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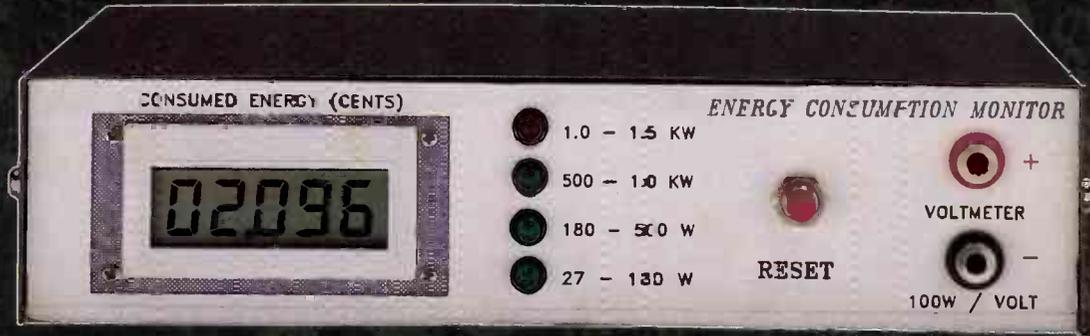
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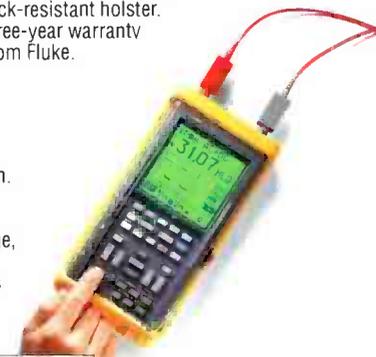
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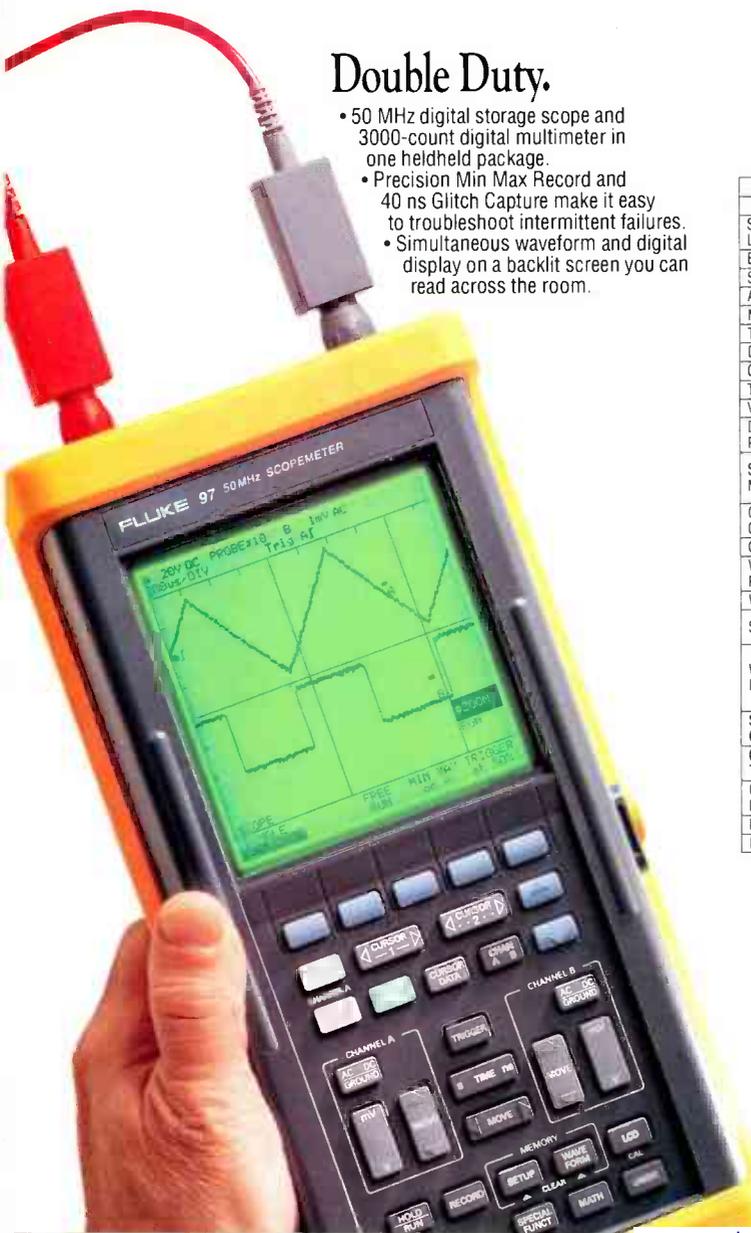


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How much power do your appliances use?
Paul Brule
- 37 VIDEO CAPTURE ON THE CHEAP!**
Build the Frugalvision image-capture board for less than \$100.
Gene Toner
- 47 THD ANALYZER**
Our inexpensive Total Harmonic Distortion analyzer tells you how good your amplifier really is.
John F. Keidel
- 53 BUILD THE BATTERY TOOL**
Get the most from your rechargeable batteries with this microcontroller-based discharger.
Fred Eady
- 63 ELECTRONIC FUSE**
Use this handy device when troubleshooting your next project
T.L. Petruzellis

TECHNOLOGY

- 60 AN INTUITIVE LOOK AT ELECTROMAGNETIC THEORY**
The final installment in the series examines the relationship between changing magnetic and electric fields.
William P. Rice

DEPARTMENTS

- 6 VIDEO NEWS**
What's new in this fast-changing field.
David Lachenbruch
- 22 EQUIPMENT REPORTS**
Fluke Model 12 handheld digital multimeter.
- 69 HARDWARE HACKER**
FM stereo chips, and more.
Don Lancaster
- 75 DRAWING BOARD**
Automotive charging systems.
Robert Grossblatt
- 78 AUDIO UPDATE**
Efficiency and speaker design.
Larry Klein
- 84 COMPUTER CONNECTIONS**
The latest news from the computer industry.
Jeff Holtzman



PAGE 47



PAGE 53

AND MORE

- 96 Advertising and Sales Offices**
- 96 Advertising Index**
- 12 Ask R-E**
- 14 Letters**
- 86 Market Center**
- 29 New Lit**
- 24 New Products**
- 4 What's News**

ON THE COVER



As the holidays approach, the last thing anyone wants to do is spend money unnecessarily. This month, we have two projects that just might help save money. You might be spending more than you should on your electric bills, due to power-guzzling appliances. Find out just how much it costs to run your household appliances with the Energy Consumption Monitor featured on page 31. To further pay its keep, the monitor doubles as a power meter when connected to a DMM. Then there's the Frugalvision—the poor man's video-capture board. It costs less than \$100 to build this image-capture board for your PC, significant savings over similar commercial products. Turn to page 37 for details.

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WHAT'S NEWS

A review of the latest happenings in electronics.

Visible red laser diode

A visible red semiconductor laser diode developed by researchers at Sanyo Electric Company, Ltd. (Tokyo, Japan) has a shorter wavelength—635 nanometers—and higher power—a maximum output of 33 mW—than any previous red laser diode.

Because red lasers are visible to the naked eye and are capable of focusing on an extremely tiny area, they can be applied to a wide range of information-processing equipment. The reduction in frequency oscillation length along with the increase in power will allow the semiconductor laser to replace helium-neon lasers in such areas as long-playing optical discs, laser printers, and high-speed, high-accuracy scanner systems used in retail stores.

The use of computer-simulation techniques, combined with a number of technological innovations, made the breakthroughs possible. An exclusive Sanyo structure, as well as tilting the semiconductor substrate during crystal growth and other crystal-growth-enhancement techniques were key to the process, reducing the output "kink" at higher power settings, which was a problem with previous applications of the technology. The newly developed semiconductor laser diode has been designed to operate continuously at temperatures up to 45°C.



A VISIBLE RED SEMICONDUCTOR laser diode developed by Sanyo has the shortest wavelength and highest power output of any such device, which might allow it to be used instead of the currently used helium-neon lasers in high-density optical discs and measuring instruments.

VCR-quality TV over phone lines

Using a new, experimental Bellcore (Livingston, NJ) technology, VCR-quality television, voice, and data can be sent simultaneously over a single copper telephone line. Asymmetrical digital subscriber line (ADSL) technology, using digital signal processing (DSP) techniques and experimental very-large-scale integrated (VLSI) circuitry, can expand the transmission capacity of today's copper-based telephone network. DSP raises weak transmissions to acceptable levels and VLSI circuitry allows that processing to be done using a few specialized high-speed microchips instead of requiring large, expensive computers.

ADSL technology is proposed primarily for the "customer loop" that links residences and businesses to the central switching office. Even though future telecommunications systems are generally expected to be based upon fiber-optics technology, a large percentage of the customer loops are still copper-based. According to Bellcore, ADSL can serve as "an interim technology that can link fiber and copper telecommunications facilities" and provide customers with a sneak preview of "information age" services—including access to library data bases, shop-at-home services, and long-distance "video learning." While ADSL is not intended to take the place of future fiber-optic networks, on the short term it can provide enough capacity for customers to be able to receive VCR-quality video along with a regular phone call. Bellcore has already developed an algorithm for the real-time compression of video signals within the capacity of an ADSL line. Customers could also use ADSL to transmit low-speed data from their PC's and fax machines or to access data banks. Those services could be provided without the expensive conditioning of lines or installation of circuit repeaters now needed to get similar services over the already-existing copper lines.

Improved current-carrying ability of superconducting crystals

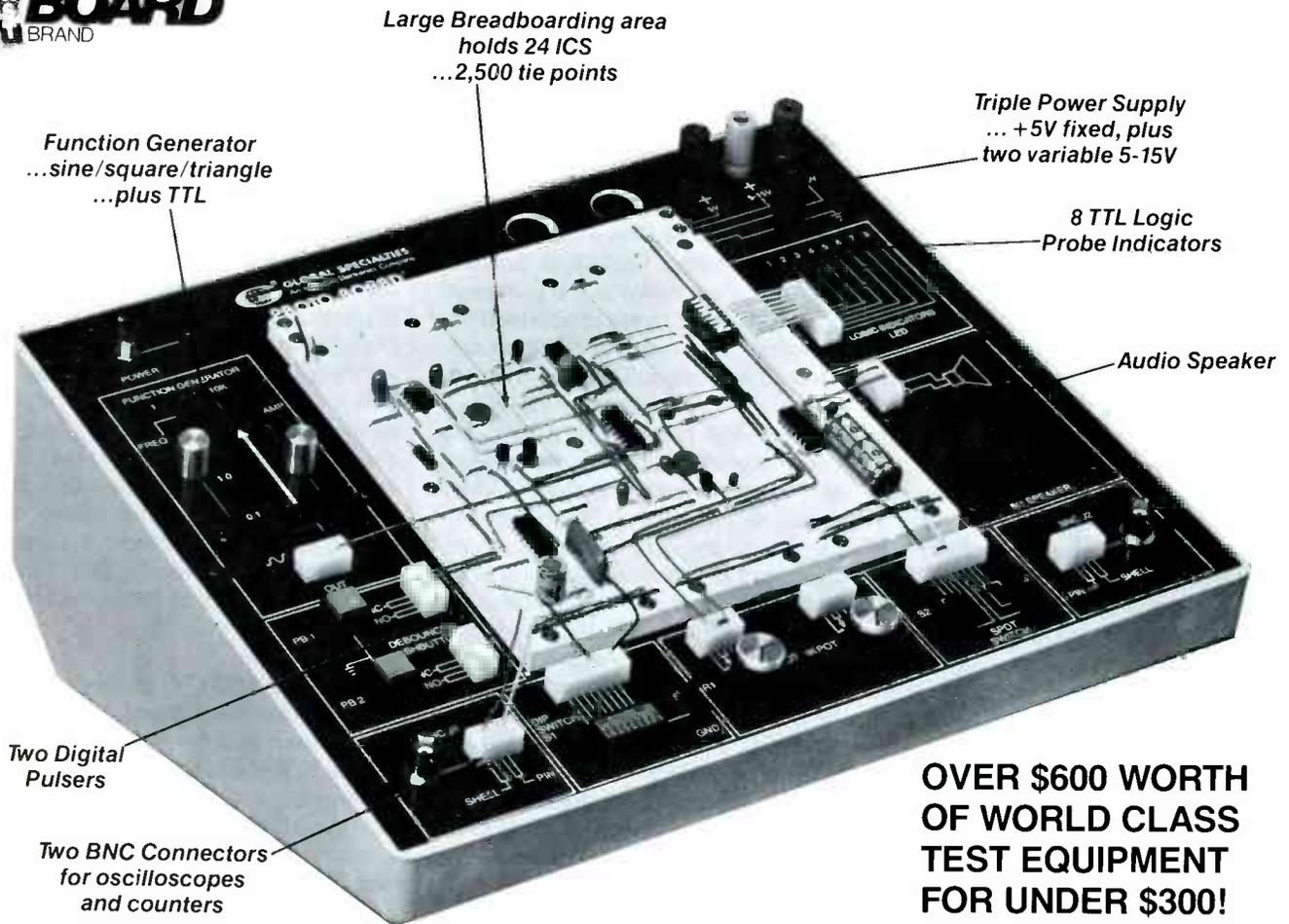
In a collaboration between scientists at IBM Thomas J. Watson Research Center (Yorktown Heights, NY), Oak Ridge National Laboratories (Oak Ridge, TN), Argonne National Laboratory (Argonne, IL), and the Iowa State University in Ames, IA, the current-carrying ability of single crystals of the high-temperature superconducting material known as yttrium-barium-copper oxide has been significantly improved. The advance might one day be used by scientists to make powerful, compact superconducting motors, generators, and magnets from the materials.

The technique consists of the deliberate, controlled introduction of defects into crystals of the superconducting material by bombarding them with a beam of very energetic, electrically-charged atoms of tin. The defects cause an increase in the maximum current that a superconductor can sustain, particularly in external magnetic fields, by "pinning"—preventing the motion of magnetic-field lines that would otherwise produce electrical resistance. The researchers discovered that the presence of those defects resulted in values of the critical current density (a measure of the maximum current that the superconductor can sustain) that are the highest ever observed for yttrium-barium-copper oxide bulk material at high-temperatures and high magnetic fields. At liquid-nitrogen temperature (77 K or minus 320°F) the critical current density was 450,000 amps per square centimeter in a magnetic field of 1 Tesla. As the heavy-ion bombardment was increased, the critical current density continued to increase as well.

The most practical projected use of the bulk material would be in superconducting wire that would use the material in the form of polycrystals, although further work is needed to make the current carrying capacity of yttrium-barium-copper oxide in polycrystalline form.

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DECEMBER 1991

VIDEO NEWS

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

DAVID LACHENBRUCH

● **Widescreen fever spreads.** If there was a major theme at the biennial International Audio-Video Fair in Berlin, it was widescreen TV with a 16:9 aspect ratio, as opposed to the conventional, squarish, 4:3 ratio. As satellites beamed down 16:9 programs in Europe's D2-MAC extended-definition system and in the compatible HD-MAC high-definition format, a half-million fairgoers were deluged with widescreen pictures of all kinds. The only thing that all of those TV sets had in common was that the screens had a 16:9 aspect ratio. Some were in high-definition HD-MAC, some (via tape) in Japan's Hi-Vision format, some in widescreen MAC, and others in standard NTSC or PAL with the top and bottom of the picture sheared off to obtain the correct aspect ratio.

The object lesson learned at the Berlin show is that the average person can't tell the difference between all the different formats. At normal viewing distance, it was extremely difficult to tell the difference, raising questions as to whether widescreen had more appeal than HDTV.

While the original widescreen sets introduced in Europe by Thomson Consumer Electronics under the Thomson, Nordmende, and Telefunken brands, were 36 inches in overall diagonal and used direct-view picture tubes (actually 34 inches in viewable diagonal by American measurements), the high cost of such sets—\$5000 and up—prompted the early introduction of sets with smaller screens. Presumably, Thomson already was feeling the effects of consumer resistance. As one show attendee put it, "The choice is between buying a widescreen TV and a used car."

Thomson thus introduced new sets with picture tubes measuring 32 and 28 inches in overall diagonal measurement (30 and 26 inches in American "viewable diagonal" terms) at lower prices. At the same time, Philips announced 46-inch projectors in the widescreen ratio at about the same price as Thomson's

36-inch direct-view sets. While some 20 brands showed widescreen sets, not all manufacturers were enthusiastic. Matsushita (Panasonic), Mitsubishi, and Sony said that their demonstrations were just to prove that they had the technology, but they would not offer sets until they were convinced that there was sufficient widescreen programming available. Nevertheless, all the major European TV makers—including Grundig, Nokia, Blaupunkt, and Metz—joined in quoting prices and delivery dates.

● **Questions remain.** While European TV manufacturers were pushing widescreen sets, the entire issue of HDTV remained tied up in politics. Backed by set makers, the European community was trying to adhere to its schedule of converting all direct satellite broadcasts to D2-MAC in anticipation of moving later to HD-MAC. But satellite broadcasters, enjoying good viewership in PAL, were reluctant to spend the money to add MAC broadcasting—not to mention complete conversion to the new system. European authorities were preparing to defray, or cover completely, the costs of adding D2-MAC transmissions and to require simulcasting in both PAL and MAC systems for a time, with the deadline for broadcasting in PAL coming in 1994. But at the time of the Berlin fair, nothing had been settled, and set manufacturers were pushing widescreen and HDTV sets on the basis of speculation.

● **PALPlus.** Until HDTV comes along, most of the European community has agreed on a system for widescreen TV called "PALPlus." It's an enhanced-definition TV system with the added ability to send a widescreen picture in full definition. Under the PALPlus system, when a PAL TV station is transmitting a widescreen program, it changes the material to a "letterbox" format, which in the standard PAL format would have only 432 lines instead of the normal 576. But the vertical information that is lost is added to the black bands above and

below the letterboxed picture. A separate signal, sent during the vertical blanking interval, tells the receiver that a widescreen signal is being sent. A standard PAL picture will be received on an ordinary set (a letterboxed picture with black bands above and below the transmitted material), but a PALPlus receiver will receive a full-definition, screen-filling, widescreen 16:9 picture.

● **Interactive TV.** Interactive Network, backed by NBC, Cablevision Systems, and others, made its debut this spring in California and plans to go nationwide this year. The network allows viewers to play along with game shows and compete for prizes. The games are carried on the Public Broadcasting System's vertical blanking interval. Homes equipped with a \$400 control unit and paying \$15 monthly can participate via a wireless handheld terminal. At the end of each interactive show, the stored data from the home unit are transmitted via a Tymnet phone circuit to Interactive Network's central headquarters, and results of the contest are displayed on the home unit a few minutes later.

● **Bullish HDTV study.** As a counterpoint to the many studies that have shown that the public can't recognize HDTV and doesn't care, a survey made by HBO two years ago has now been released. That survey, covering nearly 600 viewers in Kansas City, indicates that HDTV could win 75% of the replacement TV set market for main household TV's, even if the price is 2½ times that of a conventional set. In contrast to other studies, which show the widescreen ratio of HDTV sets to be more of an attraction than high definition itself, the HBO study found that most viewers didn't notice the wide aspect ratio or comment on it. It also showed that viewers like the big screen but not the "big box" it must be wrapped in. HBO forecast that HDTV sales will reach 10,000,000 sets as \$1 billion by the year 2000. **R-E**

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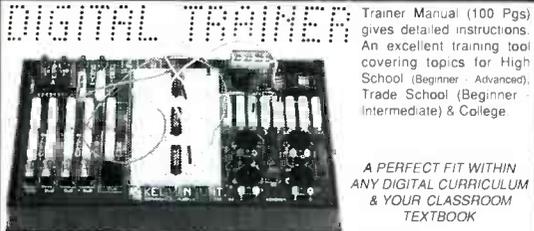
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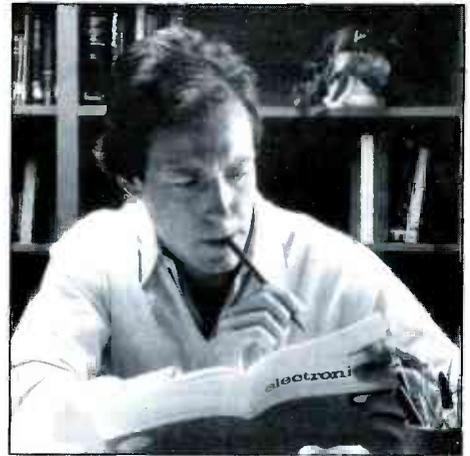
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COMPATIBLE CONFUSION

I'm thinking of buying an IBM-compatible computer but there are so many models available I'm not sure which is the right one for me. The ads are confusing because I can't find a clear explanation of what the difference is between 286, 386, 386SX, and 486 models. I also don't know how to tell which are faster than the others.—J. Behrman, Tampa, FL

Some years ago, when IBM was the only supplier in town, it was easy to keep track of what models were available and which ones were faster than others. As soon as the clone makers got into the act (and the "compatible" makers like Compaq and others), things started to get a bit more confusing. Besides making the market a bit more competitive, all the other manufacturers added improvements to try and set their machines apart from the others.

