFORMATION CARD

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#494 EMERGOP2.PS

Reprint of *Blatant Opportunist #17* from *Midnight Engineering*. Wavelets are one of the eight hacker-friendly emerging tech opportunities reviewed.

#456 WAVELETS.PS

Reprint of *The Wavelet Onslaught* from the *Midnight Engineering Companion #2*. Brief summary on wavelets and a key resource bibliography.

#403 PAK251.EXE

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#390 HACK50.TXT & #391 HACKFG50.PS

Reprint of *Hardware Hacker #50* from *Radio-Electronics*. Wavelets update, including new book, IEEE-SP tutorial, Aware application notes.

#373 HACK49.TXT & #374 HACKFG49.PS

Reprint of *Hardware Hacker #49* from *Radio-Electronics*. Mentions *Wavelets and their Applications* book and *Ultrawave Explorer* software from *Aware*.

#365 WAVELET.PAK

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#313 GURU73.TXT & #314 GURUFG73.GPS

Reprint of *Ask the Guru #73* that discusses three video compression schemes. These include wavelets, DCT/JPEG, and fractal compression methods.

#258 HACK42.TXT & #259 HACKFG42.PS

Reprint of *Hardware Hacker #42* from *Radio-Electronics*. Fundamentals of transforms, along with examples of wavelet video compression.

#195 HACK38.TXT & #197 HACKFG38.GPS

Reprint of *Hardware Hacker #38* from *Radio-Electronics*. A first introduction to wavelets and wavelet theory. Includes 13 entry sampler bibliography that shows the wide extent of wavelet aps.

FIG. 3—WAVELET TUTORIALS AND SHAREWARE available on GEnie PSRT. You can call (800) 638-9636 for your voice-connect info.

be unbearable.

At any rate, you'll still want to get the best first-stage noise figure you can. But it might not help you out too much if your external noise is much stronger than KTB. On the other hand, a slight increase in antenna gain can make a dramatic improvement in your FM reception.

That happens because of a limiter's *capture effect*. For instance, if you've got a noisy FM signal, an increase of only *two* decibels in antenna gain or S/N ratio can make up to a *seven* or *eight* decibel improvement in receiver quieting.

I've found several interesting FM antennas. The Radio Shack 15-1636 is cheap at $17 and easy to find. And it does a good job in near-fringe areas. But it is just plain too small. It measures only four feet by five feet, while a no-compromise Yagi solution will measure five by thirteen.

Radio Shack used the broadband co-linear array, rather than a Yagi design. Then, to save on the materials and size, they apparently designed it up at 120 megahertz or so and hoped there was still some gain down in the FM band. Almost always, a broadband antenna has lower gain than one cut for a single station. From their point of view, this is a useful engineering mix that gives you a small and cheap solution which meets the needs of a majority of their customers. Their gain is 6.4 dB over a dipole.

The most rugged "real" FM DX antenna is the *Cushcraft* Y-FM5. This is available by way of *Anixter*, the leading cable TV distributor chain. The gain is 9.5 decibels over a dipole, and the cost is around $70. Size is 59 by 104 inches.

Another interesting antenna is the *ChannelMaster* 4408 with a 9-decibel gain in a 138-inch boom length. The price seems high at $104.

The highest-gain stock antenna I

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have found is the *Winegard* CA-6065; it has a whopping 10.6 decibels of gain on a 127-inch boom and costs around $78. This appears to be the best choice.

Be sure to remember that raising your antenna height is usually the best way to improve the signal-to-noise ratio in typical locations. The closer to line of sight you can get, the better the results.

But I live in a pecan grove. Nuts. My trees glop over everything, most especially antennas. So some indoor solution seemed better for me.

What about building your own single-station FM antenna? In theory, you could pick up another decibel or two of S/N and as much as 8–10 dB of quieting over full-band commercial designs. Especially if you are extra careful in tuning and matching. And if you have a high loft in your living room or a wire- and metal-free attic crawl space, an indoor design can be much cheaper than a mast-mounted outdoor one—with fewer hassles. And a Yagi is just a bunch of free-floating conductors sitting in magic positions; a wood frame and

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grommeted screw eyes can be used for support.

First, note that there are two styles of driver elements to a Yagi antenna. As Fig. 4 shows, if you use a half-wavelength *dipole* hairpin loop, the terminal impedance should end up near a balanced 300 ohms.

If you use a pair of straight wires of half-wavelength total spacing, then your terminal impedance should be a balanced 75 ohms. Note that normal 75-ohm coaxial cable is unbalanced; you will need a balin or a 1:1 transformer to go from balanced to unbalanced.

Note that driver impedances inside an antenna array usually end up *lower* than those values. They also must be carefully matched for best results.

The bottom line: use a hairpin loop for 300 ohms balanced or the pair of quarter-wave wires when you want 75 ohms balanced. Either way, a final matching will still be needed.

A six-element narrowband Yagi cut for 100 megahertz is shown in Fig. 5. Use quite *thin* but rigid conductors for the best narrowband gain. Something like *bare* 12 AWG solid copper house wire might be a good choice. To cut the antenna to your desired station, *divide* the frequency in megahertz by 100, and then *divide* all sizes by the resultant number. For instance, to pick up KDKB at 93.3 MHz, all element lengths and all spacings will get divided by 0.933. Note the inverse relationship: stations *under* 100 MHz need slightly *larger* antenna designs.

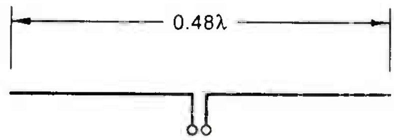
The directors should point towards your chosen station. Use a map for starters, and then try rotating a tad either way. Your beamwidth should be around thirty degrees, so pointing in just the right direction is super important.

Additional directors can, in theory be added, in a size progression. But all you gain is something like half a decibel per director, and the size does get out of hand real quick. And a careful match, or finding a local hot spot, or a tad extra height can often get you much more signal.

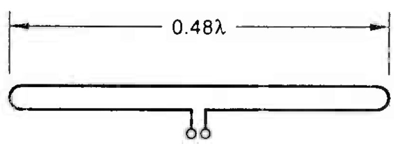
The theory behind a Yagi antenna? The optimum spacing is usually 0.2 wavelengths. The driver should be half a wavelength wide. The reflector should be around five percent longer, while the initial director should be five percent shorter. The rest of the directors should be progressively six, seven and, eight... percent shorter.

More on Yagi antennas appears in two ARRL publications, the *Antenna Handbook* and *Yagi Antenna Design*. Also see NBS technical note No. 688.

Close matching of an antenna to its transmission line is essential for the best gain. The simplest method



(A) An ordinary dipole has an impedance of a balanced 75 ohms resistive just below its resonance. But any thick conductors or nearby elements lower this resistance or add some unwanted series reactance.



(B) Folding a dipole into a hairpin loop will raise its input impedance by four times. The impedance just below half of a wavelength is a balanced 300 ohms resistive. Careful tuning is needed in the real world.

FIG. 4—FOLDING A DIPOLE can raise its resonant impedance by a factor of four.

All dimensions are shown in decimal inches. The antenna is shown top view, and assumes the station is horizontally polarized.