Let's start at the beginning.

The original IBM PC's were based around Intel's 8088, a microprocessor that dealt with data 16 bits at a time. The problem with it was that it had only eight data lines, so 16-bit data had to be taken in two bunches, eight bits at a time. This basic design decision made the printed circuit boards simpler but it also created a real bottleneck when computers built around the 8088 actually had to do 16-bit work.

The introduction of the 80286 came with IBM's AT-class machines and they marked a real improvement in speed and power. The 286 was a true 16-bit microprocessor, and the early ones ran at a clock speed of at least 6 MHz, as compared to the 4.77-MHz clock speed of the original 8088 chips.

As the market got more competitive, Intel licensed several other semiconductor manufacturers to manufacture 8088's and 80286's. It wasn't long before 8088's were available that could run at 10 MHz and 80286's appeared that could run as fast as 20 MHz. These faster chips were used by everyone except IBM

for reasons that are as mysterious to me as they are to you. That was also about the time that IBM's share of the market started to drop as well.

The next player to enter the field was the 80386. This was a true 32-bit microprocessor that ran at clock speeds as fast as 20 MHz. It wasn't long before 33-MHz chips hit the market as well. Since Intel was the sole supplier of 386's, they were a bit pricey, so they came out with the 80386SX—a chip that dealt with 32-bit data internally but only had sixteen external data lines. Similar in operation to the 8088, it took in 32-bit data in two 16-bit pieces, which caused similar speed bottlenecks as before. But it was cheaper.

The 80486 is an improved 80386. It deals with data in a much more efficient manner and has an integral math coprocessor. There's talk of an 80486SX which, as far as I can tell, is going to be a crippled version of a true 486 since it won't have a math coprocessor built in and may run a bit more slowly. In order to understand which microprocessor runs faster than another we have to put all this in perspective.

There are three things that determine how fast a computer can run: The first is the amount of horsepower, or the basic clock speed; the second is the size of the tires, or how many bits it can deal with at one time; and the third is how well the engine is tuned—or how efficient the instruction set is. A 20-MHz 286 will outperform a 16-MHz 386SX in terms of speed, but the 386SX has an enhanced instruction set that will let it do things like multitasking.

What you should buy depends on what you want to do. As things stand now, 8088-based computers are dinosaurs and the only reason to even consider buying one is that they're really cheap. But even that's not completely true because a computer has a lot more stuff in it than just the motherboard, and the overall cost of video, disk drives, and other peripherals is going to be more or less the same regardless of what you have

as a microprocessor.

If you're like most computer owners, your main use for the machine is for word processing, database stuff, and other things like games, so the best overall choice is a fast 286-based computer. It will outperform a slower 386SX and will also be less expensive.

If you're planning on doing CAD or lots of Windows-type graphics, you should look at a 386, a fast 386SX, or even a 486. You're the only one who can decide what you need but don't be taken in by the argument that a 286-based computer is going to be obsolete tomorrow or any day soon. Remember that word processing and other basic computer uses were around and thriving before the 286 (or even the 8088, for that matter) ever appeared on the market.

CABLE ID

I'm in the audio business and most of my work involves installing mikes, cables, amplifiers, and speakers for live events. One of the biggest headaches I have is keeping track of which cable goes where. Even though I've worked out a good marking system over the years, mistakes are made on nearly every job. Do you have a small, handy circuit that will make it easier to identify cables? Some of the runs are over a hundred yards long.—D. Andrews, Sandy Hook, NJ

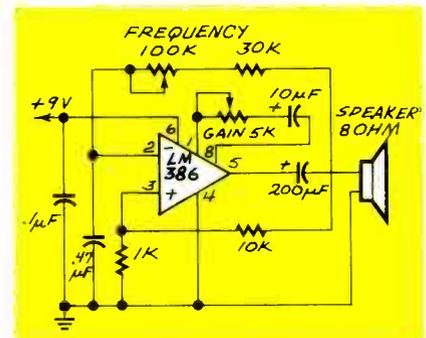


FIG. 1—TO TRACK CABLES electronically, you can use this circuit. The LM386 is set up as a simple oscillator and the potentiometers adjust the frequency and gain.

The problem with color coding wires is that there are only so many colors, it's hard to see them in the dark, and after a while the cables get so dirty you can't see the colors anyway. What you need is some way to track them electronically. I've had the same problem on various occasions and the answer is yes, you can use the same handy dandy circuit I designed for myself.

The schematic is shown in Fig. 1 and, as you can see, there's no gee-whiz stuff in the circuit at all. The LM386 is set up as a simple oscillator. Two potentiometers are used to adjust the frequency and the gain. You can build the circuit using any technique from point-to-point wiring to a printed circuit board. The best part about it is that all the parts should cost less than five bucks and you can get every one of them nearly anywhere.

Basically the circuit generates a tone (with an adjustable frequency and level), that can be fed directly into a cable or, as shown in Fig. 1, into a speaker. If you're troubleshooting a cable with bare wire ends, you can hook the output of the circuit directly to the wire, and an amplifier of some kind at the other end of the cable will reproduce the tone. When dealing with a cable that already has a mike on it, use the speaker as shown in Fig. 1, secured to the mike with a rubber band, and feed the tone in that way. Then, at the other end, you'll be able to identify which cable has the tone on it. I usually use several of these tone-generator circuits, each set to a different and discernable frequency, so I can trace several cables at once.

I've been using this circuit for years and have never had a bit of trouble with it. The oscillator is self starting and it will work for a long time before you have to change the battery.

NO NEED FOR COLOR

I recently got some software that I have to use for work but it was designed to work in color and I only have monochrome video on my computer. I don't really feel like spending money on color since this is the only thing I need it for. Is there some way for me to emulate color with my setup? I have a 286 AT with a Hercules-compatible video card.—B. Fish, Anawana, NY

There may be a way to do what you want but it all depends on the kind of video the software needs to work. There are several public domain programs around that will let you run some CGA stuff on some Hercules-compatible cards. But the key word here is "some."

I know for a fact that you'll find one of these programs, SIMCGA, on the RE-BBS (516-293-2283, 1200/2400, 8N1). There are other programs as well, and a tour of IBM bulletin boards (or services like the Source and Compuserve) will undoubtedly turn up other ones as well. There's no way I can tell you whether they'll work on your system with your software since there are just too many variables.

How successful you'll be depends on how close your video BIOS is to the original Hercules BIOS, how the video memory is organized on your card, how your software writes to the screen, and so on. The only thing you can do is to download some of these emulation programs and try them on your computer.

Before you get started on this, however, remember that every one of these programs is designed to emulate CGA stuff and that's all. If your software does EGA or VGA color, you're probably out of luck. I go up on the boards fairly often and don't remember ever seeing EGA-to-Hercules emulation software. I'm not even sure it's possible.

WHAT IS THD?

I've been shopping around for a new stereo amplifier, and I noticed something referred to as THD. I'm not sure what THD is, and what to look for when comparing THD ratings. Can you help me out?—R.V. Wendel, New York, NY

An "ideal" amplifier would exactly reproduce the input signal, amplified, at the output. However, you'll find that "real" amplifiers tend to add a bit of their own harmonics to the output signal. THD, or total harmonic distortion, is measured as a percentage of the input signal, and it's the summed levels of all the added harmonics. Although you should look for as low a THD rating as possible, the final decision should be made after you hear how the amplifier sounds. For more information on what THD is, and how you can measure it, see our article on page 47. **R-E**

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DEBUG THE PRINT-SCREEN INDICATOR

There are a couple of bugs in the "Software Solution" for the print-screen indicator (*Ask R-E*, **Radio-Electronics**, September 1991), one mine, and one yours. First, DEBUG needs to be told about the IN file, or nothing happens. When the IN file is ready, enter at the DOS prompt: C>DEBUG<in.

Second, the indicator can conflict with other resident programs, such as clock displays, that use the upper right corner of the screen. The fix is to retire to a neutral corner by changing some of the numbers. Use the bottom three rows of this table to pick up new values to replace [009D], [009F], [809D], and [809F]:

Upper Right: 009D 009F 809D 809F
Upper Left: 0001 003 8001 8003
Lower Right: 0F9D 0F9F 8F9D 8F9F
Lower Left: 0F01 0F03 8F01 8F03

You might want to change the names to something like INLR and PSL_LR.COM, to keep track of where the indicator goes. To be silly, you could even run more than one version at a time, but each one takes 416 bytes of memory.
JOHN SPRUNG
San Pedro, CA

FUEL CELLS REVISITED

I found Ralph Hubscher's article on fuel cells (**Radio-Electronics**, June 1991) to be extremely interesting and refreshing.

Interesting from the standpoint that, as an electrical engineer and sometimes teacher, I have had a deep interest in fuel cells for over 30 years. When teaching about battery systems in electronic courses, I have always included a synopsis on fuel cells. The students' initial blank faces and subsequent incredulity that something like this actually exists never cease to amaze me. It appears that the fuel cell has gone completely over the heads of the general public.

Refreshing from the standpoint that someone has finally opened the

door to some home experimentation. With the pressures growing for electrical vehicles and the proliferation of equipment requiring batteries, there is no doubt in my mind that the 21st century will be known as the "electric" century and that the fuel cell—the best-kept secret of the 20th century—will play an important part.

In closing, I would like to comment on Mr. Hubscher's reference to fuel cell and hydrogen costs being a drawback. Allis-Chalmers' extensive work on fuel cells in the 1950's, as well as Con Ed's in the 1980's (*IEEE Spectrum*, December 1983), proved that the fuel cell is cost effective. Also, much development work has been done on hydrogen generation and storage. I'm sure a nudge here or there would bring this extraordinary source of power to fruition.

Again, thanks for a great article!
PHILIP A. BLOCK
Lithonia, GA

ELECTROMAGNETIC THEORY

I enjoyed William P. Rice's series of articles called "An Intuitive Look at Electromagnetic Theory" (**Radio-Electronics**, August, September, October, and November 1991). Although it is heavy reading, it provides a basis for understanding electromagnetic waves. Articles like those are a necessary part of refreshing our minds and keeping up to date. I am an electrical engineer who uses **Radio-Electronics** to help keep me up to date.

R. MICKLEBOROUGH
Eston, Saskatchewan, Canada

QUESTIONS AND ANSWERS

There are times when *Ask R-E* cannot fully answer a question. If you were to publish the writer's address, perhaps some of the readers could write to them, and possibly shed more light on a subject than the person answering for **Radio-Electronics**.

No one person can know all the answers to every question. An example is the 8052-Basic question from D. Nikolaidis of Florida (**Radio-Electronics**, October 1991). I would have

written to him about addressing in small processors. Intel CPU's mostly jump to address 00 on turn-on. So, if he can't start his BASIC-52 EPROM's addressing at 00, he should address the EPROM at some even boundary such as A000 and then locate a small PROM at address 00 with the instruction "jump to A000" (C3 00 A0). BASIC will then start at turn-on. BASIC-52 is in the public domain and can be downloaded from Intel's RBBS (602-554-8167).

JOE KISH
Sheridan, OR

BINAURAL REMEMBRANCES

The article, "Binaural Basics" (**Radio-Electronics**, October 1991) reminded me of some work I did in the early 1960's. In the days before small, inexpensive audio delay lines, I constructed a poor-man's audio frequency delay line out of 25 feet of 1/4-inch neoprene tubing, with an ear phone on one end and a ceramic microphone on the other. All of this was put into a bud box with a 40-dB audio amplifier.

With the output of my SSB transmitter driving one side of my headset, and the other side being driven by the delayed version of that signal, the most amazing thing happened. Since no SSB station is ever on frequency, in my mind's eye, everyone on the air had their own space—even the noise had a space. I was able to literally move people out of the noise by simply tuning the receiver and changing their pitch. When receiving conditions were particularly poor, this scheme made quite a remarkable difference.

GLEN A. WILLIAMSON
Raleigh, NC

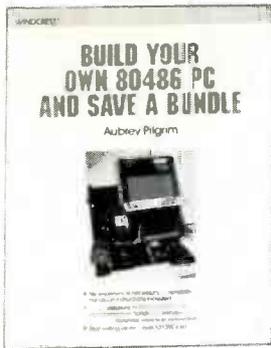
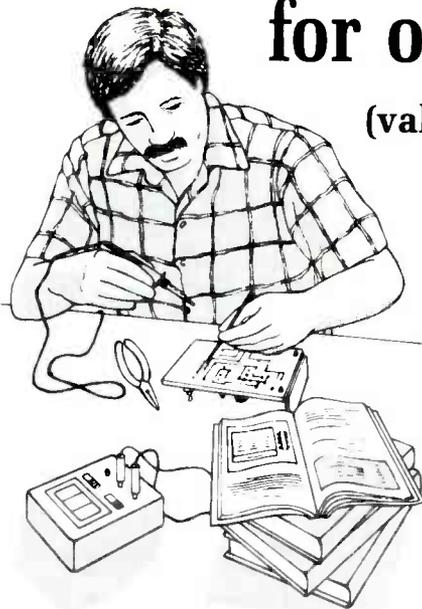
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I would like to make some comments regarding the discussion of fuse selection for speakers that appeared in Mark A. Vaught's article "Speaker Protection" (**Radio-Electronics**, August 1991).

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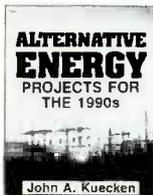
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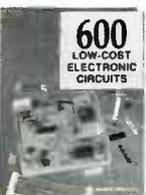
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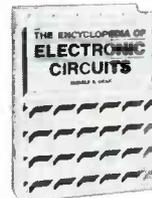
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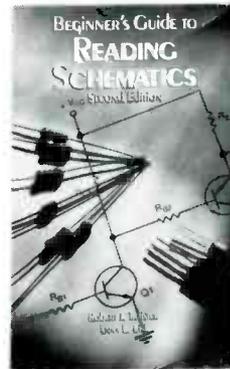
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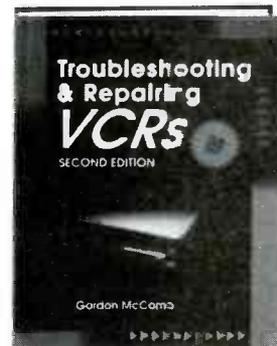
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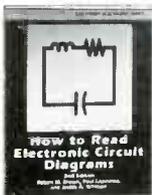
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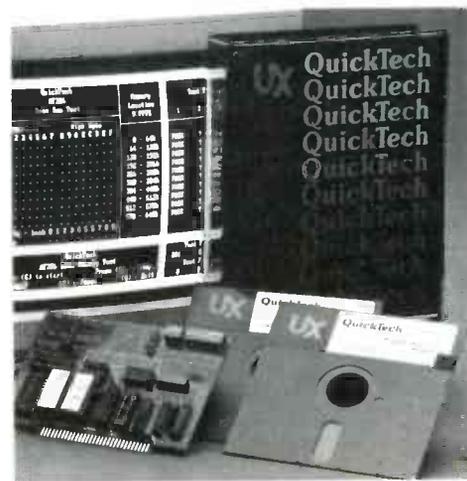
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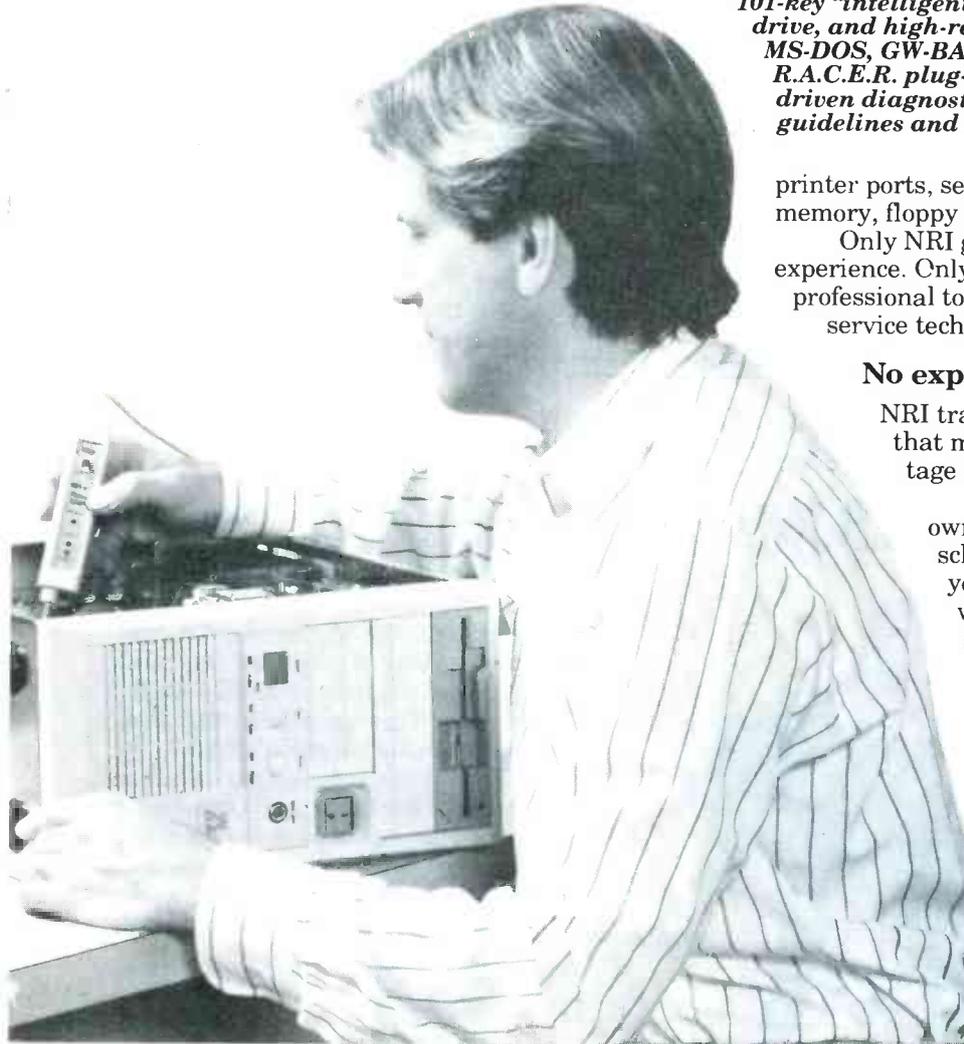


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by RMS ratings. That should be apparent, since the RMS power value can be synonymous with the product of a steady state voltage and current. Since fuse operation is dependent on the melting of an alloy, selection based on RMS values of current should be apparent.

Second, the generic term "fuse" should not be used. Each fuse type has certain characteristics and a typical time-ampere plot associated with it. When speaking of a specific application, the type of fuse should be specified.

Third, a system should be fused for its weakest link. Murphy's Law works well here: The transistor protecting the fuse blew. In a typical stereo system, that might mean the maximum collector current of the output transistors, the current driving capability of the amplifier, the speaker rating, and common sense. With the proper output transistors and fuse, reasonable short-circuit protection can be provided.

The speakers might have either RMS or peak ratings. Select the fuse based on the equivalent RMS value

of current at the nominal impedance of the speaker voice coil. For example: A 125-watt amplifier driving 8 ohms, with output transistors rated at 30 amps peak collector current, driving speakers recommended for a 15- to 100-watt amplifier at 8 ohms, which includes an internal fused tweeter rated at 35 watts peak, is used in a living room in a single residence home.

For the tweeter fuse amperage,
 $A = 0.707 \sqrt{35 \text{ watts}/8 \text{ ohms}} = 1.5$ amps.

For the overall speaker fuse amperage,
 $A = \sqrt{100 \text{ watts}/8 \text{ ohms}} = 3.53$ amps.

The amplifier fuse amperage,
 $A = \sqrt{125 \text{ watts}/8 \text{ ohms}} = 3.95$ amps.

Therefore, the amplifier fuse should be less than 3.53 amps and the tweeter fuse should be less than 1.5 amps. Since we are using this amplifier in the home and not at high-volume levels, it makes sense to pick 1.25A for the tweeter and 3A for the amplifier. If the fuses blow needlessly, then increase the value slightly.

Now, for the fuse-type selection process. The Bussman AGX series, a 1/4 x 1-inch, non-time-delay fuse, is a good bet. You cannot physically substitute fuses with different characteristics, such as time-delay, for this application

RON DOZIER
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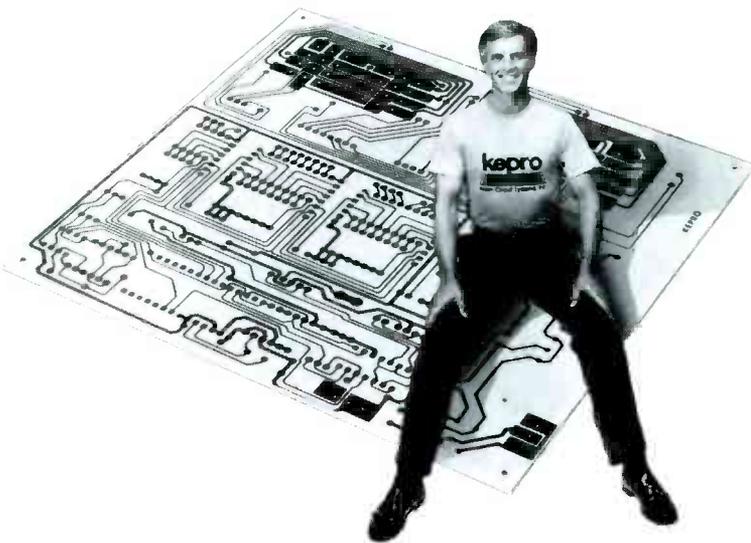
The fuse values for the speaker-protection circuit, shown in Table 1 of my article, were calculated using peak voltage values, because peak current flows during these periods. The peak voltage values themselves were determined by calculating the value of the DC rails, which must be present to create a given amount of average power dissipation within a speaker of a given impedance. Because this is true, the values in Table 1 are adequate to protect an amplifier that is capable of delivering the rated output power.