To cut your antenna for a specific station, divide the station frequency by 100 and then divide all sizes shown below by the same value.

For instance, a 93.3 Mhz station needs all the values divided by 0.933. A 104.5 Mhz station needs all of the values divided by 1.045.

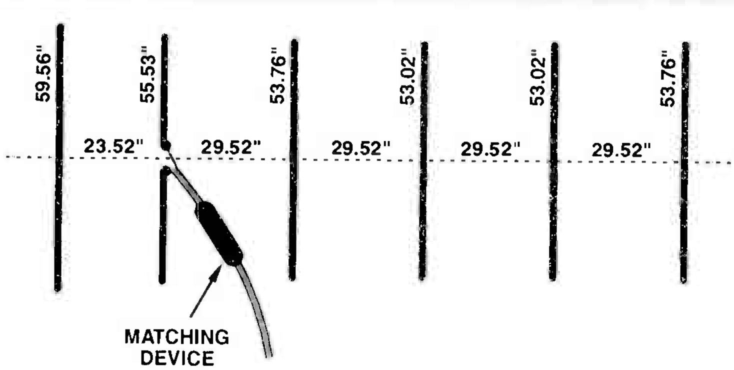


FIG. 5—AN INDOOR SINGLE-STATION long-distance FM antenna can be built using nothing but bare 12 AWG house wire. Here is one possible design. Note that the antenna size should be "cut" for your favorite station. Values shown assume an insulated boom or other supports. All elements must be very straight, rigid, parallel, and precisely centered. Contact a local radio ham for help in matching.

is called a *gamma* match, and it is done by just spreading the ends of a 300-ohm twinlead to tap maximum signal strength. Better methods appear in the books mentioned.

It would be real interesting to route both of your dipole rods straight into a VHF differential amplifier. Such an *antennafier* can greatly simplify tuning and matching. But a lot of black magic could be involved, so be sure to experiment.

Let me know all your experiences with any homemade ultra-range FM antenna designs. I'll try to publish the best of them.

New tech lit

A green *1991 Product Handbook* from *MX-Comm*. This little-known semiconductor house offers all sorts of exciting hacker chips, especially those involved with tone signalling, speech scrambling, cellular phones, and pagers. One real sleeper: MX-Comm's MX009 octal digital gain-controlled amplifier array. Lots of application-notes are also included.

Free engineering samples of its new 41VHS-1 humidity sensor have been offered on professional request from *Victory Engineering*.

Heartland America is yet another Distressed Yuppy Surplus direct-mail outfit. It has all varieties of high-tech goodies. Its latest new catalog does offer the first laser pointers that I have seen selling for less than $100.

RePlay and *Play Meter* are the two leading trade journals for the coin-operated video-game industry. While they mostly concentrate on the buying and selling of games and supply products, there are occasional technical articles plus repair books and videos.

If you are interested in starting up your own tech venture, be certain to check into my at long last available *Incredible Secret Money Machine II*. We have also begun shipping the latest *Hardware Hacker III* reprints with their newest updates. See my nearby *Synergetics* ad for more details.

A reminder here that lots of great technical downloads are available on *GEnie* PSRT.

As usual, we've gathered many of the resources mentioned together into either the *Names & Numbers* or the *Navicube Resources* sidebars. Do be sure to check these out *before* you use our no-charge tech helpline or call for a free hacker secrets brochure. **R-E**

GLITTER GLOBE

continued from page 40

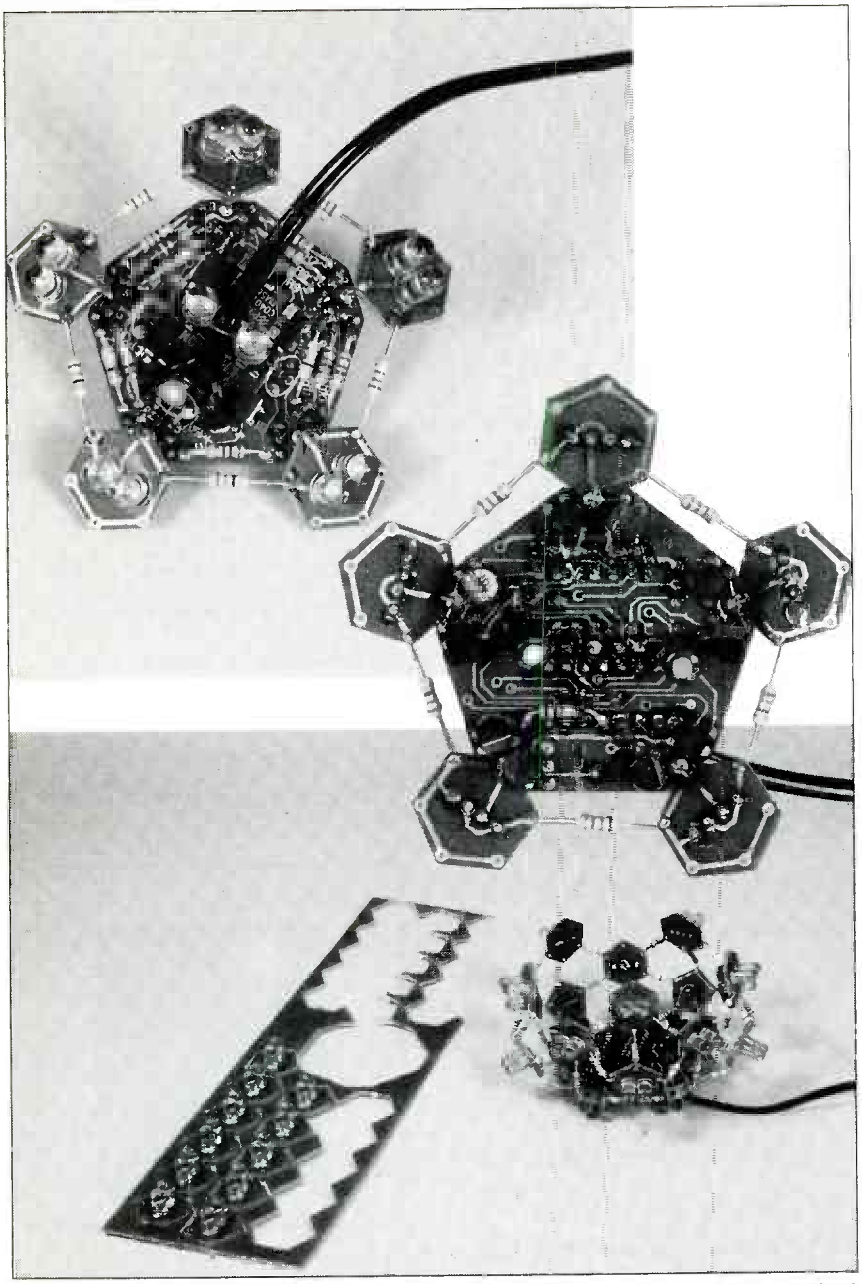


FIG. 10—BOTH SIDES OF THE CONTROL BOARD are shown with only level 1 attached (top and middle), and levels 1–4 have been added in the bottom photo.