Keep in mind that the fuse is not for direct speaker protection, but for amplifier protection—the purpose of the circuit itself is to protect the speakers from a damaged amp. If you do not drive your amp to peak power levels, then choose a fuse that will protect your amp based on a value of 0.707 times the value from Table 1.

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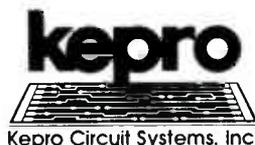


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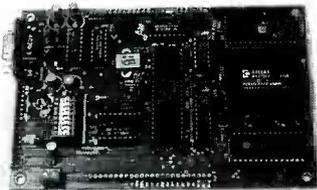
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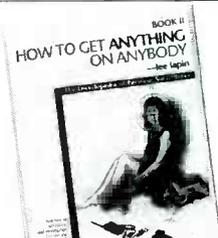
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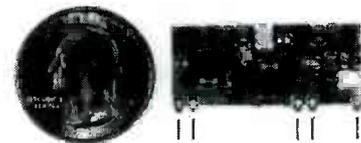
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EQUIPMENT REPORTS

Fluke Model 12 Digital Multimeter

Although there are plenty of high-quality digital multimeters on the market today, one name stands above the others in sales and customer loyalty: Fluke (John Fluke Mfg. Co., Inc., P.O. Box 9090, Everett, WA 98206). Even though many potential customers aspire to a Fluke meter, they don't always want to pay the premium price that the meters demand. Fluke, seeing a price-sensitive segment of the market that it hadn't yet tapped, has introduced its new Series 10 family. The Series 10 is designed for electronics repair persons, electrical troubleshooters, and all those hobbyists who are looking for high quality at an affordable price, and not just bells and whistles.

We examined the Model 12, the top-of-the-line of the Series 10. At \$89.95, it's also the most expensive. (The Model 10 and Model 11 are priced at \$69.95 and \$79.95.) The Model 12 is a relative small DMM, measuring roughly $1\frac{1}{2} \times 2\frac{3}{4} \times 5\frac{1}{2}$ inches. At only 10 ounces, it's also reasonable light. The front of the meter is sparsely appointed, with four pushbuttons and one slide switch, and a 4-digit LCD readout. The test-lead input jacks are on the bottom panel of the meter.

None of the Series 10 meters offer current-measuring ability. It was a decision aimed at keeping the meters' cost down, backed up by market research that showed that the vast majority of measurements are voltage and continuity/resistance checks. With those uses in mind, Fluke developed their V-Chek function (available on the Model 11 and Model 12). With the meter in the V-Chek mode—with the power switch slid all the way to the right to the continuity and diode-test position—no adjustments are necessary for many measurements. If you probe a cable you'll get an indication of continuity or resistance. If you probe a power supply—and its output is greater than 4.5 volts—the meter will switch from its resistance/continuity mode to its voltage mode and display either the



The lowest priced Fluke meters are worthy to wear the name.

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AC or DC voltage, whichever is greater. Since the input impedance in the V-Chek mode is a low 2K, it's not suitable for all applications. On the other hand, the low impedance ensures that leakage won't cause misleading readings.

Min/max mode

Intermittents are never easy to troubleshoot. But the min/max mode of the Model 12 can help. It works not only in voltage mode—where the highest and lowest voltages are recorded, along with the relative or elapsed time (on a 100-hour clock) of each occurrence—but also in the continuity mode, where it captures intermittent shorts or opens as brief as 250 μ s and displays a symbolic representation of the transition.

When powered up, the meter defaults to its autoranging mode, but any range can be manually selected. The lowest (4000 mV) voltage range must be entered manually. The model 12 also offers a capacitance-measurement mode, with five ranges

from 1 μ F to 10,000 μ F.

The model 12 is a pleasure to use. All controls can be operated conveniently with the thumb of the hand in which you hold the meter. The simple, 4-button front panel is easy to use—but not the first time you use it.

The capacitance switch is easy enough to figure out—it's a large button with the schematic symbol of a capacitor on it. The min/max operation is also easy if you've ever used the similar function before, or if you read the excellent manual that accompanies the Model 12. The RANGE switch is a button on which is a small square and concentric circle. (Fortunately, the word "range" is also embossed beside it.) While it may be obvious how to turn the manual ranging on, it may not be obvious how to return to the autorange mode: You have to hold the button down for two seconds. It's also not obvious that the same button is used to lock out the V-Chek mode, or to disable the continuity beeper.

The SELECT button has a similar problem in that it may not be immediately apparent that it's used to choose between AC and DC modes, or between continuity and diode-test mode. We should reiterate, however, that once you're familiar with the meter's convention, it's extremely convenient to use.

The Model 12 has a DC accuracy of 0.9% + 1 digit, and an AC accuracy of 1.9% + 3 digits. For resistance measurements, its accuracy is specified as 0.9% + 2 digits (400.0-ohm range), and 0.9% + 1 digit (4.000K–4.000-megohm ranges). Its capacitance-measurement accuracy is specified as 1.9% + 2 digits (0.400 μ F–400 μ F ranges), and 10% + 90 digits (10,000 μ F range).

If you don't need the min/max recording mode you may opt for the Model 11. If you also don't need the time-saving V-Chek function, or the ability to measure capacitance, you may want to opt for the lowest-priced Model 10. Our money, however, is on the Model 12. It looks like a tough act to beat.

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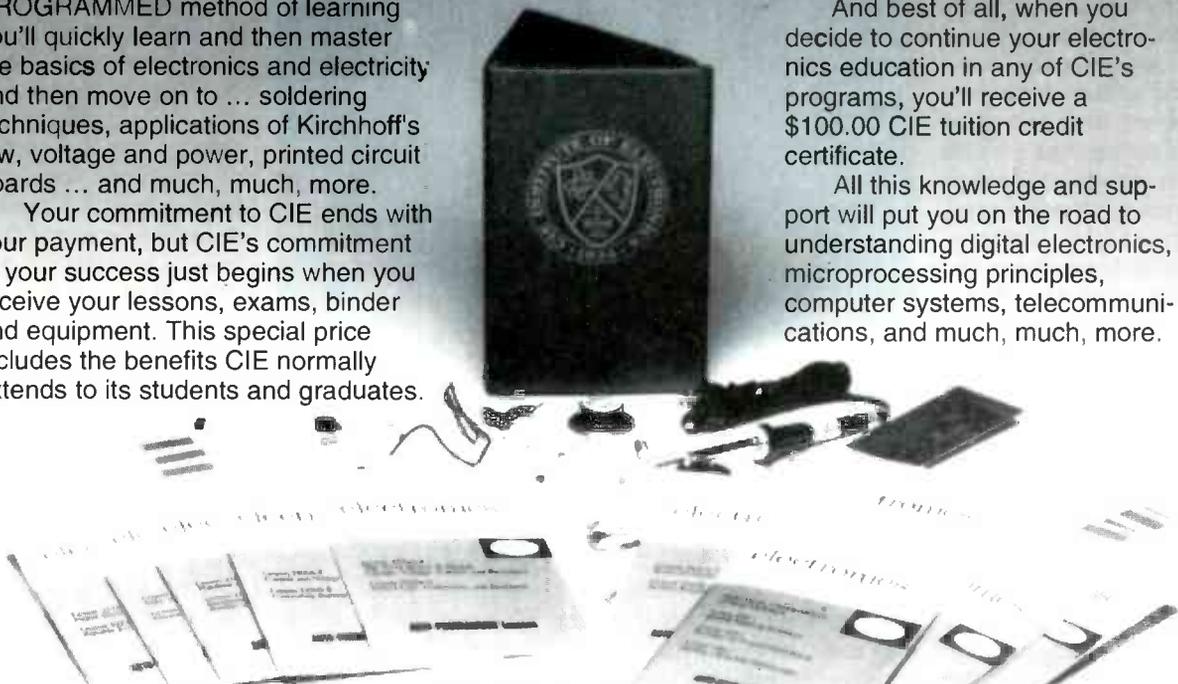
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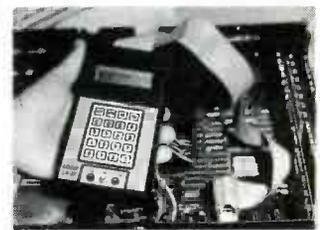
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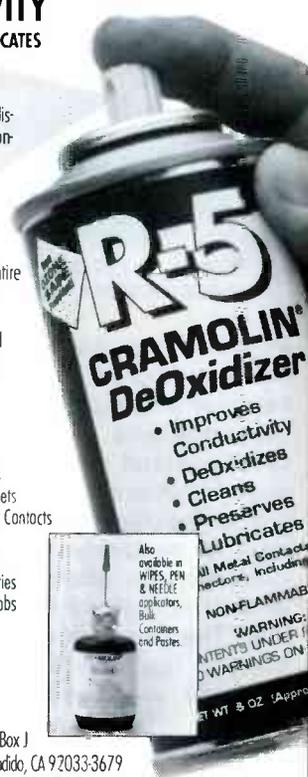
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kit includes a diagnostic software program, a circuit card for testing motherboard problems, and a detailed manual written in easy-to-understand language. The diagnostic software is menu-driven and runs its test sequence without operator interaction. The circuit board is used to test main board problems. When installed, the internal test codes are displayed as the computer powers up. If a problem occurs, a fault code will be shown on the digital display. Fault codes are listed in the manual, which presents a step-by-step procedure for diagnosing and fixing problems ranging from simple glitches to dead systems. The kit can be used to test power-supply voltages, memory, disk drives and controllers, serial ports, video drivers, keyboards, main circuit-board components, coprocessors, parallel ports, monitors, and internal clocks.

The *PC Fixer* has a list price of \$119.—**Sibex Inc.**, 1040 Harbor Lake Drive, Safety Harbor, FL 34695; Phone: 813-726-4343; Fax: 813-726-4434.

HAND-HELD FREQUENCY COUNTER. For use in traditional laboratory settings as well as in field-service applications including frequency detection and monitoring, secure installations, two-way radio, ham radio, counter surveillance, police and military tactical

situations, the *Model 2810* frequency counter from **Optoelectronics** offers fast, full-range operation and 1-mV sensitivity. The 10-digit counter detects frequencies up to 200 MHz and resolves them to 1 Hz in 1 second flat. Frequencies up to 900 MHz are resolved to 1 Hz and displayed in 4 seconds, and those up to 3 GHz are resolved to 10 Hz and displayed in 1.6 seconds. Four different gate times can be selected using a front-panel switch. Sensitivity is specified at better than 1 mV for signals up to 200



CIRCLE 21 ON FREE INFORMATION CARD

MHz and better than 10 mV for signals up to 2400 MHz. Input antennas or lab probes connect to either of two pushbutton-selectable BNC connectors, providing either high input impedance (1 Megohm) for signals up to 50 MHz or standard 50-ohms input impedance for signals from 1 MHz to 3000 MHz and beyond. The *Model 2810's* timebase is a 10-MHz crystal oscillator; options include a ± 2 -PPM temperature-compensated crystal oscillator for extra-high stability. The unit comes with an LCD readout; an optional backlight LCD is also available.

The *Model 2810* frequency counter costs \$259; the optional ± 2 -PPM TCXO costs \$100;

the optional LCD backlight costs \$45; and an extra Ni-Cd battery pack costs \$24.—**Optoelectronics Inc.**, 5821 NE 14th Avenue, Fort Lauderdale, FL 33334; Phone: 800-327-5912 or 305-771-2050; Fax: 305-771-2052.

MINIATURE MONITOR/SURVEILLANCE ROBOT RECEIVER. Monitoring up to 9,999 discrete frequencies and sweeping up to 900 bands—all user set—**Stoner Communications' Dymek DR333** can be linked to its control base by hard wire, modem, or radio-frequency communications and can be controlled through any PC-compatible computer. Software supplied with each unit covers all automatic functions plus those related to general-coverage operation, including a spectrum analyzer. The software also leads the user through all manual and automatic functions.

The *DR333* weighs only two pounds and takes up less than 0.05 cubic foot of space. It offers AM, Sidebands, CW, RTTY, FSK, and Fax modes. Standard



CIRCLE 22 ON FREE INFORMATION CARD

and optional IF filters allow the user to select bandwidths from 400 Hz to 10 kHz. In addition to the usual audio output for phones and speakers, the receiver has a 600-ohm port for recording and demodulation equipment.

Using a 12-MHz computer, frequency change is 13 steps per second; the rate is faster with a higher-speed machine. Steps can be from 1 Hz up, and dwell times on active frequen-

cies can be set from 1 ms to several seconds. Monitor and surveillance data is logged to disk memory for recall or transfer to hard copy. Automatic operation can be halted and switched to manual at any time, and the computer can be used for other tasks while the receiver operates in the background.

The *Dymek DR333* monitor/surveillance robot receiver costs \$1500; the optional IF filters cost \$200.—**Dymek Sales**, Division of Stoner Communications, Inc., 9119 Milliken Avenue, Cucamonga, CA 91730; Phone: 714-987-4624; Fax: 714-987-1016.

PLUG-IN MINIATURE SPEAKERS. Two miniature speakers for plug-in PC board applications from **International Components** are designed to simplify and speed production and reduce labor costs. Both speakers have 8-ohm impedance, 100-mW rated input power, 200-mW maximum input power, 10mm lead spacing, and ABS housing. The ferrite-magnet *Model SR900RA-PC* weighs 9.6 grams, measures 23mm wide by 15mm high, and boasts 90 ± 3 -dB sound output, with a lowest resonant frequency of 900 ± 150 Hz. The rare-earth magnet *Model SR900R-PC* weighs 3.6 grams and measures 23mm wide by 10mm high. Its sound output is 89 ± 3 dB with lowest resonant frequency of 800 ± 150 Hz.

The *Models SR900RA-*



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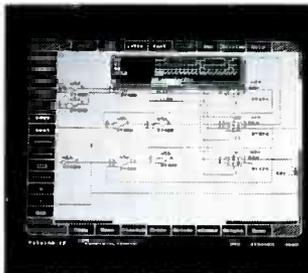
PC and SR900R-PC miniature plug-in speakers cost \$1.72 and \$1.84, respectively.—**International Components Corporation**, 105 Maxess Road, Melville, NY 11747; Phone: 516-293-1500.

SCHEMATIC EDITOR. *Mental Automation's SuperCAD* schematic editor now works with both digital and analog simulators via compatible netlists and built-in, pop-out waveform display menus. A "logic analyzer" display menu shows digital simulation results, while an "oscilloscope" display shows analog simulation (SPICE) results. *SuperCAD* is a full-featured schematic entry package that runs on IBM PC's and compatibles with 512K of RAM, CGA/EGA/VGA/Hercules graphics, Microsoft mouse, and DOS 2.0 or higher. Besides the schematic editor, the basic package includes

a netlist generator, library parts builder, an electrical rules checker, and a parts list extractor. Much of the space on the three disks included in the package consists of the library of nearly 1000 equivalent parts, divided into six categories: generic (common TTL and CMOS), memory, PLD's, 4000 series CMOS, analog, and microprocessors. Many parts include separately selectable DIP or surface-mount pinouts, and gate parts include De Morgan equivalent symbols.

Menus that cover 40% of all commands are visible at all times, and other commands are accessible through pull-down or pop-up menus. Object commands allow the circuit designer to enter lines, rectangles, arrows, text, and parts, while edit commands allow copy, move, erase, rotate, mirror, and stretch operations; and

function key operations include undraw last object, re-center schematic, tog-



CIRCLE 24 ON FREE INFORMATION CARD

gle grid, and redraw screen.

The basic *SuperCAD* package supports Epson and IBM-compatible printers. An optional package permits plotting on HP plotters and the HP Laserjet II, and allows *SuperCAD* files to be exported to other software programs (such as WordPerfect) that support the file format. Several software packages for printed-circuit layout, including both artwork gener-

ation and autorouting on one or more layers are also available.

The *SuperCAD* package costs \$99; the plotter/laser software costs \$69; additional software packages start at \$99.—**Mental Automation, Inc.**, 5415 136th Place S.E., Bellevue, WA 98006; Phone: 206-641-2141; Fax: 206-649-0767.

DUMMY LOAD COAXIAL TERMINATION. Well-suited for tuning a transmitter with an SWR/power meter, such as ham radios or field-strength meters, the *Archer Dummy Load* from *Radio Shack* can also be used for checking coaxial cable power measurements. The dummy load is designed to handle varying RF power levels by using a high heat-resistant, non-inductive, ceramic resistor that is coupled to an efficient aluminum heat sink. Its rated power is 100 watts

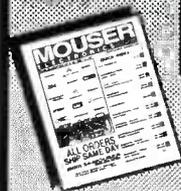
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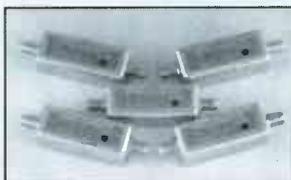


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CIRCLE 25 ON FREE INFORMATION CARD

The Archer Dummy Load (cat. no. 21-506) costs \$21.95 at almost 7000 Radio Shack Stores nationwide.—Radio Shack, 700 One Tandy Way, Fort Worth, TX 76102.

and a 10-times-per-second (approximate) sampling rate. The instrument measures capacitance from 0.1 pF to 1999 μF in eight ranges with accuracy from ±0.3% and a dissipation factor from 0.001 and 1.999; inductance from 0.1 μH to 1999 H over seven ranges with accuracy from ±0.5% and a dissipation factor from 0.001 to 1.999; resistance from 1 megohm to 1999 kilohms in seven ranges.

For any serious troubleshooting, repair, or calibration, an accurate LCR meter is a must. And, measuring roughly 10½ × 3¾ × 11¼ inches, and weighing 10 pounds, the B-800 will easily fit on your test bench.

The B-800 digital LCR bridge costs \$895.—Protek, P.O. Box 59, Norwood, NJ 07648; Phone: 201-767-7242; Fax: 201-767-7343. **R-E**

DIGITAL LCR BRIDGE. For production line, laboratory, research, and circuit-development applications, Protek's Model B-800 digital LCR bridge measures inductance, capacitance, resistance, and dissipation factors with a high-accuracy 3½-digit display for all parameters, to 1999. The unit will automatically



CIRCLE 26 ON FREE INFORMATION CARD

select parallel or series equivalent circuitry, produces rapid response measurements of components and circuits, and has a range changeover for automatic and manual modes. The B-800 has a measuring frequency of 1 kHz ± 5%, a 1-second measuring time,

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RADIO SHACK 1992 CATALOG NO. 472; from Radio Shack, 700 One Tandy Way, Fort Worth, TX 76102; free at Radio Shack stores nationwide.

The 191 pages of this catalog are filled with just



CIRCLE 40 ON FREE INFORMATION CARD

about everything electronic—all sorts of radios, of course, as well as computer equipment, video products, test equipment,

telephones, clocks, toys and games, wire and cable, components, batteries, antennas, home-automation products, switches, remote control devices, power adapters and converters, automotive equipment, speakers and accessories, microphones, and home-office gear. There are quite a few old favorites, and some new items, including the cover story: Memorex video equipment. Manufactured by Memorex for Radio Shack is a line of VCR's, TV's, camcorders, a complete satellite system, and a 13-inch TV/VCR combo. The catalog also contains new items in most other product areas, including

the DX-390 portable world-band radio, several car-audio components, a tri-band radar detector, fax machines and an automatic fax switch, cordless phones, a user-programmable outgoing telephone-call restrictor, and many other interesting items.

COAXIAL PRODUCTS CATALOG #1991B; from Pasternack Enterprises, P.O. Box 16759, Irvine, CA 92713-6759; Phone: 714-261-1920; Fax: 714-261-7451; free.