After testing the controller board, assemble the five boards of the first level. (A "1" is etched on each of them.) Assemble the level-1 boards into a ring shape using resistors R14–R18, which should already be bent to the proper length—½ or ¾ inches (see Fig. 7). Creating the top ring in that manner will set the proper spacing for the rest of the globe. Leave the top hole on each level-1 board open (the hole farthest from the number etched on the inside surface), for connecting level 1 to the globe's control board.

Figure 7 is a "component map," showing levels 1–4, and how they connect together. All connections marked "J" are zero-ohm jumpers; all connections showing a resistor symbol must be 680 ohms, and all unmarked connections are structural components and can be made from anything you like (the kit includes additional 680-ohm resistors for use in these locations). Connect the level-1 ring to the control board as shown in Fig. 8; if you are using ¾-inch spacing, level 1 mounts as shown in Fig. 8-*a*; for ½-inch spacing, level 1 mounts as shown in Fig. 8-*b*. To connect level 1, install five 1-inch leads rising vertically from the control board. Then bend them to fit the level-1 ring as shown in Fig. 8.

Next add the level-2 boards. Each level-2 board connects to level 1 with one resistor (R19–R23) and one zero-ohm jumper. Solder the resistor and jumper to each level-2 board first, and then attach them to level 1. While building the globe, you'll begin to notice patterns. For example, after level 2 is complete each new board (except for level 7) connects to the previous level with two resistors (one structural only), and one zero-ohm jumper.

Figure 9 shows the rest of the globe (levels 5–7). Note that Figs. 7 and 9 both show the outside surface of the globe. The letters surrounding each half of the globe in Figs. 7 and 9 indicate the connections between the two halves. Install each level in order from 1 to 7 (even though we have shown the globe in two halves).

Layer 2 is composed of five-point boards, so, to make a sphere, keep the lead spacing of the resistors and jumpers attached to all layer-2 boards at ⅝ inch. It's a good idea to plug in the globe after each layer is installed to make sure all LED's are working. It's best to repair errors early before they become difficult to correct. Continue adding each layer and testing the globe until it's finished. Figure 10 shows a globe in different stages of construction.

When complete, the Glitter Globe forms a surprisingly sturdy structure, and you can hold it while it's operating. If the globe is dropped or crushed, it is a simple matter to bend it back into shape. With reasonable care, it will last for decades to come. **R-E**

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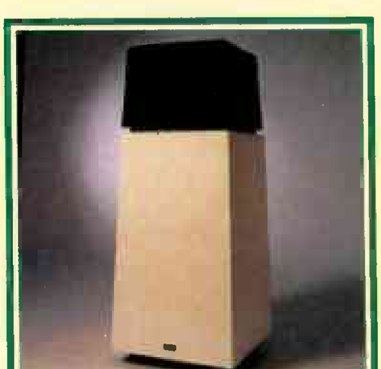

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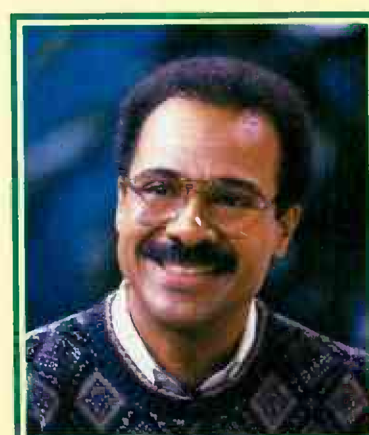

HOLIDAY SPIRIT

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DRAWING BOARD

Let's get back to our SSAVI descrambler.

ROBERT GROSSBLATT

Before we get into the nitty gritty of the SSAVI system, I have to take a few lines to make a few things clear. I've touched on them before, but it's important to repeat them. All we've gone into so far is gated sync suppression, which can be considered pretty unsophisticated these days.

The SSAVI system isn't the last word in scrambling but it's reasonably recent and it, or some variation of it, will be the scrambling system of choice for some time to come. That is true even if you consider only the economic side of changing scrambling methods.

I have no doubt that many cable companies use this scrambling technique, or at least something very similar. If that's true in your area, it would be a good idea to do some experimenting with the actual signal—hands-on experience is always the best. What you'll probably find out in the real world is that the system used in your area isn't an exact match for the one we'll be taking apart. The general principles might be the same, but the particular details will undoubtedly vary.

When the SSAVI system first started, there were some constants in the video signal that could be used to descramble it. Remember that the picture can be messed up in any one of three ways (see October's column for the details), and the instructions for the descrambler are transmitted somewhere in the vertical interval. The word "somewhere" is a late addition to the SSAVI system. When it first started, the descrambling information was always on the same line. That's where we'll start.

Once upon a time, the sanctity of the vertical interval was closely guarded by the FCC, but as alternatives to standard broadcast TV became more popular (cable, satellite, etc), more and more junk started to show up there.

When the SSAVI system started, lines 0 to 9 were left alone by a request of the FCC, but lines 10 to 13 were where the cable companies transmitted individual subscriber codes. Don't forget that there are unique ID numbers stored in an EPROM (or some other kind of memory) in the cable box. There's also logic circuits there to count the video lines, read the transmitted code, and match it up against the one stored in the box. This is a big thing for the cable companies because it prevents a New York box from being used in California. The scrambling is the same, but the codes are completely different.

The decoder circuitry is also controlled by this coding process because a match between the transmitted bytes and the ones stored in the box will enable or disable the decoder. That is true for both the premium cable services and the pay-per-view events.

That kind of coding might be important to the cable companies, but it doesn't mean anything to us. We can build an experimental descrambler without paying any attention to them.

Since the video can be transmitted with either normal or inverted picture information, one of the tasks that has to be done by the descrambler is to tell the rest of the circuit what has been done to the picture. The place to find that information was originally in line 20, but it has been moved around since the system became popular. As you can see in Fig. 1, the last half of the line will tell you whether the picture is normal or inverted. Remember that

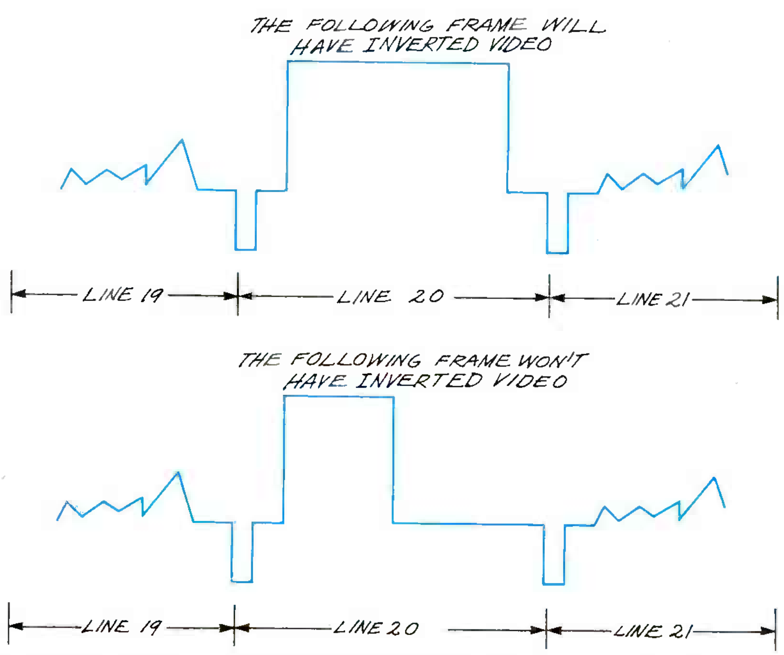


FIG. 1—THE LAST HALF OF THE LINE OF VIDEO will tell you whether the picture is normal or inverted. We're talking about the picture part of the line only.

we're talking about the picture part of the line only, and not the control section.