This 56-page catalog features a complete line of amplifiers; molded break-outs; coaxial cable; cutting tools; stripping tools; coaxial connectors, adapters,



CIRCLE 37 ON FREE INFORMATION CARD

detectors, attenuators, cable assemblies, and switches; patch cords; programmable attenuators; push-button attenuators; waveguide adapters; and twinaxial adapters and connectors. Several new high-power, high frequency attenuators that use SMA, BNC, and type-N connectors are included. **R-E**

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ADVERTISING INDEX

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Free Information Number	Page		
108	AMC Sales	46	114
75	Ace Products	21	184
107	All Electronics	94	198
—	Amazing Concepts	96	89
176	American Reliance Inc.	21	53
77	B&K Precision	27	199
109	C & S Sales	CV3	93
—	CIE	8, 23	117
193	Cable Warehouse	77	—
50	Craig Laboratories	25	189
187	Cheneko Products	21	56
—	Command Productions	46	78
177	Communications Specialists	79	191
127	Deco Industries	21	188
178	EasyTech	88	185
179	Electronic Goldmine	86	—
—	Electronics Book Club	15	186
—	Electronics Engineers B.C.	80	181
121	Fluke Manufacturing	CV2	192
—	Fordham	CV4	195, 196
197	Global Specialties	5	180
—	Grantham College	73	194
183	ISECO, Inc.	21	182
	Jameco	92, 93	
	Kelvin	7	
	Kepro Circuit Systems	20	
	M&G Electronics	91	
	MAT Electronics	28	
	MD Electronics	90	
	MJS Design	21	
	Mark V Electronics	91	
	Mouser	27	
	NRI Schools	16	
	Optoelectronics	3	
	Parts Express	87	
	Radio Shack	30	
	SCO Electronics	71	
	Signal, Inc.	25	
	Simpson	13	
	Star Circuits	28	
	TECI	79	
	Unicorn	95	
	U.S. Cable	71	
	Viejo Publications	46, 77	
	WPT Publications	79	
	Worldwide Cable	96	
	Xandi Electronics	21	

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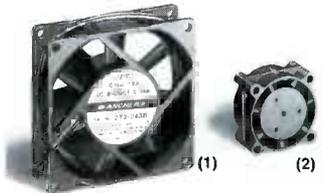
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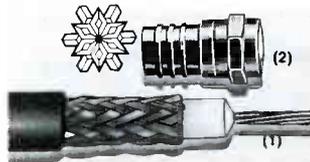
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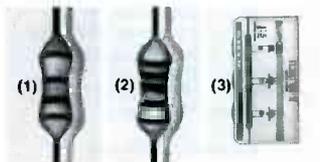
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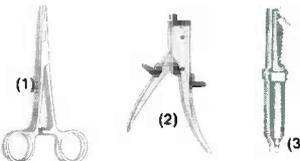
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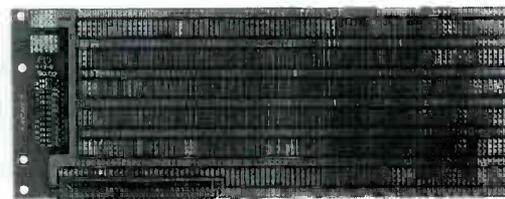
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NEW! 25-Pin Female D-Sub Connector. Right-angle mounting, designed for Experimenter's PC/XT-Compatible Plug-In Card (at left) to provide standard 25-pin input/output port. #276-1504 **2.39**

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PAUL BRULE

IF YOU'RE CONCERNED WITH ENERGY cost and conservation, as most people are, you'll be interested in our energy consumption monitor (ECM). Without the ECM, it's difficult for the average person to determine how much an individual home appliance costs to run. That's especially true for appliances with variable duty cycles such as a refrigerator which will have its compressor and fan motors, lights and other loads on at different times.

Our energy consumption monitor can display the accumulated cost in cents for the connected home appliance load. What did you spend to operate your toaster yesterday? What about your TV or air conditioner? Is the cost of energizing that spare freezer unit worth the few pennies saved when you bought your meat on sale? The ECM will help you to answer those questions quickly.

The ECM can also be used as a power meter by connecting a DMM to the voltage output of the monitor. Using the DC scale of your meter, each volt represents 100 watts. For example, a reading of 0.56 volts would translate to 56 watts.

To give you an idea of what the average residential Long Island, NY consumer pays monthly for operating various appliances, refer to Table 1. The monthly cost was based on a rate of 13¢ per kilowatt-hour (kWh). The average Long Island resident uses about 600 kWh's per month, which translates into a monthly electric bill of \$91.81.

The current electric rates for the Long Island, NY area are among the highest in the U.S. and vary depending on the season and the total amount of kWh's used. The summer rates are 12.87¢ for 0-250 kWh's used and 14.1¢ for 250-350 kWh's. The winter rates are 12.87¢ for 0-250 kWh's and 12.33¢ for 250-350 kWh's. Of course electric rates will vary, depending on the size of your family, the region of the country in which you live, and the utility company who services you. The information provided is only a rough basis to compare your own power con-

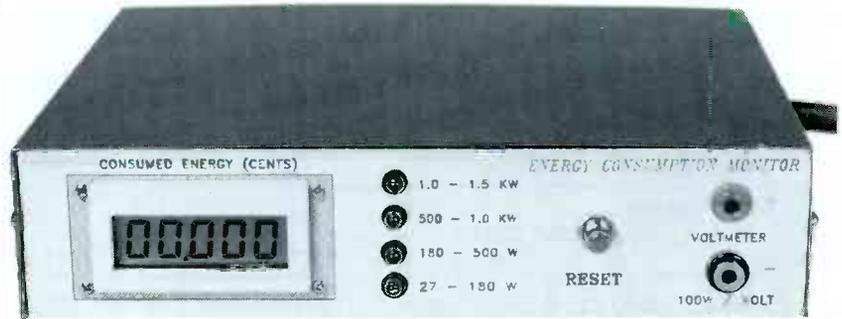
sumption to that of the average Long Islander. Let's see how this useful device works.

About the circuit

The ECM circuit consists of four sections, as shown in the block diagram of Fig. 1. A power converter generates a voltage that is proportional to the true or real power consumed by the load. That voltage feeds both a bar-

the monitored load is fairly constant at about 117 volts, we can say that the power is proportional to $I \times \cos\theta$. To obtain the phase angle, both the voltage and current must be monitored. Transformer T1 supplies the voltage, while the current-proportional voltage is obtained by stepping up (by a factor of 20) the voltage drop across shunt resistors R1-a-d via T2.

ENERGY CONSUMPTION MONITOR



Build this energy consumption monitor and find out how much it costs to run your household appliances.

graph and a voltage-to-pulse converter. The bargraph gives an approximate indication of the amount of power used, and the voltage-to-pulse converter produces a pulse whose frequency is proportional to the power. The pulse triggers the counter module which displays the cost of powering the monitored load.

The power converter

In order to determine the actual power consumed by an appliance, we must find the phase angle between the voltage and current in the overall circuit. We know that

$$P = V \times I \cos\theta$$

where $\cos\theta$ is known as the power factor. Since the voltage of

The ECM is capable of accurately monitoring the effective power of inductive loads. If a capacitive load is connected to the ECM, only the apparent power, not the effective power, will be monitored, causing some degree of inaccuracy. That shouldn't pose much of a problem because just about all reactive household loads are inductive. However, some appliances such as refrigerators, freezers, and air conditioners use capacitor-start inductive motors, which are characterized by a high starting torque. Those types of motors will present a capacitive loading effect on the power line, but only during start-up, which is a very short time interval compared to

TABLE 1—AVERAGE WATTAGE, USAGE AND COST OF HOUSEHOLD APPLIANCES

Appliance	Wattage	Estimated Monthly Usage (Hours)	Monthly Consumption (kWh)	Monthly Cost*1
Food Preparation				
Broiler	1,140	6.3	7.2	\$0.94
Coffee maker (drip)	1,200	9.8	11.8	\$1.53
Microwave oven	1,450	10.9	15.8	\$2.05
Oven range	12,200	4.8	58.6	\$7.62
Toaster	1,146	2.8	3.2	\$0.42
Home Entertainment				
Color TV (tube)	240	180.0	43.2	\$5.62
Color TV (solid state)	145	180.0	26.1	\$3.34
VCR	20	120.0	2.4	\$0.32
Radio	71	100.9	7.2	\$0.94
Stereo	109	83.3	9.1	\$1.18
Refrigerator				
Frost free, 10-15 years old	—	continuous	141.2	\$18.36
Ref./freezer, frost-free, 10-15 years old	—	continuous	153.0	\$23.80
18-cubic foot ref./freezer, new	—	continuous	100.65	\$13.08
16-cubic foot ref./freezer, new	—	continuous	77.66	\$10.10
Air Conditioning				
Room AC, 6,500 BTU's*4 (before 1980)	EER*2 7.2-930	116.0	108.0	\$14.04
Room AC, 6,500 BTU's (after 1980)	EER 8.5-770	116.0	89.0	\$11.57
Room AC, 6,500 BTU's (after 1980)	EER 9.5-680	116.0	79.0	\$10.27
Central, 3-ton AC (before 1980)	SEER*3 8-4,500	180.0	810.0	\$105.00
@ 12,00W/ton (after 1980)	SEER 9.5-3,790	180.0	682.0	\$88.60
40,000 BTU's (after 1980)	SEER 11.0-3,270	180.0	589.0	\$76.57
Fan (window)	200	150.0	30.0	\$3.90
Water heater	—	—	350.0	\$45.50
Washer (1 load/day)	512	16.8	8.6	\$1.12
Clothes dryer (1 load/day)	4,856	17.0	82.6	\$10.74
Dishwasher (1 load/day)	1,201	25.2	30.3	\$3.94
Iron	1,100	—	5.0	\$0.65
Vacuum	630	6.1	3.8	\$0.50
Clock	2	708.3	1.4	\$0.18
Blow dryer	1,235	6.8	8.4	\$1.10

Notes*

1. The monthly cost is based on an average rate of 13¢/kWh.
2. Energy efficiency ratio.
3. Seasonal energy efficiency ratio.
4. BTU's/EER = watts.

All figures noted in this table were obtained from Long Island Lighting Company's (LILCO) Energy Conservation Department.

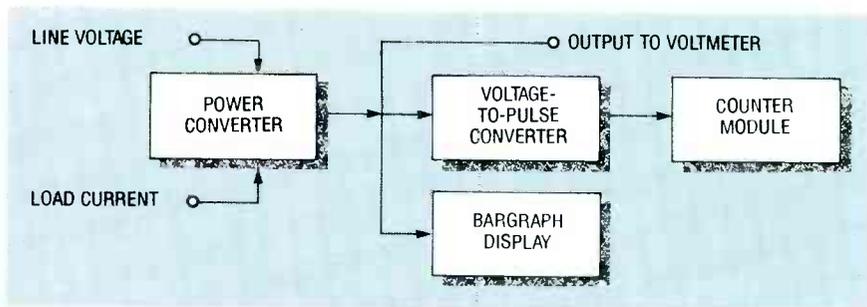


FIG. 1—THE BLOCK DIAGRAM of the energy consumption monitor.

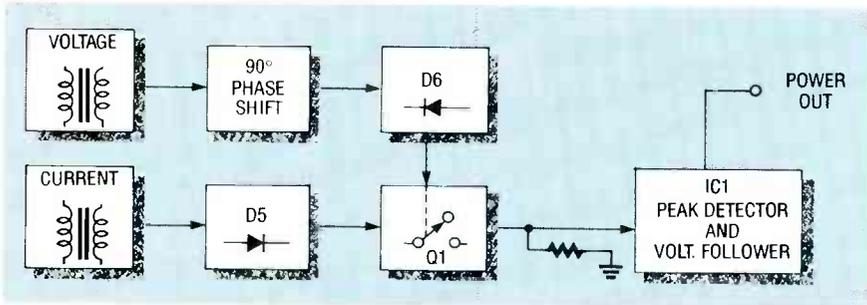


FIG. 2—THE BLOCK DIAGRAM OF THE POWER CONVERTER section of the ECM.

the continuous operation of such appliances.

Figure 2 shows a block diagram of the power converter circuit. The voltage from the potential transformer T1 (Fig. 3-a) is delayed by 90° (Fig. 3-b), controlling transistor switch Q1 (Fig. 3-c), which turns on during the negative cycle of the wave. Now, let's consider how three types of loads are monitored: purely resistive, equally resistive and inductive, and purely inductive.

In a purely resistive AC circuit, the current is in phase with the voltage, therefore the half-wave rectified signal from the current transformer will look like that of Fig. 3-d. Since the switch (Q1) is on until the first 90° of the wave, the peak of that wave (Fig. 3-g) will be passed on to the peak detector consisting of IC1. We can now say that $V_{OUT} = V_{PK}$ of the current transformer.

In a circuit consisting of equal resistance and inductive reactance, the current will lag the voltage by 45°. That signal, when half-wave rectified (Fig. 3-e) and gated by Q1 will look like that of Fig. 3-h. As you can see, the switch allows only the first 45° of the wave to be sampled by the peak detector, therefore

$$V_{OUT} = V_{PK} \sin(90 - \theta).$$

since

$$\sin(90 - \theta) = \cos\theta,$$

then

$$V_{OUT} = V_{PK} \cos\theta.$$

An ideal inductor does not dis-

sipate any power, and its AC current will lag the applied voltage by 90°. As a result, once the half-wave rectified current waveform (Fig. 3-f) of such a load is switched by Q1, the resulting output is zero, therefore

$$V_{OUT} = V_{PK} \cos\theta.$$

(Fig. 3-i.)

The schematic of the energy consumption monitor is shown in Fig. 4. Components R6-R8 and C5-C7 form a 90° phase shift network which switches Q1 on via R9 and R10 during the negative-going part of the wave. The voltage present at the secondary of the current transformer (T2) is half-wave rectified by D5. Diodes D3 and D4 limit the secondary voltage to approximately 40 volts peak to protect D6 and Q1 from excessive voltage should a high-current surge occur. When Q1 is turned on, it will couple any of the half-wave rectified signals to R11, and to the peak detector consisting of IC1-a, D7, C9, and R12. The wiper of R11 is set to calibrate the peak detector output so that it produces 1 volt for every 100 watts consumed by the load. Finally, that voltage is buffered via the voltage follower IC1-b to feed an external voltmeter, the bargraph meter, and the voltage-to-pulse converter.

The voltage-to-pulse converter is basically a voltage controlled oscillator (VCO). The power voltage (from IC1-b) charges C10 via R13 and R14 until the capacitor

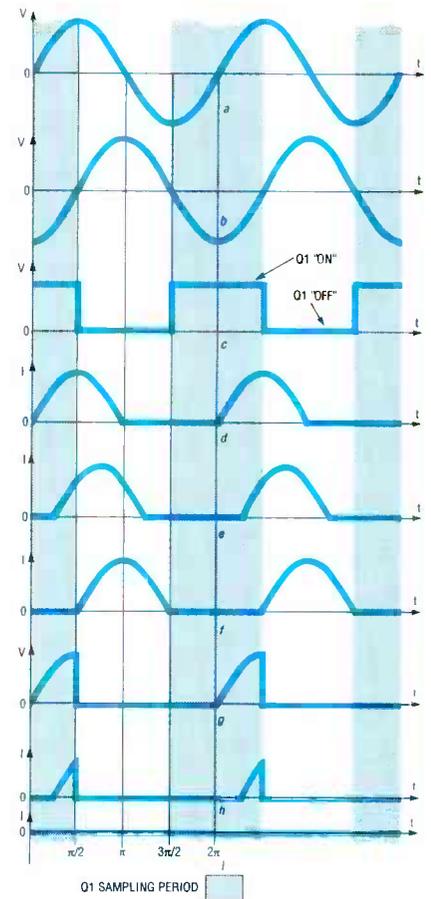


FIG. 3—POWER CONVERTER waveforms: sinusoidal waveform from T1 (a); T1 voltage is delayed by 90° (b); Q1 turns on when the delayed voltage goes negative (c); half-wave rectified current signal from a purely resistive load (d); half-wave rectified current signal from a resistive and inductive load (e); half-wave rectified current signal from a purely inductive load (f); when Q1 turns on, it captures the first 90° of the current signal of a resistive load (g); sampled current signal of a resistive and inductive load (h); sampled current signal of a purely inductive load (i).

voltage attains the trigger voltage of the Schmitt trigger, consisting of IC2, R16, and R17. Once triggered, the negative voltage swing from the output of IC2 quickly reverses the capacitor charge via R15 and D8, and is ready to repeat the cycle again. The higher the voltage feeding the RC timing network, the higher the pulse repetition, or frequency, will be. That pulse is used to increment the counter module through voltage-divider resistors R18 and R19. Diode D9 assures that the counter sees a pulse of the proper polarity. A nice feature of the display counter is that it is powered by a single AA battery mounted on the back. That makes sure the count is retained if the ECM is

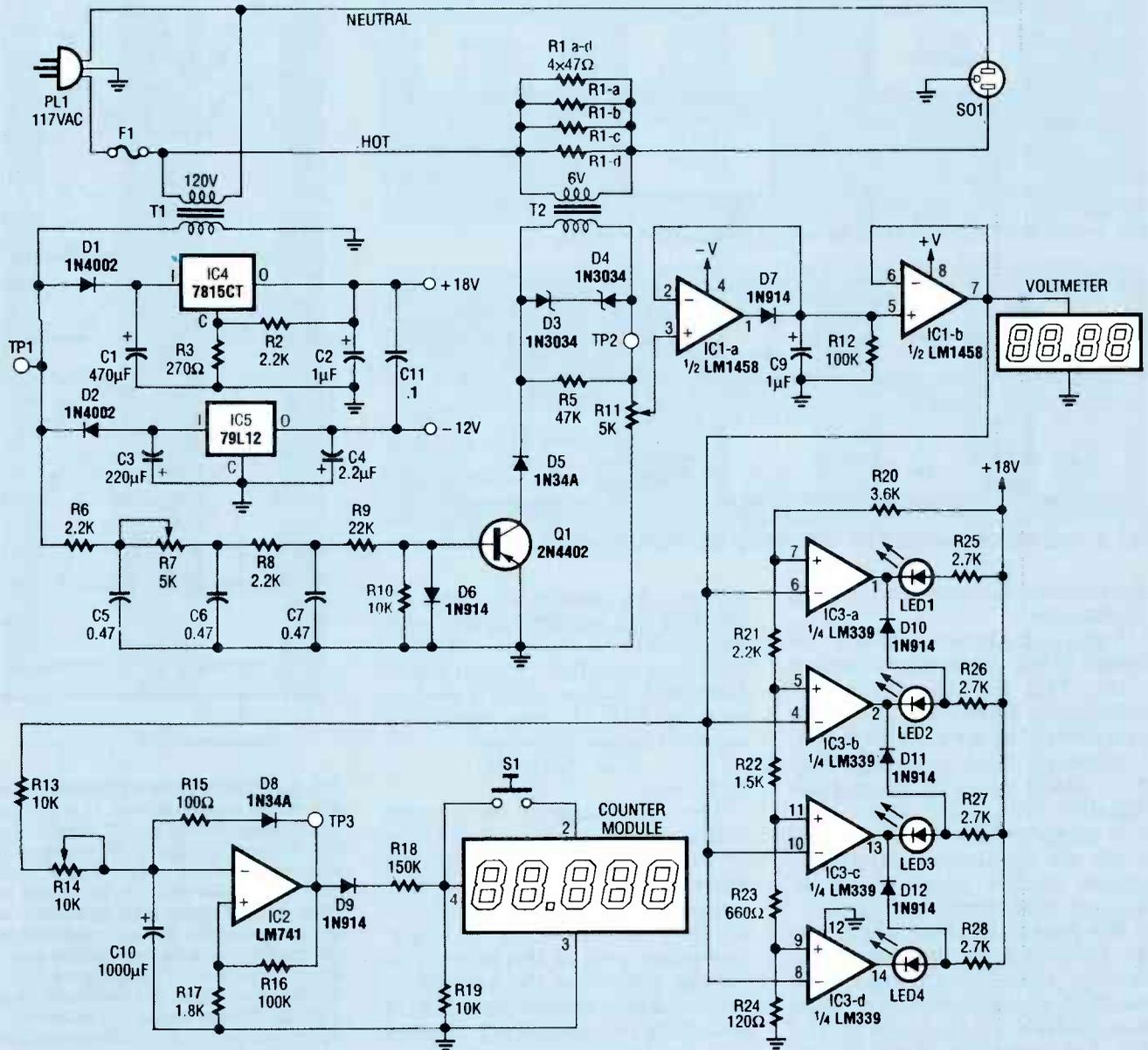


FIG. 4—THE SCHEMATIC OF THE ECM; R6–R8 and C5–C8 form the 90° phase shift network, which switches Q1 on. R11 calibrates the peak detector output so that it produces 1 volt for every 100 watts consumed by the load.

unplugged, or in the event of a power failure.

At the heart of the bargraph is IC3, a quad comparator. The power voltage drives all of the comparator's inverting inputs while each of the non-inverting inputs are tied to different voltage references derived by the voltage divider network of R20 to R24. As the voltage signal increases above the reference voltage level, the open collector output of that particular comparator goes low, switching its corresponding LED on. Diodes D14, D15, and D16 ensure that

the previously lit LED is turned off as the power increases, thus allowing no more than one LED to remain on at a time.