If the following field is normal, the last half of the line will be black, and if the picture is normal, the whole line is white. One of the things a decoder needs, therefore, is some way to detect the line and store the data it contains. The stored data is then used as a switch by the circuit to route the video through an inverter if the picture is being transmitted upside down.

This is pretty straightforward stuff. Since we're looking at only one piece of information, all we need is a place to store one bit of information. Your basic piece of cake. The circuitry needed to detect the data, however, is a bit more complex. We need a reference in the signal. So establish a zero point for a line counter, and some counting circuitry to keep track of which line is being received.

You might be wondering what we can count if the signal is being scrambled. But remember, that in the vertical interval (the first 26 lines of video), the signal is being sent in the clear.

Now that we have an approach to handling the possibility of an inverted picture, the last problem to tackle is the one of varying horizontal sync pulses. Sometimes they're there, sometimes they're absent, and sometimes they're not at the proper level. Anything that unstable is a pretty poor choice for a reference signal. So, to avoid a mammoth circuit design problem, the best way to deal with it is to scrap the transmitted horizontal sync (even when it's there), and come up with a way to generate the signal ourselves.

That can also seem to be an insurmountable problem but, just as in the case of the inverted picture, the answer is going to be found in the vertical interval. Once again, remember that the first 26 lines of video are sent in the clear and, even during the rest of the video frame, (no matter what's going on with the picture), the horizontal sync pulse is never inverted. It might be weak or missing entirely, but it's never upside down. That's important to keep in mind because if we generate our own horizontal sync, we don't want an upside down, positive-going sync signal present. If that was the case, the two sync signals would add together and cancel, which is not a good thing.

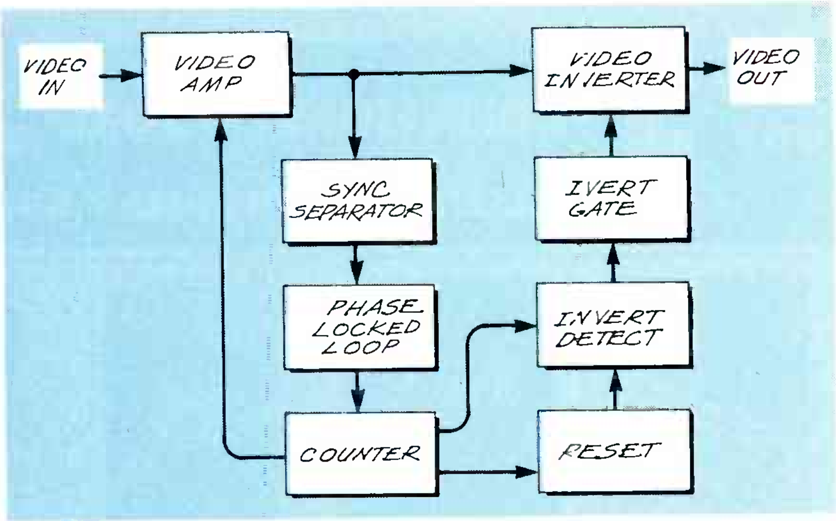


FIG. 2—THIS CIRCUIT WILL MAKE SURE the picture is always present at the output in a non-inverted state, and that it has horizontal sync pulses present at the right level and the right position.

We've talked about how to regenerate sync when the signal being received is unreliable. If you don't remember it or haven't read it, go back to October's column and review it. Basically, the approach is to take the horizontal pulses sent in the clear during the vertical interval and use them as the reference for a phase-locked loop that will supply the missing pulses during the rest of the video frame. If you've got twenty or so reliable pulses per frame, you can accurately generate the missing two hundred and forty or so for the rest of the frame.

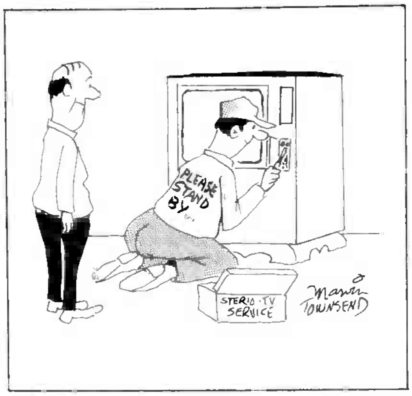
The block diagram of the circuit we need is shown in Fig. 2. In a nutshell, the job of the circuit is to make sure the picture is always present at the output in a non-inverted state, and that it has horizontal sync pulses present at the right level and the right position.

The scrambled video is fed to an op-amp and the output is sent to a sync separator—the same basic circuit that's found in every TV set in the universe. The sync pulses drive a phase-locked loop whose output is decoded to provide the missing sync pulses for the video lines outside the vertical interval (where most of the interesting stuff is found). These generated sync pulses are mixed with the incoming video and then sent, through a gated inverter, to the back of your TV set.

The gated inverter is controlled by a signal that tells it whether or not the picture portion of the video is upside down. The control signal is derived by watching the state of line 20, as we discussed before.

All this sounds incredibly complicated but, if you look over the block diagram, you'll see that it's just a collection of gates and counters—the same sort of stuff we've been messing around with for years.

The only box in the diagram I haven't explained is the reset circuit for the counter. I'll explain that in the next column but you should be able to figure out for yourself exactly what it is. If you get it right, you've got a good handle on the subject of video in general and scrambling in particular. If you can't figure it out, spend the next month getting ready by boning up on the essentials of basic video theory. **R-E**



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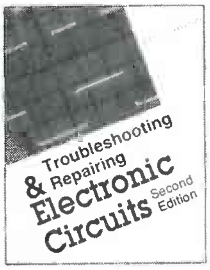

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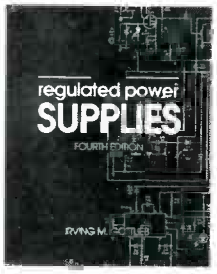

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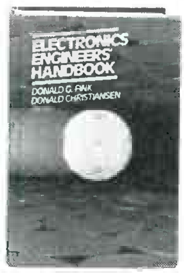

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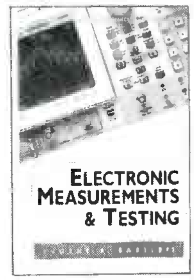

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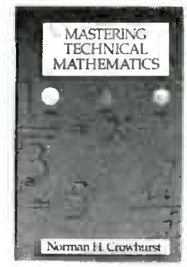

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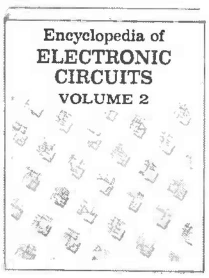

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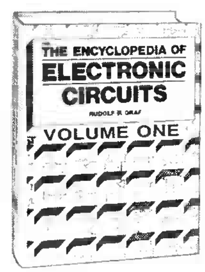

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For quick-reference and on-the-job use, this sourcebook puts over 1,300 state-of-the-art designs at your fingertips. From A (alarm circuits) to Z (zero crossing detector circuits) this compendium excels in content, scope, and design.
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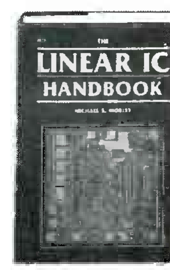

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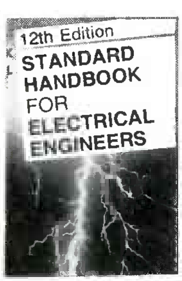

020975-XXX **$104.50**
The essential reference for all electrical engineers. Completely revised and updated, this classic handbook covers the generation, transmission, distribution, control, conservation, and application of electrical power.
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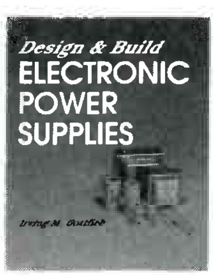

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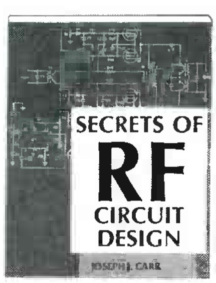
This guide brings you up-to-date on today's most advanced power supply circuits, components, and measurement procedures. Covers switching rates up to 3-MHz and higher as well as the 20-kHz standard. 176 pp.



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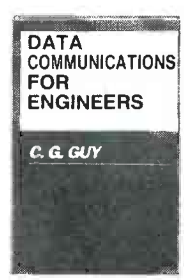

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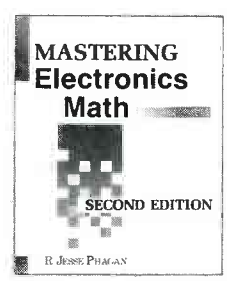

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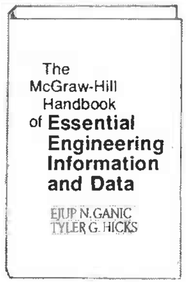

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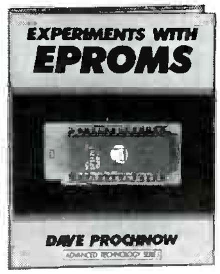

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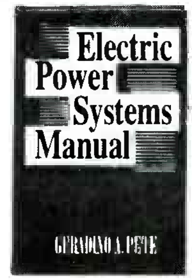

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Keep the lines clean and fault-free with this organized approach to power systems analysis. You'll apply theoretical concepts to the solution of every-day power systems problems with the help of this book. 288 pp., 150 illus.

050806-XX **$54.95**
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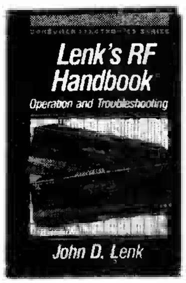

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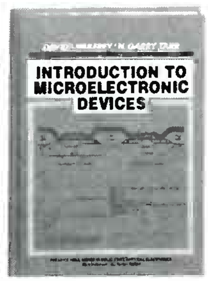
Packed with simplified, circuit-by-circuit troubleshooting examples, this handbook provides the practical know-how you need to operate and troubleshoot modern RF equipment. 352 pp., 150 illus.



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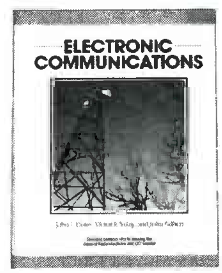

3365P **$24.95**
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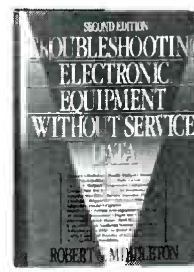

9290-XX **$36.00**
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AUDIO UPDATE

It's a matter of hear today, gone tomorrow

LARRY KLEIN

It's an unhappy paradox that at a time when music reproduction is approaching perfection, there is widespread failure in the music listener's ability to hear it fully. Four years ago I wrote in this column about the audiometric hearing tests given by the Audio Engineering Society at their 1986 Los Angeles convention. The more-than-200 AES members tested showed small but consistent hearing losses that exceeded those expected from the normal aging process. A wide variation of hearing thresholds was measured in the sensitive 3- to 6-kHz range with more than 10% of the respondents showing significant hearing loss at 4 kHz.

It's a sure bet that things have not improved any in the last six or seven years. In fact, from what I hear, the quantity and level of ear-damaging environmental sounds have escalated beyond reason. Under environmental sounds, I include everything from power mowers and blowers to live and reproduced rock music. Can anything be done to tame the wild decibels?

English ears

For some reason, many of the extensive research studies on hearing loss and music listening have been done in the U.K. Several years ago, two researchers at the University of Keele tested two groups of Staffordshire high-school students; one group had frequent exposure to loud music at rock concerts, discos, and through personal stereo headphones. The control group (I wonder where they found them) had little or no such exposure.

Although conventional diagnostic tests revealed no overall hearing loss, two problems did become evident with more precise techniques. There was evidence of the group's diminished sensitivity to a narrow band of mid frequencies and, surprisingly, a reduced ability to distinguish between adjacent musical pitches.

Environmentally engendered hearing loss is not limited to kids addicted to rock concerts, loud headphones, and killer car-stereo systems—all of which have been measured at noise levels over 110 dB. The older, if not wiser, generation is also surrounded by equipment that is not intentionally loud but just happens to be. I'm referring to a variety of home, yard, and recreational equipment. These include power tools (my radial-arm saw cutting through hardwood makes quite a racket!), power mowers, and leaf and snow blowers. Recreational vehicles such as outboard motor boats and snowmobiles, are also potent sources of the kind of sustained sound levels that can be particularly damaging.

In general, the rule seems to be that constant sound levels, particularly in a narrow band, are more harmful than louder intermittent sounds. In other words, if your sound-pressure level (SPL) meter needle seems stuck at the 90-dB level, the sound is likely to be far more damaging than if the needle is swinging wildly with occasional 100-dB peaks.

Since the ear-damaging effects of noise result from cumulative exposure over time, noise-dosage meters have been developed for industrial use. They average out the varying sound-pressure level to provide an equivalent continuous sound level, or L_{eq}. Such devices are analogous to the radiation-dosage meters that are supposed to keep workers in the nuclear industries safe. Experience has shown that some hearing loss will occur in 20% to 25% of workers exposed to the legally allowed limit of 90 dB (L_{eq} in dBa) for 8 hours. That is the sound level of heavy street traffic or a subway train.

MAXIMUM ALLOWABLE OSHA LEVELS

The Occupational Safety and Health Act (OSHA), which became law in late 1970, places limits on the noise conditions to which employers may subject their workers. The maximum allowable sound levels and daily exposure periods are given in the table. For industries that fall under the jurisdiction of the act, those limits have the force of law, and an employer is obliged to take corrective steps if it is found that any employee is being exposed to noise that exceeds the limit.