The power-supply section is fairly straightforward. The transformer's (T1) voltage is half-wave rectified, and is then filtered by C1. The voltage divider R2 and R3 is used to boost the output voltage of regulator IC4 to approximately 18 volts. IC4 could easily be replaced with a 7818 voltage regulator, thereby eliminating the need for R2 and R3 (a shorting jumper would have to replace R3). Except for the voltage-divid-

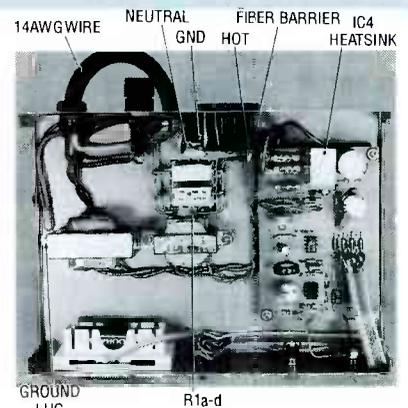


FIG. 5—HERE IS THE FINISHED prototype. It's a good idea to use standoffs to mount the transformers so that R1-a-d's connections are adequately spaced from the case. The author also used a fiber barrier between the PC board and the AC socket for added protection.

PARTS LIST

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

R1-a-d—0.39 ohms, 5 watts

R2, R6, R8, R21—2200 ohms

R3—270 ohms

R4—not used

R5—47,000 ohms

R7, R11—5000 ohms, trimmer potentiometer

R9—22,000 ohms

R10, R13, R19—10,000 ohms

R12, R16—100,000 ohms

R14—10,000 ohms, trimmer potentiometer

R15—100 ohms

R17—1800 ohms

R18—150,000 ohms

R20—3600 ohms (see text)

R22—1500 ohms

R23—680 ohms

R24—120 ohms

R25-R28—2700 ohms

Capacitors

C1—470 μ F, 35 volts, radial electrolytic

C2, C9—1 μ F, 35 volts, tantalum

C3—220 μ F, 63 volts, radial electrolytic

C4—2.2 μ F, 35 volts, radial electrolytic

C5, C6, C7—0.47 μ F, 100 volts, polyester

C8—not used

C10—1000 μ F, 16 volts, radial electrolytic

C11—0.1 μ F, 50 volts, ceramic

Semiconductors

D1, D2—1N4002 diode

D3, D4—1N3034, 39 volts, Zener diode

D5, D8—1N34A germanium diode

D6-D12—1N914 diode

Q1—2N4402 PNP transistor

IC1—LM1458 dual op-amp

IC2—LM741 op-amp

IC3—LM339 quad comparator

IC4—LM7815 or LM7818 voltage regulator (see text)

IC5—LM79L12 12-volt negative voltage regulator

LED1—red LED

LED2-LED4—green LED

Other components

F1—15-amp fuse

SO1—chassis-mount, grounded AC socket

T1—18 volts (or 24 volts), 200 mA transformer

T2—6 volts, 200 mA transformer (connected as a step-up transformer)

Counter module—LCD electronic counting module (Radio Shack number 277-302)

S1—momentary SPST push button switch

Miscellaneous: 2 chassis-mount banana sockets, fuse socket, strain relief, PC board, hardware, wire, metal enclosure (Radio Shack 270-272A).

NOTE: The following items are available from Paul Brule, 12L67 Harbourview Rd., Port Colborne, Ontario, Canada L3K 5V4. An etched and drilled PC board, \$15.95; a kit consisting of all resistors, capacitors, semiconductors and PC board for \$59.95; a lettered faceplate and template which fits a Radio Shack 270-272A case, \$7.95. Please include \$2.50 for shipping and handling. All prices are in US funds.

er resistors, the negative supply is basically a mirror image of its positive counterpart.

Construction

Figure 5 shows the authors completed prototype. Transformers T1 and T2, SO1, F1, LED1-4, counter display, S1, J1 and J2 are mounted on the enclosure, while the remaining secondary circuitry is installed on a single-sided PC board. The foil pattern is provided if you would like to make your own, or you can obtain an etched and drilled board from the source mentioned in the parts list. Mount and solder all components according to the parts placement diagram shown in Fig. 6, observ-

ing correct polarity. The 7815 regulator should be fitted with a heat sink. You can do that by drilling a ½" × 1-½" × ⅛" piece of aluminum and mounting it to the T0-220 case.

The ECM should be enclosed in a suitable metal case as hazardous line voltage is present. It is important to use no. 14 AWG or heavier gauge wire for all primary wiring. Make sure the neutral side of the plug corresponds to that of the socket. The photograph in Fig. 5 shows where the hot (power supply black lead) and neutral (white lead) conductors are connected.

Grounding should be made by terminating the green grounding conductor of the power-supply

cord and socket ground lead to a closed-loop connector. Mount the connector through the transformer mounting screw and secure to the chassis ground through a star washer to bite through the painted or plated metal case. You can also sand the paint away to make a good contact. Resistors R1-a-R1-d should be adequately ventilated by using a louvered enclosure top. Those resistors could get quite hot if constant heavy loads over 1000 watts are monitored.

Now it's time to mark a decimal point on the counter display. Using a fine-tip black felt pen, mark the decimal point on the display between the third and fourth digit so that, when the monitor is properly calibrated, each count represents 1/1000 of a cent.

When wiring T2, remember to wire the 6-volt winding across the shunt resistors R1-a-R1-d so that you're using it in a step-up mode.

Locating a 3.6K resistor for R20 may be rather difficult since that is a non-standard value. The author happened to have a few of them in his parts collection, but you may consider wiring a 3.9K and a 47K resistor in parallel to obtain that value.

Calibration and testing

Before applying power to your circuit, double check your wiring. If you're using IC sockets, leave IC1, IC2, and IC3 out of the circuit. Apply power and check for +18 volts and -12 volts at the outputs of IC4 and IC5, respectively. Those voltages may be slightly lower by a fraction of a volt. If you have removed the IC's and the voltages are okay, then unplug the unit, install the IC's, re-apply power, and re-check the supply voltages.

The next step is to check the transformer phasing. In order to do that, temporarily install a jumper from ground to the cathode of D5. Now connect a 100-watt light to the load socket. Using a voltmeter on the AC scale, make sure the voltage between TP1 and TP2 is lower than that measured between TP1 and ground. If it isn't, reverse the two PC-board connected T2 leads. Re-check and remove the jumper.

With *NO LOAD* connected to

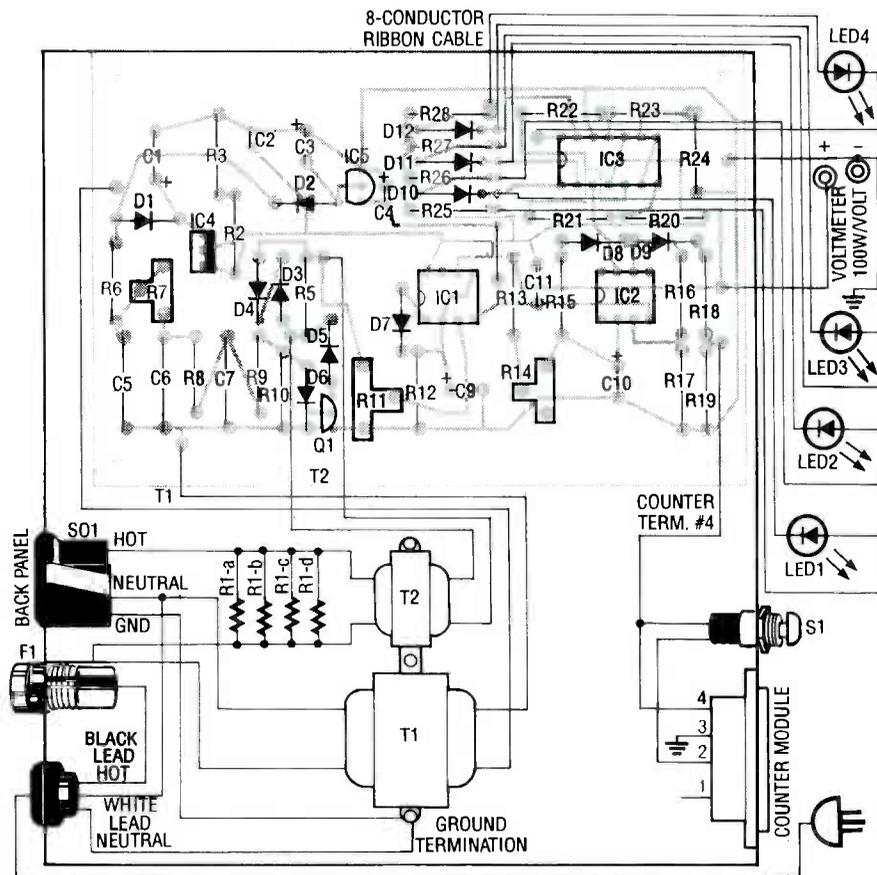
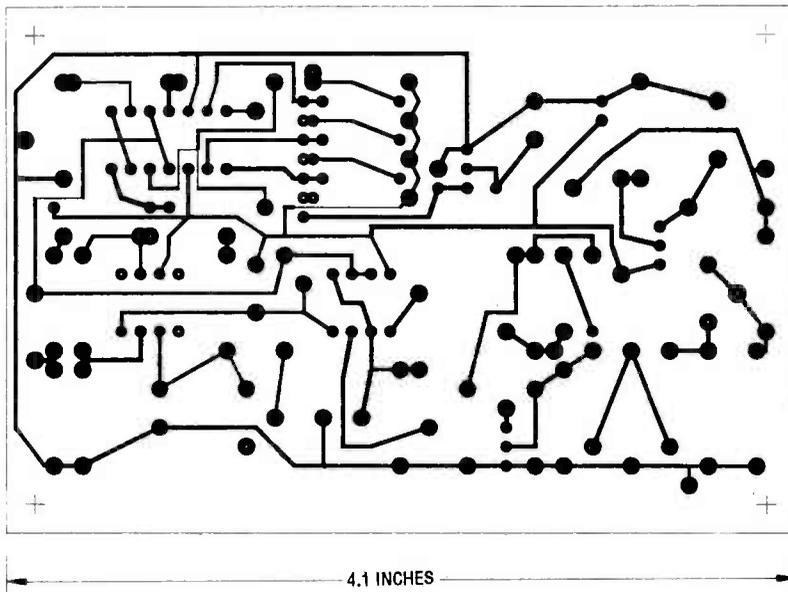


FIG. 6—PARTS PLACEMENT DIAGRAM AND WIRING connections. Use 14 AWG wire for all primary leads, and make sure you wire the hot and neutral leads of the power supply cord to the proper terminations on the AC socket.



THIS IS THE FOIL PATTERN of the solder side of the PC board.

cents per kilowatt-hour (check your billing statement or power company for that rate). Adjust R11 to read that value on the voltmeter. That will enable you to calibrate R14 so that you obtain one pulse per second (1 Hz) at TP3. A doubling or halving of V_{CAL} should approximately double or half the pulse rate. Remember, each pulse represents $\frac{1}{1000}$ of a cent.

Disconnect the jumper used in the previous procedure and connect a 100-watt light as a load. Using an oscilloscope, monitor the waveform at TP2 and set R7 so that the sampling ends at the very peak of the incoming waveform, which should look like the waveform of Fig. 3-g.

Finally, power calibration is the last to be performed. With the 100-watt light connected adjust R11 so that a DMM, connected to the external voltmeter jacks, displays 1.00 volt DC. You may want to verify that wattage by measuring the voltages across shunt resistor R1, and the line. With those two voltage readings, the power may be calculated using the formula

$$P(\text{watts}) = V_{SHUNT} \times V_{LINE} / R_{SHUNT}$$

where R_{SHUNT} is the shunt resistance (four 0.39-ohm resistors in parallel = 0.0975 ohms). V_{SHUNT} is the voltage drop across R1 and V_{LINE} is the AC line voltage.

That completes the assembly and calibration of the ECM. There is one point that should be mentioned here. The voltage to pulse converter will not start until there is a load of approximately 30 watts, meaning that the counter will not increment unless the load is heavier than that value.

For those of you wondering if investing in an energy consumption monitor is worthwhile, consider this: You'll be able to determine how much it costs to run a particular appliance for a certain length of time. So it's easy enough to figure out if it's actually cheaper to run the microwave oven for five minutes or the conventional oven for ten minutes, and so on. Using the energy consumption monitor, you'll also be able to determine if buying extra meat at really good sale prices actually saves you money in the long run. The greatest advantage of the energy consumption is keeping one step ahead of your power company.

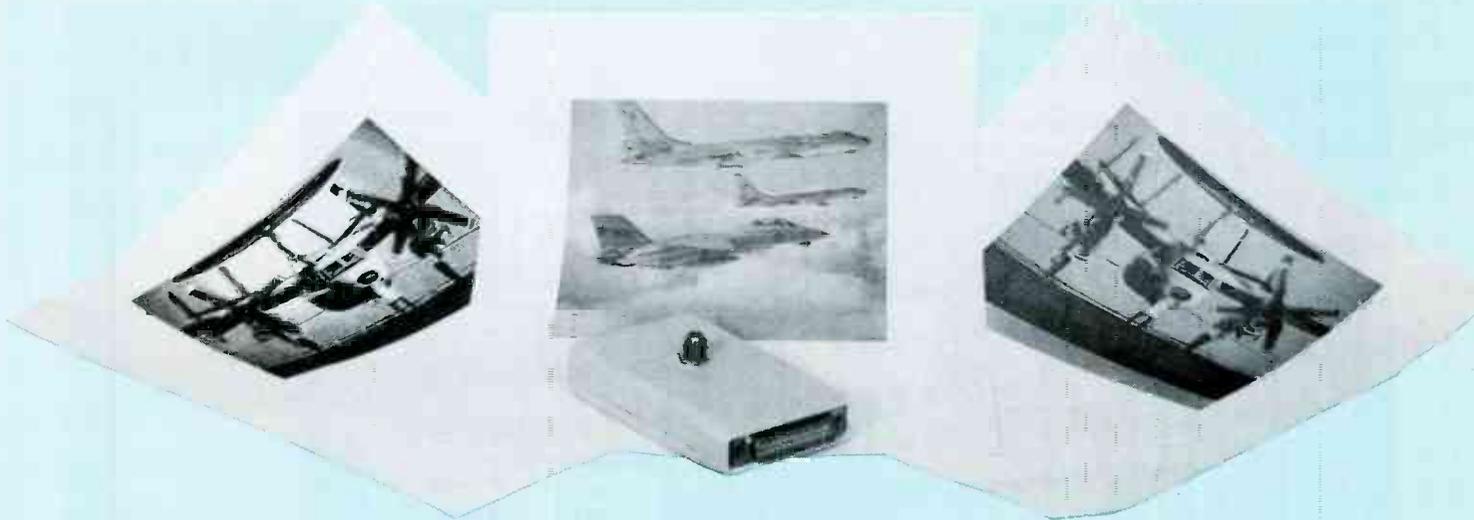
R-E

the ECM, connect a jumper between the +18-volt supply and TP2. Connect a DC meter to the power-voltage output and check to see that the voltage varies from 0 to approximately 16.5 volts as R11 is varied from one end to the

other. As you do that, the LED's should increment at about 0.27, 1.8, 5, and 10 volts. Now, using the formula

$$V_{CAL} = 36/\text{rate}$$

where V_{CAL} is the calibration voltage and rate is your cost in



Build the Frugalvision—a low-cost image capture device for your PC.

VIDEO CAPTURE ON THE CHEAP!

GENE TONER

IN OUR AUGUST '90 ISSUE, **RADIO-Electronics** introduced a low-cost image capture board for the PC. For \$199, it was one of the least expensive, highest performance real-time image capture boards ever offered for the PC. The author later redesigned the board to increase its speed and functionality, and add a phase-locked loop for better pixel alignment (\$269). Further developments led to a scientific-level resolution, real-time, AT bus-level Supervision 16, a 512×480 pixel version, offered at \$369.

But not everyone was happy. Many readers wanted an image-capture system for under \$100—the magic number! They didn't mind that some performance was sacrificed. Real-time capture wouldn't be a requirement, just let everyone have the ability to capture useful pictures, cheaply.

Okay, no more mister nice guy. We'll show you how you can build the Frugalvision—an image-capture board for under \$100! No, the board doesn't capture in real

time, it takes about eight seconds to capture an image, so the subject had better stay real still! (In fact, we recommend that you use the system to copy existing still scenes and photographs.) What it can do is this:

- Capture an image with a resolution of 256×244 pixels with 64 shades of gray.
- Lock onto any standard (RS-170) video source with a phase-locked loop input section.
- Perform DC restoration of the input video signal.
- Automatically detect input signal strength and adjust the digitization reference accordingly (referred to as autowhite level), and pass the pixel value to the PC via the printer port. What you get is a very useful digitized image on the PC.

Our standard Supervision software has been updated to support this board, so all of the functionality such as image processing functions, industry standard file formats, and printing functions is included.

How we did it

In order to reduce the cost to less than \$100 for an assembled unit, some decisions were made early in the design stage. We consider a minimum requirement for a workable digital image to be a resolution of 256×244 , with 64 levels of gray. A resolution of 256 pixels per horizontal line requires a digitization rate of about 5 MHz, which is also the required burst data transfer rate if no buffer memory is available. There are no PC's currently available which support that kind of transfer rate over the standard IO channel without the use of direct memory access (DMA). We also like to use the original 4.77-MHz PC as a baseline for all of our designs so we don't have to make excuses to people with older machines. All of our real-time capture boards have a full picture's worth of buffer memory mounted onboard for that reason.

To avoid the cost of a buffer memory and all its associated circuitry, we decided not to capture

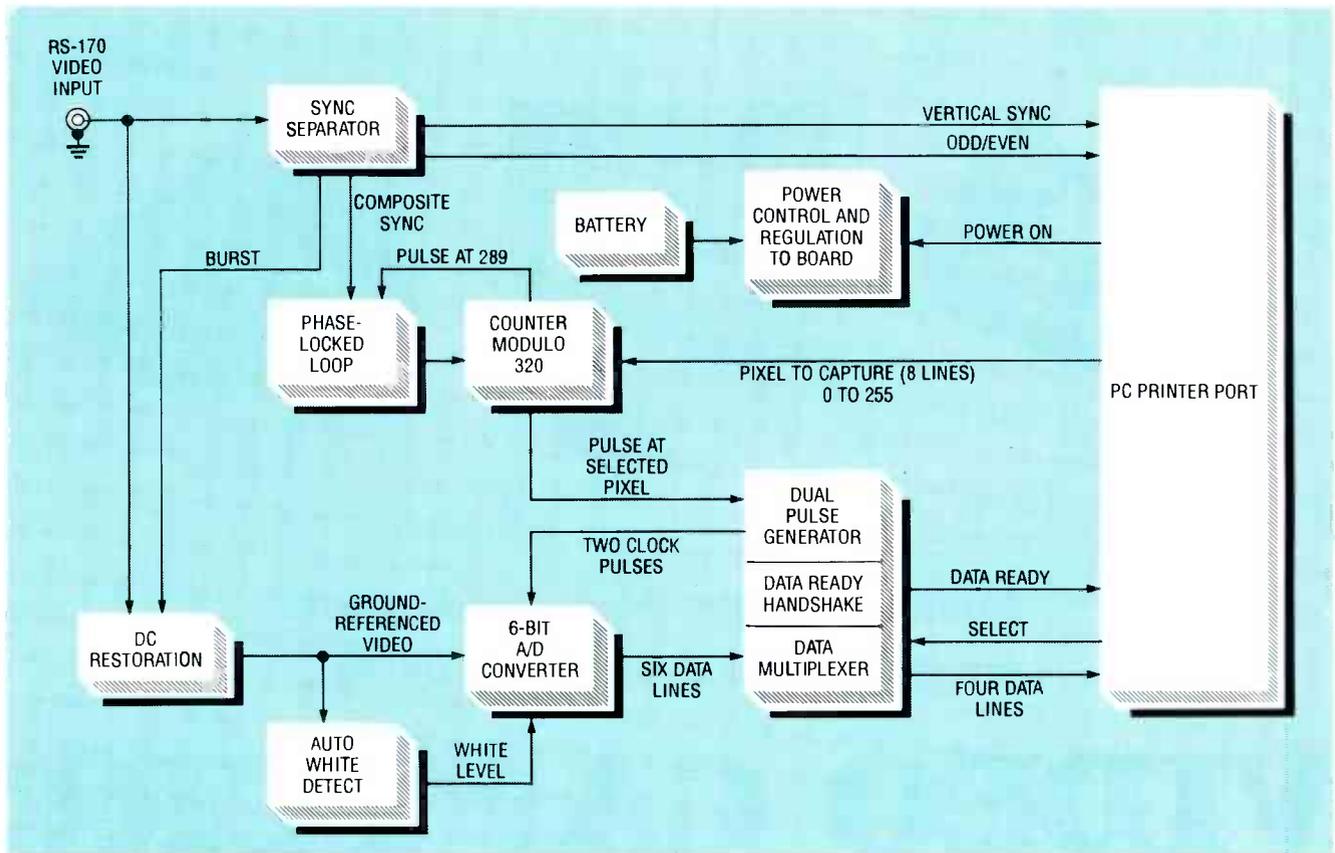


FIG. 1—BLOCK DIAGRAM of the image capture board.

in real time. The device also attaches to the standard printer port to save the cost of I/O bus-decoding hardware.