TABLE 1—MAXIMUM ALLOWABLE OSHA LEVELS

Exposure duration level (hours per day)	Maximum level (L_{eq} in dBA)
8	90
4	95
2	100
1	105
½	110

Damage report

Exactly how does hearing damage occur? Aside from eardrum rupture caused by a high-pressure pulse from a loud nearby sound, rapid pressure changes and diseases of the auditory nerve and central nervous pathways, the major area of damage occurs in the microscopic hair cells residing in the spiral-shaped cochlea of the inner ear. Dr. John Rosowski of Harvard Medical School has been investigating the problem. At relatively low levels of intensity, he says, damage appears to be proportional to the amount of energy entering the ear during a particular period of time.

But beyond some critical level of sound pressure, the hair cells become much more susceptible to trauma. With only a small increase in SPL beyond this critical point, the damage increases significantly and disproportionately.

The microscopic hair cells are the specific transducers that convert the vibrations in the inner ear to the electrical impulses sent to the brain. Each hair cell, which has a diameter about ⅛ that of a hair, is topped off by 20 or so stereocilia that resemble the bristles on a toothbrush. Scanning electron micrographs of sound-damaged microcilia show them bent, fused, and even missing. That results in a medical diagnosis of "nerve deafness," an irreversible condition.

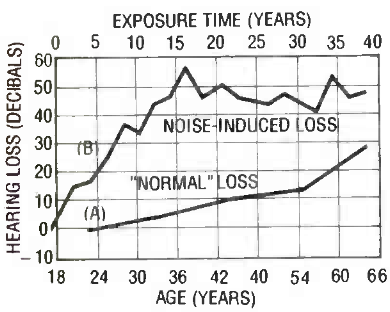

FIG. 1. LOSS OF HEARING is a natural result of aging (a), but a much more severe loss can result from long-term exposure to an excessively noisy environment (b). Both curves are at 4 kHz, but high-frequency hearing goes first.

In general, everyone who lives in a civilized (meaning noisy) environment is subject to some hearing loss over time. [See Fig. 1-a.] At first, the loss appears only in the upper frequencies usually reproduced by tweeters. In time, however, the loss progresses downward to the upper midrange frequencies that differentiate the sounds important to speech comprehension.

Now hear this

There is good evidence that individuals vary in their physical tolerance of loud sounds. Nevertheless, there are some ground rules that those who care about their hearing should follow. Since ear damage is cumulative, resulting in a gradual deterioration, sounds that are instantly heard as too loud—that cause ringing or other inner ear noises—should be avoided or at least diminished by placing damp cotton wads in the ears or by the use of more effective medically-approved ear-protection devices. However, loud, but not obviously excessive, sound sources, musical or otherwise, can also be damaging in the long run.

I have an audiophile friend who wears earplugs in the subway and in other noisy environments. Aside from the noise level in public places, you should consider ear protection when performing such activities as power-tool carpentry and lawn care. Even wads of cotton stuffed tightly in your ear canals will help. It's not just that you are saving yourself an immediate headache, but you might avoid a hearing-aid purchase 30 or 40 years from now. Don't be dumb today—and deaf tomorrow. **R-E**

EQUIPMENT REPORTS

continued from page 16

(5000 counts) signals with crest factors up to 3.0 can be measured. At full scale, a signal must have a crest factor less than 1.5 to be measured accurately.

The *HD160* offers impressive overload and safety protection. The voltage inputs can withstand up to 1000 volts AC or DC. Both current jacks are protected by fuses. An added safety feature protects the meter, user, and the device under test: When a probe is inserted in one of the current jacks and the function switch is set to a non-current mode, the meter's display will show an error message to warn the user.

The *HD160* is priced at $199. The capable, rugged high-quality meter will be appreciated by anyone who needs a DMM for serious professional use. **R-E**

COMING NEXT MONTH

The January 1993 Issue goes on sale December 3, 1992

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Keep informed on world events and learn RF construction techniques!

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Computers and Consumer Electronics

JEFF HOLTZMAN

Computers and consumer electronics are merging. Kodak and Tandy have added fuel to the fire with their recent introductions of Photo-CD and the Visual Information System (VIS), respectively. Photo-CD and VIS join CD-ROM Interactive (CD-I) and Commodore Dynamic Total Vision (CDTV) as the major attempts to put computer-like interactivity on a television screen, thereby capturing the hearts and minds—and pocketbooks—of noncomputerized consumers. VIS, CDTV, and CD-I are direct competitors; although similar in some ways, Photo-CD is really in a category by itself. (You might also want to keep in mind upcoming CD-based systems from Nintendo and Sega.) Photo-CD, CD-I, CDTV, and VIS all share the following in common:

- They are meant to be operated in the family room, not in a home office or corner of the bedroom.
- They use the home entertainment system (TV and stereo) for audio and video output.
- They emphasize early education, games, entertainment, and reference works.
- They use some form of CD-ROM as the primary delivery medium.
- They operate with simple infrared remote-control devices rather than computer keyboards.
- They are meant to appeal to less technically sophisticated consumers than computer users.
- They cost in the $600–1000 range.

To understand what each of these technologies has to offer and which is likely to be successful, let's summarize the key points of each.

CDTV This system descends from a long-time player in the personal-computer market. Starting way back with the Pet (in the late 1970's), and moving on through the C-64, and then to the Amiga, Commodore has always had a presence in personal computing. However, the company has never developed and executed a clear marketing strategy, hence has been a sideline player in most areas. The single exception is video production on the Amiga, where word of mouth and an unbeatable price/performance ratio have brought success. CDTV was introduced in the early summer of 1991, and has yet to achieve major acceptance. CDTV consists of a stripped-down Amiga 500 computer that has been specially modified to respond to commands from an infrared remote. The unit can be expanded to be a functional Amiga 500 by adding keyboard, disk drive, memory, and mouse. CDTV is sold by Commodore dealers.

CD-I Philips Consumer Electronics introduced the CD-I system in the fall of 1991 after several delays. It consists of a proprietary 68000-based system running a special version of the OS-9 operating systems. CD-I players are sold by consumer-electronics outlets. Approximately 65 CD-I titles are available, including several "celebrity" titles narrated by Danny Glover, Mia Farrow, Robin Williams, Jack Nicholson, Raul Julia, and Sir John Gielgud. One CD-I disc explores jazz giants such as Charlie Parker, Miles Davis, and Sarah Vaughn. Another disc explores the paintings of Rembrandt, and includes narration in seven languages (Dutch, English, French, German, Italian, Japanese, and Spanish). Titles start at $15; most are priced in the $20 to 40 range.

VIS Like Commodore, Tandy has been involved with personal com-

FIG. 1—KODAK'S PHOTO-CD puts 100 images in five different resolutions on a single CD-ROM disc. The player displays images on your TV screen and plays regular audio CD's through your stereo. A future upgrade will allow you to add audio and text to a Photo-CD disc, thereby allowing annotated, navigable slide shows.

puters since the earliest days. Its chief products include the TRS-80 series, the Color Computer, the Model 100/200 portables, a line of semicompatible PC's, and a line of fully compatible PC's. While never achieving great success in the business community, the PC compatibles have, nonetheless, held their own in the hobbyist/consumer market. VIS, is in fact, the "Wintendo" device discussed here in the October issue that has fueled the industry rumor mill for months. Unlike the other products discussed here, VIS software architecture is based on MS-DOS and Modular Windows, a ROM version of Microsoft's Windows optimized for use in a consumer (television) environment. Virtually all leading content developers, including Berlitz/Cruise Watch, Broderbund, Compton's New Media, Electronic Arts, Lucas Arts, Sierra, and others, are developing VIS titles; AimTech (IconAuthor) and OWL (Guide) have authoring systems, and Microsoft might have something up its sleeve in that area as well.