So, you might wonder, how does one digitize a signal which normally requires a 5-MHz transfer rate with a much slower rate? We use the following technique. The horizontal line rate is 15.750 Hz for an RS-170 video signal. During each horizontal line, a single data sample is taken, and passed to the PC via the printer port. The single sample is the desired pixel. For example, if the 50th pixel on a line is sampled, 50 pixel times are counted from the start of the horizontal sync pulse. A sample is taken by the A/D converter, the PC is informed that a sample is ready, the PC transfers it into main memory, and the procedure repeats on the next horizontal line until the 50th pixel for all horizontal lines is taken. The next column of pixels is then captured one by one, until all pixels are captured. The scan of the picture is in the vertical direction as opposed to the horizontal direction, which is normal with a real-time digitizer. The rate required to do that is the horizontal scan rate as opposed

to the pixel rate, which a 4.77-MHz PC is just capable of doing if carefully programmed in assembly language. Figure 1 is a block diagram of the various systems required to digitize an image in this fashion.

PC printer port background

The PC's printer port is somewhat of an oddity, mixing output-only lines, input-only lines, and open-collector lines with pull-ups capable of being read back. This mixed bag of capabilities has remained with us from the first PC's up through today's PS2's and EISA machines, allowing the digitizer to be connected to any compatible machine.

The PC and its BIOS are capable of dealing with three printer ports residing on the machine at once. The base addresses of the printer ports are 03BC, 0378, and 0278. The first place the BIOS looks for a port is at 03BC, then 0378, and then 0278. The first one it finds becomes LPT1, the second LPT2, and so on. The 03BC port is usually found on display-adaptor cards such as a monochrome graphics printer (MGP) card, and the other two addresses on standard IO cards

such as a serial/parallel game card where the address would be jumper selectable, along with its associated interrupt.

The printer port is mapped into three addresses, the base address, the base + 1, and the base + 2. The base address is a port with eight output lines. Those lines are output-only, and usually feed character data to a printer. We use these lines to select a pixel within a horizontal video line to capture and specify the column. Data bits 0 through 7 correspond to printer port connector pins 2 through 9.

The second address, base + 1, consists of four output open-collector lines with read back capability. What that means is if the outputs are placed in a high condition (the open-collector driver is not pulling the output low) the output can be driven by an external source. Reading those lines reveals the state of the external signal as long as the internal driver is off.

The first line is the BUSY signal, mapped to pin 1 of the interface. It is an inverter used to switch the input data multiplexer and reset the DATA READY input. That signal maps to bit 0 of base + 1.

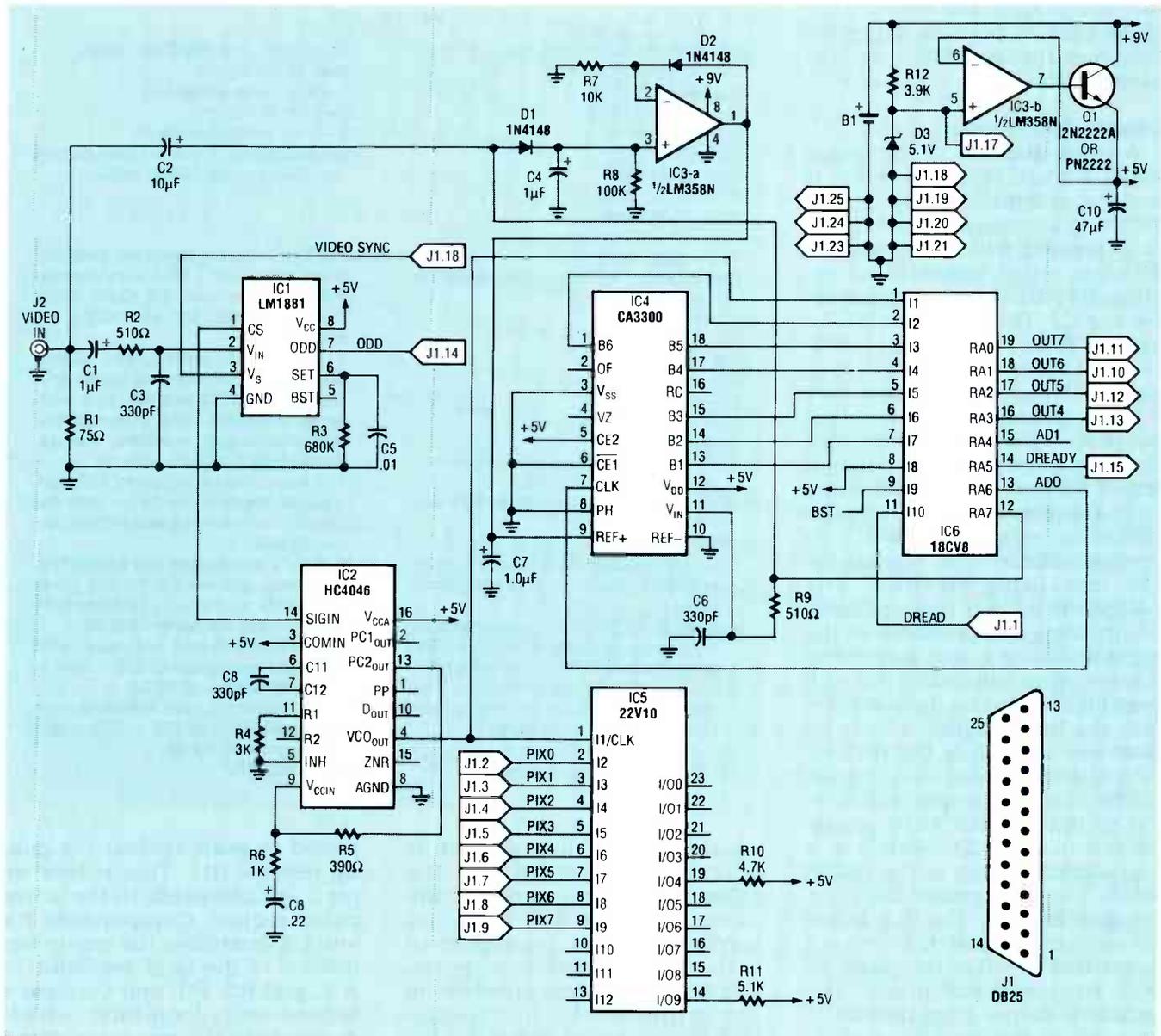


FIG. 2—SCHEMATIC OF THE FRUGALVISION. The video signal enters sync separator, IC1, which produces the odd/even signal used by the software and the burst signal for DC restoration. The composite-sync signal feeds into IC2, a PLL. IC2's output is fed into IC5, the counter module 320, where the oscillator operates at 320 times the horizontal-sync frequency. The output cells in IC6 are used to force the video signal to circuit ground. That ground-referenced signal is then fed to IC4, a 6-bit flash A/D converter.

and is called READ DATA. Bit 1 of base + 1 is the AUTO FEED signal. It is an inverter showing up as pin 14 of the interface. We use that signal to read in the state of the ODD/EVEN output of the sync separator, telling us if we're dealing with an odd video field or an even video field. Since we're digitizing our picture over the time of many fields, it is important to perform our digitization on only odd or only even frames to preserve pixel alignment.

The third signal, SELECT, appears as bit 2 of the base + 1 byte. It is an inverter which maps to

pin 17 of the interface. We use that line as an output to control power to the digitizer board. The fourth bit, bit 3 of the base + 1 byte called INIT, is logic high and maps to pin 16 of the interface. We use that signal to input the state of the sync supporter's vertical-sync output. Bit five of the base + 1 byte is the interrupt-enable bit for the printer port. A zero disables interrupts from the printer port, and in our case is left in that state as the digitizer does not use interrupts, but polls the status of the DATA READY input when an image is being digitized.

The remaining bits are unused and should not be relied on to be in any particular state.

The base + 2 port is a collection of five input lines. Bits 0, 1, and 2 of the byte are unused. Bit 3, called ERROR, maps to pin 15 of the interface and is logic high. We use that line to input the DATA READY signal generated by the digitizer board. Bit 4, SELECT; bit 5, PAPER END; bit 6, ACK; and bit 7, BUSY are all logic high, and map to pins 13, 12, 10, and 11 respectively, and are used to input our data. The 6 bits of data come from the A/D converter as the high four bits first, and then the low two bits become available when the READ DATA line is placed in a logic high.

Pins 18 through 25 of the inter-

face are ground, but we even get these pins to perform a certain function for us, which we will discuss later.

Circuit description

A block diagram of the image capture board is shown in Fig. 1, and the schematic in Fig. 2. The video signal enters the sync separator section, which consists of a 75-ohm input-termination resistor R1 followed by coupling capacitor C2. This capacitor blocks any DC from reaching IC1, a National LM1881 sync-separator chip. IC1 supplies its own bias level to the signal for decoding purposes. The signal then goes through a low-pass filter consisting of R2 and C3 to remove any high-frequency noise from the incoming video to allow IC1 to produce stable sync signals for the remaining circuits. The LM1881 is a great piece of video engineering and produces all the signals anyone might want from a video input, including the odd/even signal used by the software, and the burst signal, which we later use to provide DC restoration of the incoming video signal.

The composite-sync signal is fed to IC2, a 74HC4046 phase-locked loop (PLL), which is a high-speed version of the CMOS 4046. The HC version will operate past 15 MHz. The PLL forces an oscillator to match an output pulse and a reference pulse in both frequency and phase. The oscillator output from the PLL is directed to the counter modulo 320 block so that the PLL oscillator operates at 320 times the composite (horizontal) sync frequency. The PLL also insures that the rising edge of the modulo 320 counter output and the rising edge of the composite-sync signal are perfectly aligned.

The counter modulo 320 block is implemented within IC5, a 22CV10 IC. The 22CV10 is a class of CMOS programmable logic known as programmable electrically erasable logic (PEEL). The 22CV10 features up to 22 inputs and 10 programmable output macrocells fed by a programmable AND array and a fixed OR array, and once programmed is electrically erasable.

We now have a circuit which is dividing the complete horizontal scan line of the video up into 320

All resistors are 1/8-watt, 5%.

R1—75 ohms
R2, R9—510 ohms
R3—680,000 ohms
R4—3000 ohms
R5—390 ohms
R6—1000 ohms
R7—10,000 ohms
R8—100,000 ohms
R10, R11—4700 ohms
R12—3900 ohms

Capacitors. All are axial tantalum types.

C1, C4, C7—1 μ F
C2—10 μ F
C3, C6, C8—330 pF
C5—0.01 μ F
C9—0.22 μ F
C10—47 μ F

Semiconductors

IC1—LM1881N video-sync separator - (National Semiconductor)
IC2—74HC4046AN phase-locked loop (Philips)
IC3—LM358N dual op-amp
IC4—MP7682JN 6-bit A/D flash converter (Micro Power) or CA3306 (Harris/RCA)
IC5—PEEL22CV10P-25 programmable-logic timing generator (Gould Div. AMI or International CMOS Technology)
IC6—PEEL18CV8P programmable-logic user interface (Gould Div. AMI or International CMOS Technology)
Q1—PN2222 NPN transistor
D1, D2—1N4148 signal diode

PARTS LIST

D3—5.1-volt, 500 mW Zener diode

Other components

J1—DB25 male solder cup
J2—F-61 connector
J3—9-volt battery connector
Miscellaneous: 9-volt alkaline battery, double-sided PC board, solder.

Note: The following items are available from Idec, Inc., 1195 Doylestown Pike, Quakertown, PA 18951, (215) 538-2600 (VISA, MC and AMEX accepted):

- An etched, drilled, and plated through double-sided PC board, pre-programmed IC5 and IC6, plus software, full parts lists with sources and source part numbers, and assembly instructions—\$49.95.
- A complete kit including software plus all required hardware with assembly instructions and no warranty—\$89.95.
- A fully assembled and tested Frugalvision unit with a 90-day parts and labor warranty, complete with Supervision software—\$99.95.
- Supervision/8 and software, with standard resolution of 256 x 244 x 256 gray levels—\$199.95.
- Supervision/16 and software with high resolution of 512 x 488 x 256 gray levels—\$369.95.

Add \$6.00 S&H.

equal pixels, of which we want to select 256 which are in the active video. Figure 3 shows the significance of count 289 being returned to the PLL for alignment with the horizontal-sync pulse. The horizontal-sync pulse lies in the center of the horizontal-blanking interval. We want the blanking interval to represent counts 256 through 320 of the modulo 320 counter, and counts 0 through 255 to match up with the active video. In this case, the blanking interval is $320 - 256 = 64$ counts long.

The center of the horizontal sync is 32 counts into the interval. $256 + 32 = 288$, or for us 289 since we need an active-low

period to work against the pull-up resistor R11. This is how we get a full 256 pixels in the active video region. Components R4 and C8 determine the center frequency of the local oscillator in IC2, and R5, R6, and C9 form a second-order loop filter, which determines the response speed and the damping ratio of the PLL. These components were carefully selected to provide the proper performance when upset by the vertical sync and equalization pulses from the incoming video.

The incoming video is then coupled to the DC restoration block by C2. The goal now is to force the video signal to be at circuit ground at the black-level ref-

PROGRAMMABLE LOGIC SOURCES

Gould Div. AMI
2300 Buckskin Rd.
Pocatello, ID 83201

International CMOS Technology
2125 Lundy Ave.
San Jose, CA 95131

SOFTWARE SOURCES

Design Computation, Inc.
Sherman Square
Route 33
Farmingdale, NJ 07727
(201) 938-6662

Catenary Systems
470 Belleview
St. Louis, MO 63119
(314) 962-7833

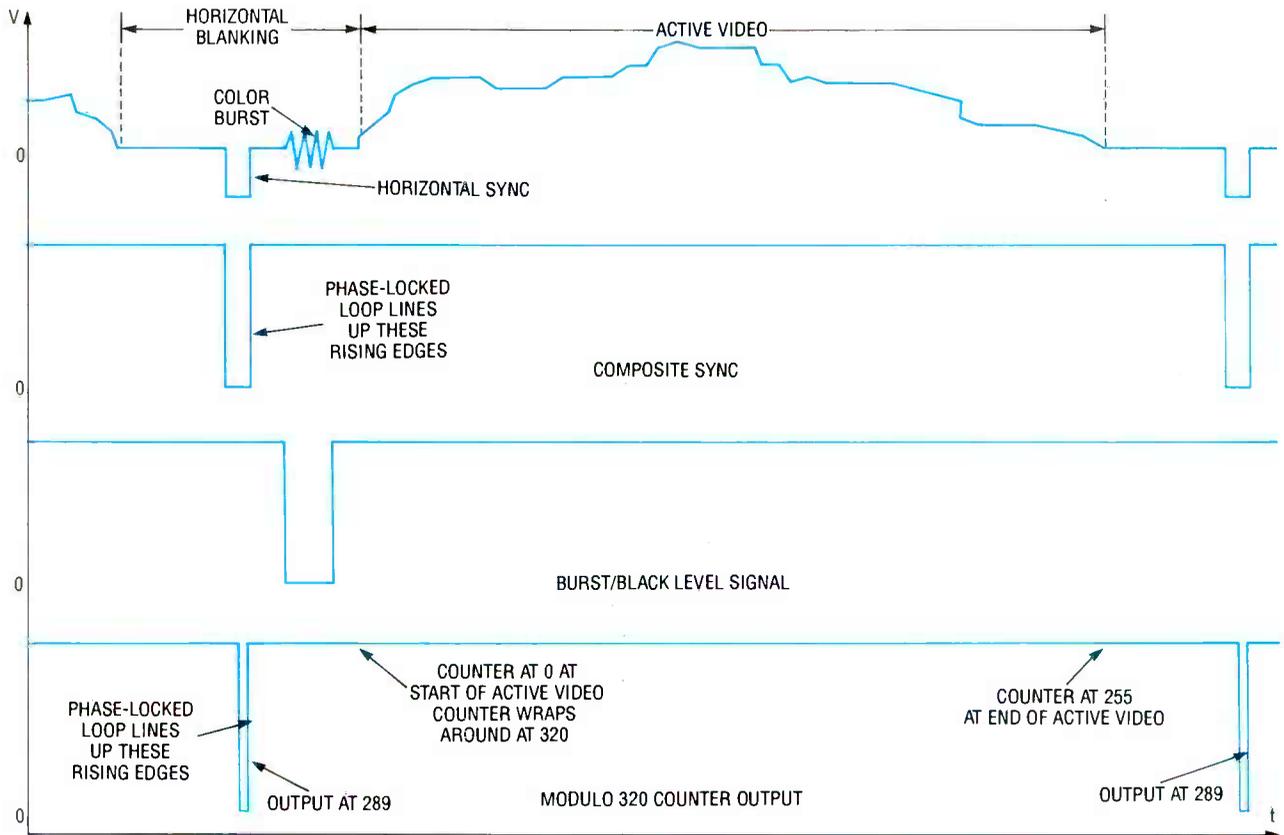


FIG. 3—WAVEFORMS SHOW THE significance of count 289 being returned to the PLL for horizontal-sync alignment.

erence period of the signal, which occurs just after the color burst at the end of the horizontal-blanking interval. This is accomplished by using one of the output cells in IC6, an 18CV8 PEEL and the burst output of the LM1881.

The 18CV8 contains eight programmable output macrocells fed by a programmable AND array and a fixed OR array. Each cell can be configured as a combinatorial output or a registered output, has its own tri-state control term, and a common clock from pin 1 of the IC.

In order to clamp the incoming video signal to ground, one of IC6's macrocells is programmed to be low at all times, but only to enable its tri-state output when the burst signal is low (active). This way, the output emulates an open-collector output. When the output turns on, it clamps the video signal to ground when the burst is active, and floats the rest of the time, allowing the normal video to come through.

The ground-referenced video signal is then fed to IC4, a flash A/D converter. The converter is a 6-

bit flash unit, made either by Micro Power MP7682 or Harris/RCA CA3306. The converter has both ends of its conversion reference available. The low end of the reference connects to ground to correspond to the ground-referenced video signal. The upper end is fed by the auto white detect block. The converter digitizes all signals lying within the two references into 64 discrete codes. The conversion is performed in one clock pulse, and the result transferred to its output on the second clock pulse. A low-pass filter consisting of R9 and C6 is applied to the incoming video before entering the converter to eliminate the color carrier, if one should be present.

The auto white detect block consists of C4, C7, D1, D2, R7, R8 and IC3-a, an LM358 op-amp. A rudimentary ramp-and-hold circuit is comprised of D1, C4, and R8. The diode allows voltages greater than the capacitor voltage to charge the capacitor, lower voltages are blocked from discharging the capacitor. This way, the capacitor will charge up to the highest voltage in the incom-

ing signal and hold at that point. A drawback to the arrangement is that there is a difference of one diode forward voltage drop between the actual value stored on the capacitor and the true peak. Bleed resistor R8 discharges the capacitor slowly so the circuit can follow slowly changing signal peaks.

The peak-diode voltage is fed into pin 3 of IC3-a. Diode D2 in the feedback loop of IC3-a forces the output to be one diode drop above the incoming signal so the output of the op-amp is restored to the true level of the stored peak. A load to the op-amp is presented by R7 so that its output circuits can function properly, and C7 filters any high-frequency variations and lowers the impedance of the output as seen by the positive reference input of the A/D converter.

All the work is done except for synchronizing the software and the hardware, and getting the data into the PC's printer port. When the counter modulo 320 block detects a match between the desired input pixel and the actual pixel, a pulse is sent to

IC6. This pulse arms the dual-pulse generator to produce two pulses to the A/D converter, which makes the data available for input, and sets the DATA READY output.

From our discussion about the printer port, it should be clear that no one port will allow the simultaneous input of the six data lines from the A/D converter, so some sort of data multiplexer is needed. A multiplexer is used in IC6, and is controlled by the SELECT line from the printer port. The software can read the top four bits of data immediately when it finds DATA READY true. Software then raises the SELECT line to see the other two databits, and in doing so, resets DATA READY for the next conversion.

Some comments on the PEEL's are in order here. Do not use a normal 22V10 for IC5 as the strobe term (pin 19) requires 17 product terms, and a 22V10 has 16. The 17th product term is derived by feeding back the output into the tri-state enable term. A normal 22V10 in combinatorial output cannot feed that term back from its tri-state output pin. PEEL part 22CV10 can be put into a 22CV10Z mode where additional feedback terms are available beyond those present in a standard 22CV10. A software listing to program IC5 and IC6 can be downloaded from the **Radio-Electronic** BBS under file name V10PEEL.ZIP (516-293-2283, 1200/2400, 8N1). A printout of the software listings are also provided for your information.

Power regulation is controlled by an output line from the interface and IC3-b, Q1, C10, D3, and R12. The board is powered by a 9-volt battery, and the power control circuit's job is to make the battery last. A reference of 5.1 volts is formed by R12 and D3, which can be switched off by the output line of the interface. Since the output line can pull the output low, or allow it to float, the reference can be switched from 5.1 volts to near ground. The reference is fed to the non-inverting input of IC3-b, which is configured as a voltage follower with Q1, providing increased current capability.