The DOS/Windows platform is good for several reasons. Content developers don't have to buy specialized and costly development platforms; standard PC's (with emulation boards) will do the trick. Porting VIS titles to and from other systems (e.g., MPC-compatible PC's) will be simpler than porting to or from a whole new architecture. Tandy's immense retail network ensures broad product availability and servicing. Zenith will also be selling VIS systems under its own brand name.

Photo-CD Kodak's technology is not currently designed to compete in the interactive-TV market, although it does have architectural features that might eventually provide interactivity. Photo-CD is designed to appeal to both professional and broad consumer bases. In the consumer world, Kodak hopes Photo-CD will supplement the family photo album and slide projector. In a professional setting, it will be useful for desktop publishing, corporate image databases, stock photo image bases, medical imaging, image archiving, and probably lots more. Photo-CD works like this: You take or mail a standard roll of print or slide film (up to 4 × 5 inches now, with larger formats coming) to a special Photo-CD processor, which then scans each image at five resolutions ranging from catalog-quality "thumbnails" (128 × 196) to publication-quality scans (6000 × 4000).

Depending on image size and content, it is possible to store about 100 images per disk in the standard consumer Photo-CD format. Other professional formats are available that allow storage of as many as 6000 low-resolution images (e.g., for image catalogs).

For family-room use, Photo-CD's can "play back" on special players (like that shown in Fig. 1) that also handle audio CD's, and on select computer-based CD-ROM drives (in particular, those claiming CD-ROM/XA compatibility). For computer-based use, Kodak has introduced low-cost PC- and Macintosh-based software packages for viewing images and getting them into standard bitmap formats such as PICT, TIFF, and EPS. Some commercial graphics editors (e.g., Publishers Paintbrush) already offer built-in Photo-CD support. Apple has announced that it will support the Photo-CD format directly in System 7 software, and via QuickTime (Apple's set of technologies and specifications for time-dependent data, (e.g., audio and video sequences). Kodak has also announced several advanced image-editing packages.

Photo-CD uses a multiple-write technology that allows several sessions to be placed on a single disc at several times. If you're interested in using multi-write capabilities on a computer, make sure your CD-ROM drive can handle it. Check Kodak's hotline at the number shown in the sidebar for information on compatible CD-ROM drives, processing centers, and software availability.

Resources

- **The Visual Display of Quantitative Information ($40), Envisioning Information ($48), Graphics Press, Box 430, Cheshire, CT 06410, (203) 250-7007.**
  CIRCLE 41 ON FREE INFORMATION CARD

- **Photo CD, Eastman Kodak Company, 343 State Street, Rochester, NY, 14650-0519, 800-242-2424.**
  CIRCLE 42 ON FREE INFORMATION CARD

- **Pro 16 Multimedia System, MediaVision, 3185 Laurelview Court, Fremont, CA 94538, 800-348-7116, 510-770-8600.**
  CIRCLE 43 ON FREE INFORMATION CARD

- **Visual Information System, Tandy Corporation, 1800 One Tandy Center, Forth Worth, TX 76102.**
  CIRCLE 44 ON FREE INFORMATION CARD

- **Compact Disc Interactive, Philips Consumer Electronics Company, One Philips Drive, P.O. Box 14810, Knoxville, TN, 615-475-0317.**
  CIRCLE 45 ON FREE INFORMATION CARD

- **Commodore Dynamic Total Vision, Commodore Business Machines, Inc., 1200 Wilson Drive, West Chester, PA 19380, 215-431-9100.**
  CIRCLE 46 ON FREE INFORMATION CARD

You want a revolution?

Will CDTV, CD-I, VIS, or Photo-CD bring about some revolution in the computer industry, the consumer electronics industry, or both? Are they destined for the junk heap, along with the early personal computers and dedicated video games of the 70's and 80's?

They're probably all headed for the junk heap sooner or later, but VIS and Photo CD have the best chance of survival during the next few years. Commodore's on-again/off-again marketing style inspires confidence in neither developers nor consumers. Philips' system has some technical advantages, for example hardware-assisted full-motion video based on the industry-standard Motion Picture Expert Group (MPEG) compression format. But even that is an add-on to the basic player. Development systems are proprietary, and there is a lack of broad industry support.

Photo-CD, on the other hand, offers immediate advantages to the computing community, especially desktop publishing and professional imaging concerns.

Broad appeal is problematic in that Photo-CD will be competing for consumer dollars against VIS and the other systems, all of which offer more general-purpose functionality.

It seems unlikely that people would want to buy more than one CD-based digital information appliance to connect to their TV's and stereos. Viewed in that light, Photo-CD might find it difficult to crack the home market. If VIS (or the other systems) could provide Photo-CD compatibility, then Kodak might lose the player battle but win the format/usage war. There is a lot of money to be made in processing Photo-CD's and in selling processing its workstations.

Photo-CD stands a very good chance of survival, simply because the publishing and imaging industries need it. The consumer market might go for it, depending on consumer awareness of the more general-purpose nature of VIS. I think Kodak would be smart to work with Tandy to ensure that VIS can play Photo-CD discs.

On paper, VIS looks like the safest bet among the interactive systems, both for developers and consumers. Like CDTV, VIS is really a general-purpose computer, albeit not in the present incarnation an expandable one. Because VIS is so closely related to the DOS/Windows platform, content developers can create and port titles at low cost and low risk. Assuming Tandy stays with the architecture, upgrading to higher-performance technology (e.g., full-motion video) should be fairly painless. Also, if anywhere near the number of promised titles actually materialize by the time VIS hits the market (presently aimed for Christmas 1992), Tandy will have a huge advantage.

VIS is extremely interesting. If it succeeds, it will mark the first success of a manufacturer in more than a decade in trying to penetrate the consumer market with a general-purpose digital information system. Computerphiles will probably view VIS as under powered. But with the Windows platform underpinning the system, there's lots of potential for growth.

I'm looking forward to hooking a VIS system up to my home-entertainment center. However, I know up-front that it's a throw-away purchase; the computer industry is still evolving so rapidly that VIS will be superseded by something. My hope is that, between now and obsolescence, my kids will get more from it than from a video game.

FIG.2—TANDY'S VIS or Video Information System runs a Windows-like operating system designed by Microsoft.

Product watch

I've looked at several multimedia upgrade kits over the past year, and have reached several conclusions. First, the base MPC specification is pretty low-fi. Nonetheless, results can still be startling. The best MPC upgrade kit I've found is from MediaVision. It includes what is currently one of the best CD-ROM drives on the market, NEC's SCSI-based CDR-83, along with the ProAudio Spectrum 16-bit stereo audio card, which has a built-in SCSI interface. The bundle also includes a slew of software, including Lotus 1-2-3, Compton's Multimedia Encyclopedia, a CD-based version of Sierra's King's Quest V, an authoring tool called Action from Macromind, and numerous DOS and Windows utilities for recording, mixing, and playing back sound and MIDI files. The utility software varies widely in quality, user interface, and usefulness, and it does not include a Windows-based MIDI editor, the major shortcoming of the package. The methods for configuring system interrupts and I/O port use is poorly documented, but once running, the package works like a charm.