When the computer is off, the output voltage is low. When the

LISTING 1

PEEL18CV8 8-BIT COUNTER WITH FUNCTION CONTROLS

P22CV10Z

```
"DESCRIPTION          FRUGAL TIMING GENERATOR
"
"                      PEEL22CV10
"
"                      CLK { 1 24 } Vcc
"                      PIX0 { 2 23 }- B1 ( - = output )
"                      PIX1 { 3 22 }- B3
"                      PIX2 { 4 21 }- B5
"                      PIX3 { 5 20 }- B7
"                      PIX4 { 6 19 }- ST
"                      PIX5 { 7 18 }- B8
"                      PIX6 { 8 17 }- B6
"                      PIX7 { 9 16 }- B4
"                      ODD {10 15 }- B2
"                      {11 14 }- B0
"                      GND {12 13 }
"
"PIN ASSIGNMENTS
"
CLK      pin 1
PIX0     pin 2
PIX1     pin 3
PIX2     pin 4
PIX3     pin 5
PIX4     pin 6
PIX5     pin 7
PIX6     pin 8
PIX7     pin 9
ODD      pin 10
"
"Outputs"
"
ST       pin 19 = pos com feed_or
B8       pin 18 = pos reg
B7       pin 20 = pos reg
B6       pin 17 = pos reg
B5       pin 21 = pos reg
B4       pin 16 = pos reg
B3       pin 22 = pos reg
B2       pin 15 = pos reg
B1       pin 23 = pos reg
/B0      pin 14 = neg reg
"
"Internal Nodes"
"
AC       node 25          "Asynchronous Clear node.
SP       node 26          "Synchronous Preset node.
"
EQUATIONS
"
B0      := /B0
ENABLE B0 = B8 * /B7 * /B6 * B5 * /B4 * /B3 * /B2 * /B1 * B0
"
B1      := /B1 * B0
          + B1 * /B0
"
```

computer is on and boots up, DOS configures the printer port so that power is off. The software turns the power on only when an image is actually being digitized. Note that the ground pins on the interface are divided into two groups, even though they are connected inside the interface. The negative line from the bat-

tery is connected to one group of ground pins, and the rest of the components on the board to the other group. This way, when the digitizer is removed from the computer, the negative line from the battery is mechanically disconnected from the components on the board, turning the power off and disconnecting the battery.

```

B2 := /B2 * B1 * B0
+   B2 * /B1
+   B2 * /B0

B3 := /B3 * B2 * B1 * B0
+   B3 * /B2
+   B3 * /B1
+   B3 * /B0

B4 := /B4 * B3 * B2 * B1 * B0
+   B4 * /B3
+   B4 * /B2
+   B4 * /B1
+   B4 * /B0

B5 := /B5 * B4 * B3 * B2 * B1 * B0
+   B5 * /B4
+   B5 * /B3
+   B5 * /B2
+   B5 * /B1
+   B5 * /B0

B6 := /B6 * B5 * B4 * B3 * B2 * B1 * B0
+   B6 * /B5
+   B6 * /B4
+   B6 * /B3
+   B6 * /B2
+   B6 * /B1
+   B6 * /B0

B7 := /B7 * B6 * B5 * B4 * B3 * B2 * B1 * B0
+   B7 * /B6
+   B7 * /B5
+   B7 * /B4
+   B7 * /B3
+   B7 * /B2
+   B7 * /B1
+   B7 * /B0

B8 := /B8 * B7 * B6 * B5 * B4 * B3 * B2 * B1 * B0
+   B8 * /B7
+   B8 * /B6
+   B8 * /B5
+   B8 * /B4
+   B8 * /B3
+   B8 * /B2
+   B8 * /B1
+   B8 * /B0

ST = PIX0 * /B0 + /PIX0 * B0
+   PIX1 * /B1 + /PIX1 * B1
+   PIX2 * /B2 + /PIX2 * B2
+   PIX3 * /B3 + /PIX3 * B3
+   PIX4 * /B4 + /PIX4 * B4
+   PIX5 * /B5 + /PIX5 * B5
+   PIX6 * /B6 + /PIX6 * B6
+   PIX7 * /B7 + /PIX7 * B7

ENABLE ST = /B8 * /ST

AC = B8 * /B7 * B6 * /B5 * /B4 * /B3 * /B2 * /B1 * /B0

```

This eliminates the need for an on/off switch, and never allows the unit to be left on, draining the battery.

Construction

A photo of the authors finished image-capture board is shown in Fig. 4. As you can see, it is a very compact board, so 1/8-watt re-

sistors are used. To fit in the low-profile packaging, axial tantalum and ceramic capacitors are used. The circuit is mounted on a double-sided PC board. An etched, drilled and plated-through PC board is available from the source mentioned in the parts list, or you can make your own from the foil patterns we have

provided.

Follow the parts-placement diagram shown in Fig. 5 when installing the components. All the normal precautions for handling static-sensitive CMOS circuits should be observed. Use a soldering iron with a fine tip and a power rating of 30 watts or less. Load and solder the IC's first, being sure to orient pin 1 correctly. Make sure you observe the correct polarity on the tantalum capacitors. Follow with the resistors, then the diodes, and finally the connectors.

The DB25 connector is a tight press fit on the end of the board. The side of the connector with 13 pins lines up with the traces on the component side of the board, with the row of 12 pins on the solder side of the board. Line up the pins and traces and push the connector and the board together. Apply solder to the pins and traces to insure a good electrical contact. The last component is Q1, normally supplied in a plastic TO-92 case with in-line leads. The flat side in the case is a match for the legend on the circuit board. Bend the center lead in a direction opposite the flat side to fit the staggered hole pattern in the board. Push the part down into the board until the bottom of the case is about 1/8 inch from the board, then solder the leads. Finish the assembly by cleaning the flux residue from the board. Any standard electronic flux remover can be used, or a solvent which leaves no residue such as 1,1,1 trichloroethane, which is available in hardware stores.

Troubleshooting and use

Inspect both sides of the assembled board for any shorts or solder bridges. This is a small board so use a magnifying glass for this job. Correct any flaws now. The power-supply portion of the circuit can be checked by connecting a 9-volt battery to the battery clip, and a jumper from any of the connector pins 23, 24, or 25 to any of pins 18-21. All of those pins are now ground. Connect a volt meter from ground to pin 20 of IC6. A 5-volt $\pm 10\%$ reading should be present. If not, check the voltage at pin 5 of IC3, which is the Zener reference. If this is not very close to 5 volts,

there's either a problem with the Zener (check the polarity and for shorts) or with the input to the op-amp. If the Zener reference checks out, check the placement of Q1. If all this checks out, there is probably a short downstream somewhere. A failed IC is a possible, but not probable cause. Check your soldering and parts placement first.

If all looks good with the power supply, you can attempt to take a picture. Since most people interested in imaging on the PC will have a hard disk, we will discuss that arrangement. Make a new directory of the main program on your PC, call it whatever you like. Place the floppy disk with the Supervision software (you must have version 2.6 or higher for Frugalvision support) in your floppy drive and copy its contents to the new directory. Now enter this directory and run the program VSETUP, and enter the appropriate answers for your system, saving the results.

Take whatever jumpers you put on the card off and connect it to the printer port of your PC. Attach a video source to the board via the F-61 connector and make sure the source is sending video. The card is designed to work with baseband video (as supplied by most cameras) and not with RF-modulated video. (If you normally attach your video source to the antenna terminals of your TV, this is not the correct video for Frugalvision.) Now run VGRAB. The program will check for the presence of a Supervision or Frugalvision board. If none is identified, a commercial telling you about IDEC will appear on the screen. If that occurs, go back and check that your setup is producing video, a fresh 9-volt battery is connected to Frugalvision, and you answered the questions in VSETUP correctly.

If all is correct, and you have a scope, you can check some of the following points on the card. Look for a 1-volt peak to peak video signal on R1. This is a 75-ohm termination and should be the only termination in the video cable. If the signal is significantly below 1 volt, it is usually caused by another termination in the system. If another termination is present, such as on a video monitor in the system, both

LISTING 2

PEEL18CV8 SYSTEM CONTROLLER

P18CV8

```
"DESCRIPTION          FRUGAL USER INTERFACE
"
"                      PEEL18CV8
"
"                      |-----|
"                      |  \  /  |
"                      |-----|
"          CLK { 1      20 } Vcc
"          D5  { 2      19 }- OUT7   ( - = output )
"          D4  { 3      18 }- OUT6
"          D3  { 4      17 }- OUT5
"          D2  { 5      16 }- OUT4
"          D1  { 6      15 }- AD1
"          D0  { 7      14 }- DRDY
"          ST  { 8      13 }- AD0
"          BST { 9      12 }- VID
"          Gnd {10      11 }- DRD
"
"
```

"PIN ASSIGNMENTS

```
CLK      pin 1
D5       pin 2
D4       pin 3
D3       pin 4
D2       pin 5
D1       pin 6
D0       pin 7
ST       pin 8
BST      pin 9
DRD      pin 11
```

"Outputs"

```
VID      pin 12 = pos com feed_or
AD0      pin 13 = pos reg feed_reg
DRDY     pin 14 = pos com feed_or
AD1      pin 15 = pos reg feed_reg
OUT4     pin 16 = pos com feed_or
OUT5     pin 17 = pos com feed_or
OUT6     pin 18 = pos com feed_or
OUT7     pin 19 = pos com feed_or
```

"Internal Nodes"

```
AC       node 21          "Asynchronous Clear node.
SP       node 22          "Synchronous Preset node.
```

EQUATIONS

```
VID = BST * /BST          OUT4 = D2 * DRD
ENABLE VID = /BST        + D0 * /DRD

DRDY = /ST                AD0 := /AD0
+ DRDY * DRD             + AD0 * AD1

OUT7 = /D5                AD1 := /AD1 * AD0
+ AD1 * /AD0              + AD0 * AD1

OUT6 = D4                  AC = /ST

OUT5 = D3 * DRD           + D1 * /DRD
```

should not be terminated. Correct that problem. If all is well here, move to pin 2 of IC1, which should be a baseband video sig-

nal with the sync tips at 1.5 volts. If that's not the case, check around IC1 for shorts or open (cold solder) joints.

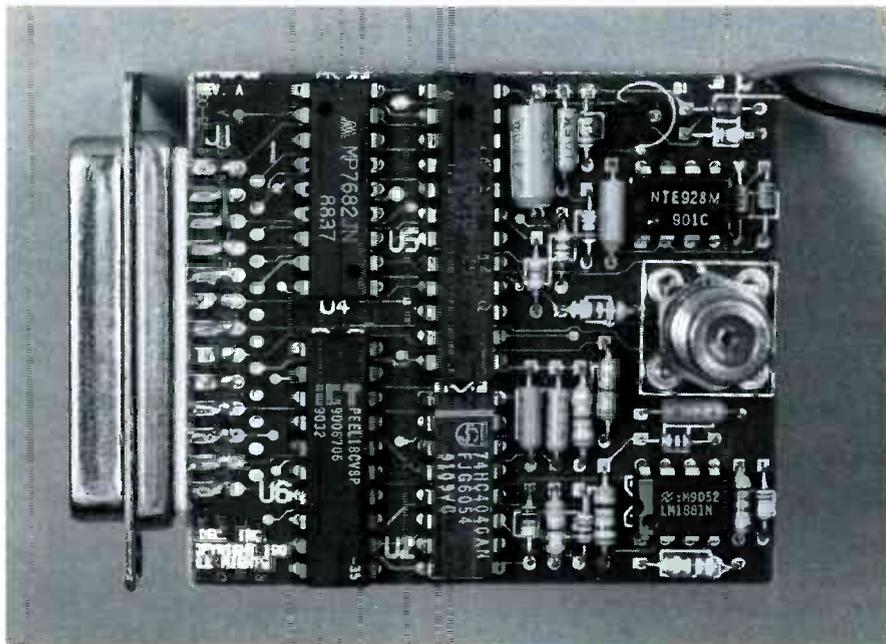


FIG. 4—THE AUTHOR used 1/8-watt resistors for a compact finished product.

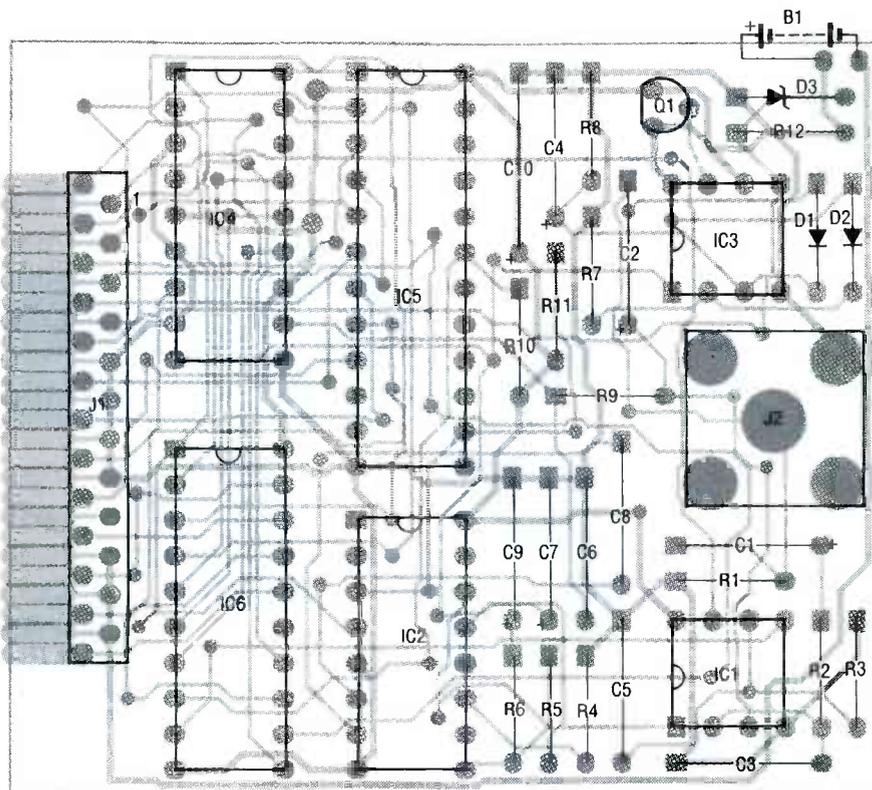


FIG. 5—FOLLOW THIS PARTS-PLACEMENT diagram when assembling the Frugalvision.

If all is correct, check pin 1 for a strong (0 to 5-volt) composite-sync signal. Check pin 3 for a vertical-sync signal, pin 5 for a good color-burst signal (looks like the composite sync signal) and pin 7 for the odd/even signal. The odd/even signal is the real indicator of circuit health, and is the first one to become erratic. It should be a 0 to 5-volt square wave with a re-

peatable half cycle time of 16.6 ms, the period of one RS-170 field. If one or all of these signals are not present, check the whole area. The 680K-ohm resistor R3 is most important in producing the odd/even signal. It should not be replaced by any other value, and because of its high impedance, all flux should be removed from the board.

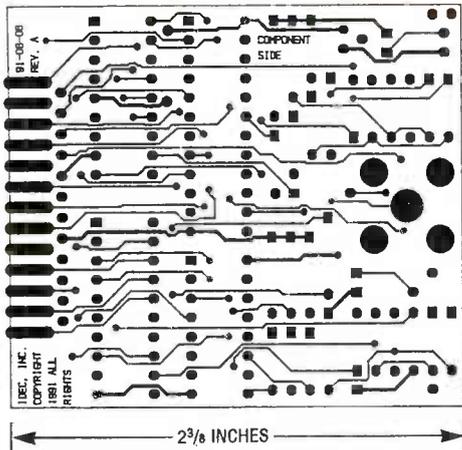
If everything is okay up to this point, pin 4 of IC2 should be producing a waveform with a frequency close to 5 MHz. Another check on the phase-locked loop is to monitor pin 9. This should be a signal whose normal level is between 2 and 3 volts, with a spike at every vertical sync (16.6 ms interval) decaying rapidly back to the steady DC level. If that does not occur, check around the PLL and its associated parts for opens or shorts. The remainder of the circuits interact with the software, and are very difficult to trouble shoot. Being digital in nature, they are very reliable. Since the board does not have nor require any adjustments, boards which fail to generate a picture are normally due to errors in construction, parts placement, orientation, and improper soldering.

If VGRAB finds the card correctly (no commercial), the main menu will appear on the screen. Simply press enter to capture and image. This process takes about eight seconds, and then the screen is blank during this period with the exception of the "Press esc to return" message on the right side of the screen. When the picture is displayed, return to the main menu to save the image or for additional image processing functions.

Since Frugalvision does not pass the printer-port lines through, the printer must be disconnected when capturing images, and reconnected when printing. A solution to this is a separate printer port for Frugalvision. Frugalvision processes data at very high speed, and therefore should not be connected to any significant length of cable (more than about 3 inches), so connection to a printer-port switch box is out. The author has tried it and doesn't like the picture. Since capturing images is not done all the time, flipping cables is normally acceptable. In that case, remember that when Frugalvision is connected, a printer is not so don't try to use the printing functions of Supervision software until a printer is connected back up.

Software comments

A very capable software package the author used for sche-



COMPONENT SIDE for the PC board.

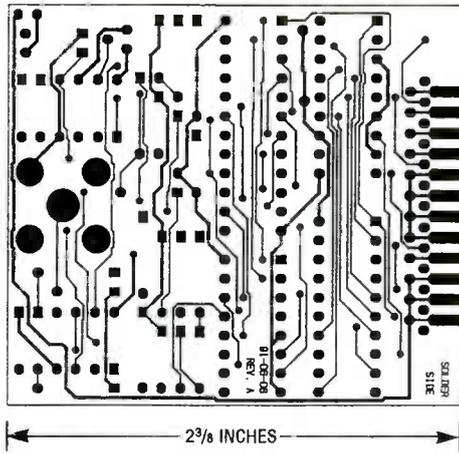
matic capture and board auto-routing is the Draftsman-EE, a PC-based CAE tool from Design Computation, Inc. Design Computation also offers excellent customer support.

Frugalvision's images work with many different software packages, but older paint programs, which state they are TIFF and PCX compatible, are compatible with older versions of those standards. Specifically, they are compatible with TIFF B

(black and white, no grays) and 16-color PCX. The author's program produces TIFF G (gray scale) and 256-color PCX which is a requirement to store the 64 and 256 gray-scale images. Newer programs such as PC Paintbrush 4 work well with the files but usually require a VGA screen to do so.

High-end publishers such as Ventura and Pagemaker accept Frugalvision files with no trouble, and do an excellent job of printing images.

For the image experimenter, there is a very effective C-language library of image processing and hardware support functions from Catenary Systems called the *VICTOR* image processing library. It contains full standard memory, EMS and extended memory support, laser printer support, and low-level hardware support for Frugalvision cards. In fact, nearly all the functions in VGRAB are done by using the support in that package. Anyone doing serious programming in the image-processing field should look into the *VICTOR* package.



SOLDER SIDE for the PC board.

Catenary also produces *COLOR KIT*, another software product that works with Frugalvision boards. This product provides three colored plastic filters (red, green, and blue) to place in front of the camera lens at capture time. Three files are saved and the color-kit software assembles these files into a full-color image. The pictures that are produced on a 256-color VGA screen have to be seen to be believed.

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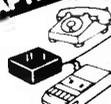
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Circuit description

As shown in Fig. 1, an NE5534N low-noise, low-distortion op-amp, IC1, is configured as a Wien Bridge sine-wave oscillator. Carefully matched RC values (R2-C1 and R3-C2) in the frequency-selective positive feedback network contribute to its low distortion level. Resistor R1 and bulb LMP1 form the stabilized negative feedback network that provides a constant-amplitude output signal. DC offset control R4 keeps DC current out of LMP1, which minimizes second harmonic distortion content. Filter network R6-C6 further reduces any residual-distor-

tion. After passing through fixed and variable attenuators, plus a buffer amp (IC2), the signal emerges at output jack J1.

The output signal from J1 drives the input of the device under test (DUT), usually an amplifier. The DUT's output, which includes some degree of distortion, is applied to the input of the analyzer at jack J2. The fundamental frequency (1 kHz) is then removed from the output signal of the DUT, leaving only harmonic distortion components.