Bookshelf

You probably take that voltage-versus-time display on the front of your oscilloscope for granted. What you might not know is that graphical displays of data were not even invented until the latter half of the nineteenth century, long after the invention of calculus. An Englishman, William Playfair, and a Swiss-German, J. H. Lambert, claim the honor of first publishing the many basic techniques of statistical graphics. You might also be unaware of what makes bar charts, time series, and other kinds of graphs really work. Why is that important? Because most technical professionals use spreadsheet, data-analysis, and visualization programs to analyze and display data, be it voltage, current, resistance, impedance, dollars, or other quantities. Computer tools give you lots of options for displaying your data using color, gray scales, hatching, perspective, and more. However, unless you're careful, you can get into trouble, graphically speaking, and thereby obscure your real message.

If you ever produce a chart or graph as part of your job, you absolutely must look at two books by Yale statistics professor Edward R. Tufte: *The Visual Display of Quantitative Information* (originally published in 1983), and *Envisioning Information* (1990). Alternate titles for those two exquisite works could be Volumes I and II of Use and (Especially) Abuse of Statistical Data in Graphical Form. In example after example, Tufte shows and tells why some things work and others don't, along the way exposing numerous misguided attempts at "improving" the presentation of statistical data. Tufte understands that effective communication of information involves carefully meshing form and content. He practices what he preaches. Beg, buy, or borrow copies of these works. You won't be disappointed. **R-E**

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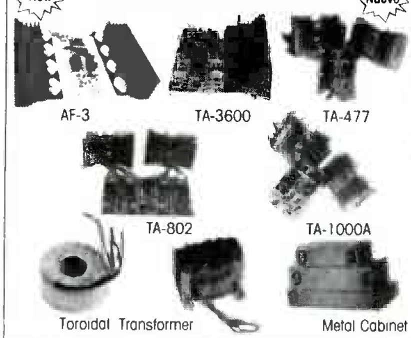

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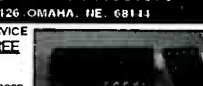


BY PURCHASING CABLE EQUIPMENT FROM MULTI-VISION ELECTRONICS THE PURCHASER AGREES TO COMPLY WITH STATE & FEDERAL LAWS REGARDING PRIVATE OWNERSHIP OF CABLE TV EQUIPMENT, IF YOU ARE UNSURE OF THESE LAWS CHECK WITH YOUR LOCAL OFFICIALS.

((FEATURING))
1. Call Identifiers
2. Power Antenna's
3. Mind-Machines
4. Wireless Cable Receivers T.V. 1.9-2.7 GHz
5. Stun-Guns
6. Surveillance
7. Dual Deck VCR

CONSUMER CORNER

New solid-state and digital TV sets, stereos, and videorecorders are tougher to repair than old-fashioned tube type sets and require special training for the service technician who works on them.

Only a few states have laws requiring competency tests for licensing technicians who repair consumer electronics, but fifteen years ago the International Society of Certified Electronic Technicians (CET) began its own certification program to qualify these technicians and those in industry. To carry the CET designation, technicians must have four years experience and pass a rigid examination on general electronics and a specific area of expertise such as audio or radio-TV.

Many consumers look for a Certified Electronic Technician in the shop when they need any electronic item repaired.

Free Consumer Checklist

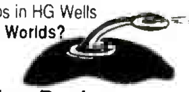
A consumer checklist for selecting a service shop is av-

Modern electronic equipment such as digital TVs or stereos should be repaired by specially trained people.

ailable free by sending a stamped, self-addressed envelope to: Checklist, ISCET, 2708 West Berry, Fort Worth, TX 76109. The list reminds consumers to check such items as "Does the business have the parts for your particular brand?", "Did you get an estimated price?", and "Did you check this company with the Better Business Bureau?"

AMAZING ✷ ELECTRONIC PRODUCTS and KITS

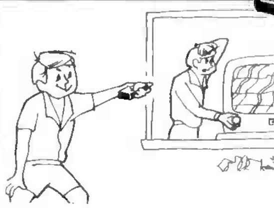
Remember those Martian Space Ships in HG Wells War of the Worlds?



MYSTERY
Levitating Device
Objects float on air and move to the touch. Defies gravity! Amazing gift, conversation piece, magic trick or great scientific project.
ANT1K Easy-Ass'y Kit/Plans $19.50

3 MILE
FM Wireless Microphone!
Crystal clear, ultra-sensitive pickup transmits voices, sounds to any FM radio. For security, monitoring children, invalids. Be the local DJ!
MVP1 Plans $7.00
MVP1K Kit/Plans $39.50

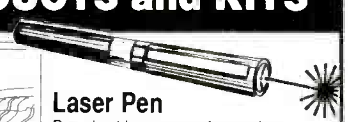
3 MILE
Telephone Transmitter!
Automatically transmits 2 sides of phone conversation to any FM radio. Tunable, easy-assembly PC board. Operates only when phone is in use.
VWPM7 Plans $7.00
VWPMK7 Kit/Plans $39.50



TV & FM Joker/Jammer
Pocket size device lets you remotely disrupt TV or radio reception. Great gag! Discretion required. Easy-build electronic kit. **EJK1KM $19.50**

100,000 V - 20' Range Intimidation Device!
Electronic module, may be enclosed for handheld, portable, or fixed uses.
ITM2 Plans (creditable to kit) **$10.00**
ITM2K Kit & Plans $49.50

READY-TO-USE, AUTOMATIC
Phone Recording System
Complete with extended play tape recorder & line interface switch. Automatically records both sides of conversation. *Check Local Laws on Proper Use!* Ready-to-Use System.
TAP20X System $149.50



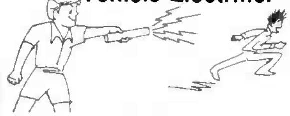
Laser Pen
Pen sized laser, great for movies, drive- ins, pointer. Ready to use, with batt's. **LAPN1 Laser Pen . $149.50**

Pocket Laser Kit
3mw or 5mw kits, with solid state 670nm diode. Caution, Class IIIa item.
VRL3KM 3mw Laser Kit ... $99.50
VRL5KM 5mw Laser Kit .. $119.50

MORE Laser Kits!
LAS1KM 1mw Laser, 632nm, HeNe Easy to Build Kit $69.50
LAS4KM 3mw Version, Kit $99.50

LATO5 Low Cost HeNe Laser Tube! .5mw Tube & Plans .. only $24.50
Other parts available separately.
Great Low Budget Science Project!

Shocker Force Field Vehicle Electrifier



Make hand shock balls, shock wands electrify objects, charge capacitors. Great pay back for those wise guys!
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Includes an in depth study of the techonology used and has troubleshooting hints.

Tri-Mode Tutorial.............$9.95
Includes a gate by gate study of the circuit and has troubleshooting hints.

Snooper Stopper...........$39.00
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Soder-Wick Facts # 22:

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