Combination notch/high-pass filter circuits IC3 and IC4 (both TLO74's) perform the removal function. One feature of IC3's three-stage RC active filter is that it maintains a constant 45-dB notch depth over its full tuning range. The filter is connected in series with an identical second filter (IC4), to provide a 90-dB notch of the fundamental signal. The resultant frequency response of the combined filters is 27 dB down at 20 Hz, which helps suppress 60-Hz hum and

THD ANALYZER

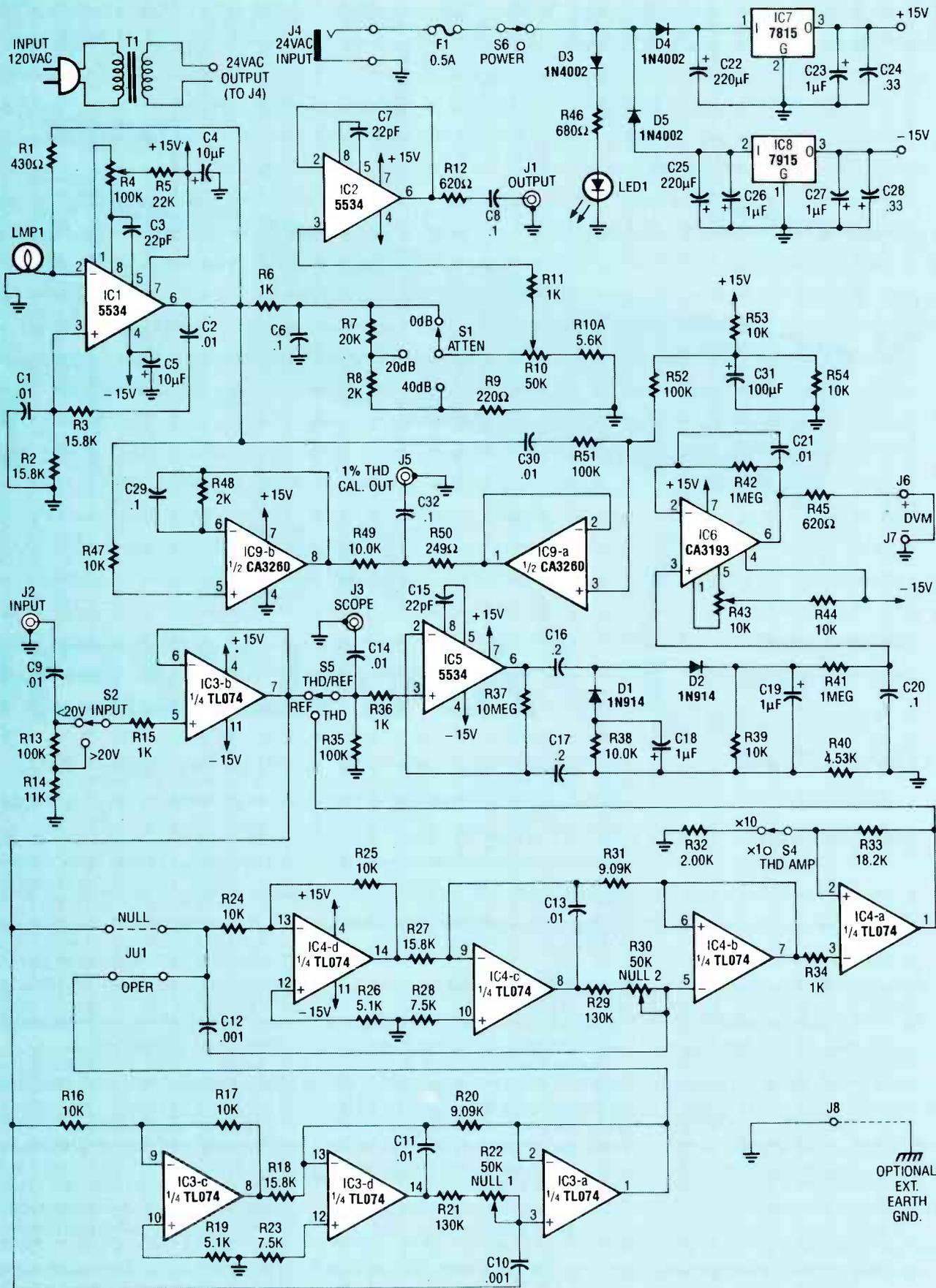


FIG. 1—SCHEMATIC DIAGRAM of the simple THD analyzer. An NE5534N op-amp (IC1) is configured as a Wien Bridge sine wave oscillator. Carefully matched RC values in the frequency-selective positive feedback network contribute to the low distortion level. Resistor R1 and incandescent bulb LMP1 form the stabilized negative feedback network that provides a constant-amplitude output signal.

other low-frequency noises. Above the 90-dB notch frequency, the response is flat (± 0.5 dB) from 2 kHz to 100 kHz.

When S4, the THD/REF switch, is in the THD position, a signal containing only THD components is channeled through from the output of the $\times 1/\times 10$ THD amp (IC4) to the input of the AC-to-DC converter, IC5. Although both polarities of the applied signal are rectified by this circuit, only the positive averaged signal is fed to the low-pass filter R41-C20. The output buffer, IC6, is a CA3194 precision op-amp, stable enough to provide accurate volt, millivolt, and microvolt DC level output signals to an external DVM.

Dual op-amp IC9, a CA3260, serves as a calibrator. The first stage affords precision half-wave rectification of the master oscillator's signal. That same applied signal is AC coupled by C30 to the second stage, biased at $\frac{1}{2} V_{CC}$, for linear transfer to its output. Voltage divider R49-R50 mixes a very small portion of half-wave output at pin 7 of IC9 with a much larger full sine wave seen at pin 1. Since the signal swings slightly more positive from its quiescent level than it does in the negative-going direction, it is considered to have a specific amount of second harmonic distortion. That amount, by design, is one percent.

Wall transformer T1 feeds half-wave power diodes D4 and D5 through connector J4, fuse F1, and power switch S5. Capacitors C22 and C25 are the principal filters for the positive and negative supplies, respectively. Smaller filters, C23 and C27, along with high-frequency transient suppressors C24 and C28, are included at the output side of regulators IC7 (a 7815 +15-volt regulator) and IC8 (a 7915 -15-volt regulator).

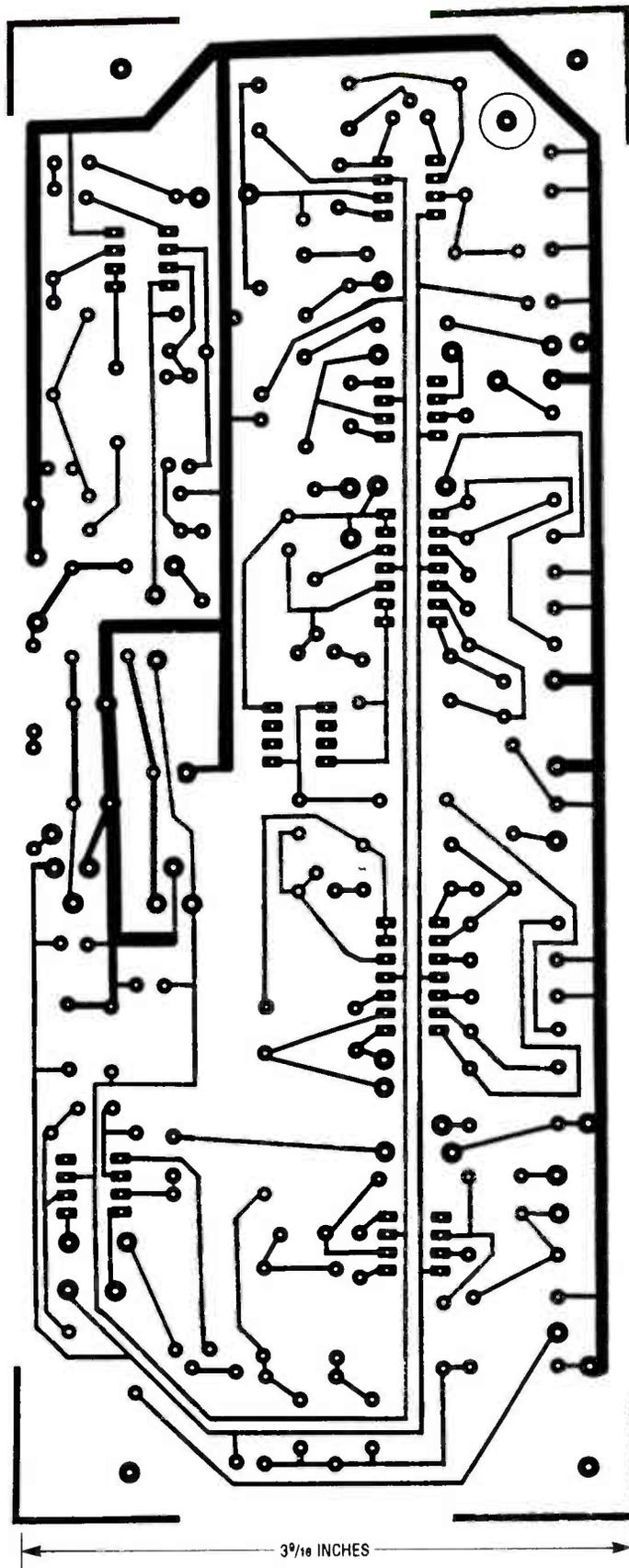
Construction

Breadboard assembly of the analyzer is not recommended, although a seasoned builder may wish to attempt it. It's best to either make your own PC board from the foil pattern we've provided, or order one from source mentioned in the parts list.

Mount all components as shown in Fig. 2. Check orienta-

tion of all polarized parts as you install them, and the use of IC sockets is suggested. All power-

line wiring, including the LED1 indicator, uses two wires plus a shield. Connect the shield wires



FOIL PATTERN for the THD meter shown actual size.

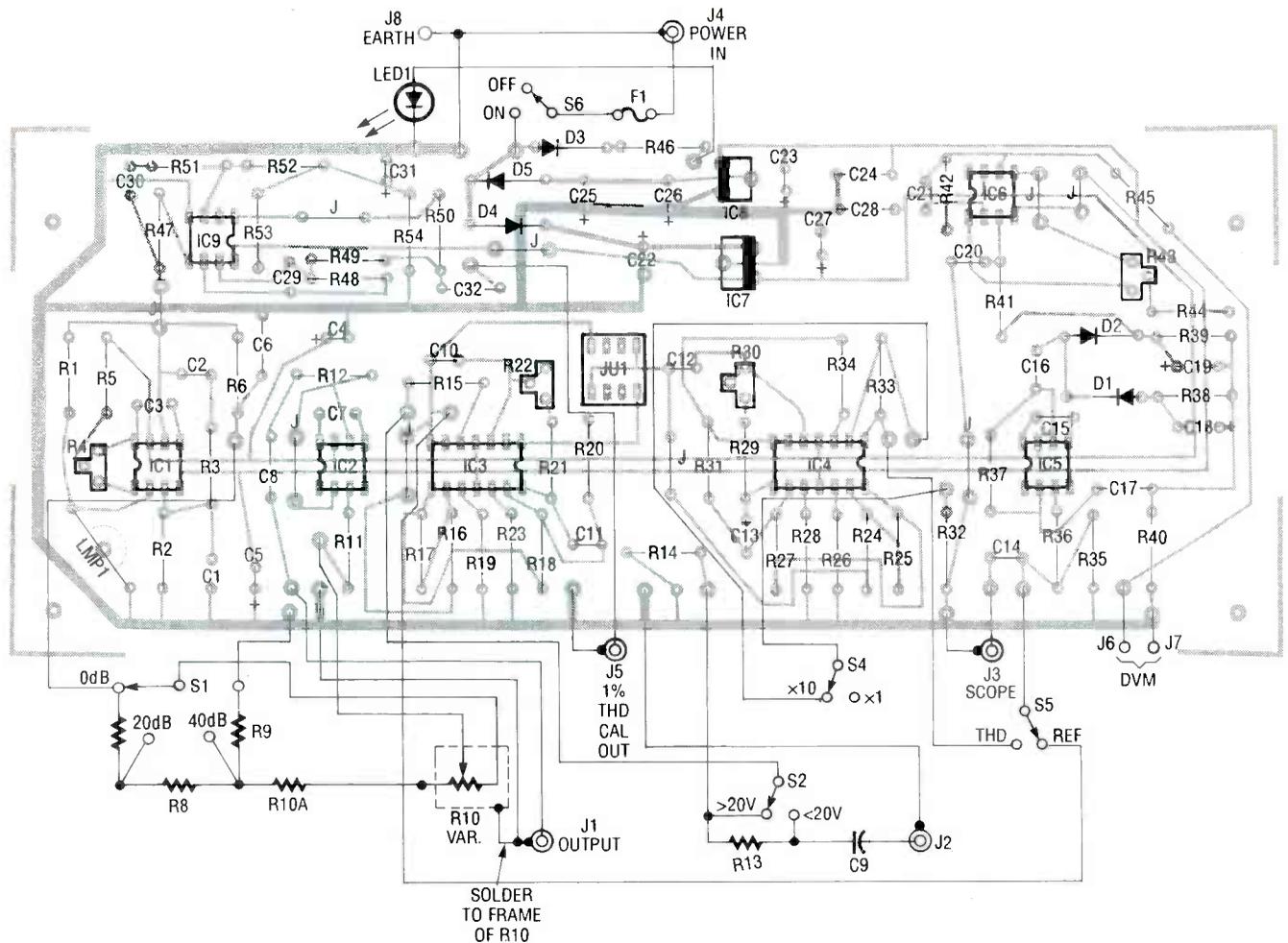


FIG. 2—PARTS PLACEMENT DIAGRAM. Note that JU1 is actually an 8-pin DIP socket in which a jumper is placed in either the far-left or -right side (see text). Also note the six components soldered to the front-panel-mounted controls.

together and then to ground, to prevent hum pick-up. Also, ground the frame of potentiometer R10. Bare ground wires for each BNC connector may be wrapped around the connector body prior to installing the retaining nut. The ground binding post (J8) on the rear panel provides an optional, external earth-ground connection when measuring microvolt-level THD signals. Just connect J8 to circuit ground. The grommet used to hold bulb LMPI should have a 1/4-inch inside diameter. It is glued to the top side over the hole for maximum resiliency.

In addition to the components that are soldered to the circuit board, also note that five resistors and one capacitor are soldered across the terminals of panel-mounted controls S1, R10, S2, and J2 (see Fig. 2).

Capacitors C1 and C2 must be matched to better tolerances

than their marked 1% values. If you don't own or can't borrow a capacitance meter, you can build and use the simple circuit shown in Fig. 3. Adjust the calibration potentiometer with any one of the four 0.01 μF capacitors (C1, C2, C11, or C13) inserted as C_x , to read 1.000 volt on your DMM's 2-volt DC range. (You can consider the reading to be 0.01000 μF .) Now measure the remaining three capacitors and select the two that are closest in value. Absolute value is not important; we simply want them to be the same value. However, if one capacitor measures 80 pF lower than another, you can solder an 82-pF mica capacitor on the underside of the PC board in parallel with the selected capacitor. The leftover 1% 0.01 μF capacitors can be used for C11 and C13 without having to be closely matched.

Likewise, resistors R2 and R3 must be close in value. Using

your DMM on its 20K resistance range, select two 15.8K resistors that are the closest in value. If the match is less than perfect, solder a small-value resistor in series with the lower value to raise it to the exact value of the higher one. You can mount two resistors in place of one by putting one through each hole in the board and soldering the raised ends together. Again, the leftover 1% 15.8K resistors can be used for R18 and R27 without having to be closely matched.

You may wish to build your own enclosure for the THD meter. A silk-screened front panel measuring 9 3/4 inches wide by 3 inches high can be purchased from the source mentioned in the parts list. If you decide to purchase the front panel, and build your own enclosure, build it to fit the front panel and drill several 1/4-inch holes in the top panel near the voltage regulators to allow heat to escape. Otherwise you can purchase the same enclosure used for the prototype; the exact

PARTS LIST

All resistors are ¼ watt, 5%, unless otherwise indicated.

R1—430 ohms
 R2, R3, R18, R27—15,800 ohms, 1%, metal film
 R4—100,000 ohms, PC-mount potentiometer
 R5—22,000 ohms
 R6, R11, R15, R34, R36—1000 ohms
 R7—20,000 ohms
 R8, R48—2000 ohms
 R9—220 ohms
 R10—50,000 ohms, panel-mount potentiometer
 R10A—5600 ohms
 R12, R45—620 ohms
 R13, R35—100,000 ohms
 R14—11,000 ohms
 R16, R17, R24, R25, R38, R39, R49—10,000 ohms, 1%, metal film
 R19, R26—5100 ohms
 R20, R31—9090 ohms, 1%, metal film
 R21, R29—130,000 ohms
 R22, R30—50,000 ohms, PC-mount potentiometer
 R23, R28—7500 ohms
 R32—2000 ohms, 1%, metal film
 R33—18,200 ohms, 1%, metal film
 R37—10 megohms
 R40—4530 ohms, 1%, metal film
 R41, R42—1 megohm
 R43—10,000 ohms, PC-mount potentiometer
 R44, R47, R53, R54—10,000 ohms

R46—680 ohms
 R50—249 ohms, 1%, metal film
 R51, R52—100,000 ohms, 1%, metal film

Capacitors

C1, C2, C11, C13—0.01 μ F, 100 volts, 1% Mylar
 C3, C7, C15—22 pF, 300 volts, mica
 C4, C5—10 μ F, 25 volts, tantalum
 C6, C8, C20, C29, C32—0.1 μ F, 50 volts, Mylar
 C9, C14, C21, C30—0.01 μ F, 50 volts, Mylar
 C10, C12—0.001 μ F, 100 volts, 1% Mylar
 C16, C17—0.2 μ F, 50 volts, Mylar
 C18, C19, C23, C27—1.0 μ F, 25 volts, tantalum
 C22, C25—220 μ F, 50 volts, electrolytic
 C24, C28—0.33 μ F, 50 volts, Mylar
 C26—1 μ F, 50 volts, tantalum
 C31—100 μ F, 25 volts, electrolytic

Semiconductors

IC1, IC2, IC5—NE5534N low-noise op-amp
 IC3, IC4—TL074 quad low-noise op-amp
 IC6—CA3193E precision op-amp
 IC7—7815 positive 15-volt regulator
 IC8—7915 negative 15-volt regulator
 IC9—CA3260E dual MOSFET-input op-amp
 D1, D2—1N914 diode
 D3—D5—1N4002 diode

LED1—Red light-emitting diode

Other components

S1—Panel-mount, 2-pole, 6-position switch
 S2, S4—S6—Panel-mount miniature SPDT toggle switch
 S3—Not used
 JU1—8-pin DIP socket or jumper block
 T1—120VAC/24VAC, 200 mA wall transformer
 J1—J3, J5—Panel-mount male BNC connector
 J4—Coaxial power input jack
 J6—J8—Panel-mount binding post
 LMP1—Incandescent bulb, #327
 F1—Fuse, 0.5A, 120 VAC

Miscellaneous: Project case (Jameco Electronics H2507), two ½-inch diameter instrument knobs, seven 8-pin IC sockets, (not including JU1), fuse holder, LED bezel, grommet, shielded cable, wire, solder, hardware, etc.

Note: The following items are available from Instrumex, P.O. Box 490, Blue Bell, PA 19422:

• Etched, drilled, and plated PC board and silk-screened plastic front panel (both to fit case mentioned above—\$25.00 + \$3.00 S&H)

PA residents must include 6% sales tax.

Allow 2–4 weeks for delivery.

model number is listed in the parts list, and the front panel is designed to fit it perfectly. Figure 4 shows the completed prototype.

Adjustments

Using a DMM on its millivolt-DC range, connect it between pin 6 of IC1 and ground. Adjust R4 for a reading of 000.0 mV on the meter. Next, set the INPUT switch (S2) to ">20V," the THD AMP switch (S4) to "×10," and the THD/REF switch (S5) to "THD." With the DMM still set to read millivolts DC, connect its leads across the + and - DVM binding posts (J6 and J7) and adjust R43 for a reading of 000.0 mV on the meter.

Filter-null adjustments may be made with an oscilloscope or DMM on its lowest AC voltage range (typically 2 volts). Insert a jumper in the JU1 jumper block (NULL-OPER) in the left-most position when facing the front panel (next to R22, or the "null" posi-

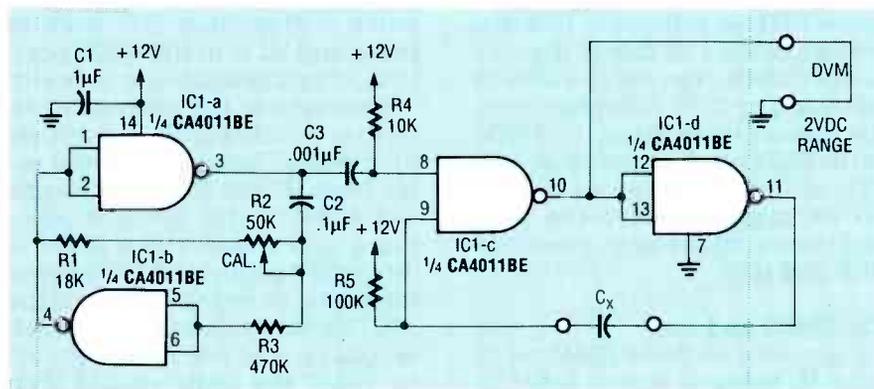


FIG. 3—HERE'S A ONE-IC CAPACITANCE TESTER used to match C1 and C2. See text for details.

tion). Connect a short coaxial cable between OUTPUT jack J1 and INPUT jack J2. With power on, and S2 in the "<20V" position, S4 in the "×1" position, S5 in the "THD" position, and the rotary ATTEN-DB switch (S1) and VAR potentiometer (R10) in the minimum attenuation position, or fully counter-clockwise.

Connect a scope or voltmeter to

the IC4-pin-7 side of R31, and connect the ground lead to any ground in the area. If you're using a scope, set VOLTS/DIV switch (on the scope) to any position between 5 and 50 mV/div. Carefully adjust potentiometer R30 for the best null on a scope screen, or lowest reading on a meter.

Transfer the test probe to the

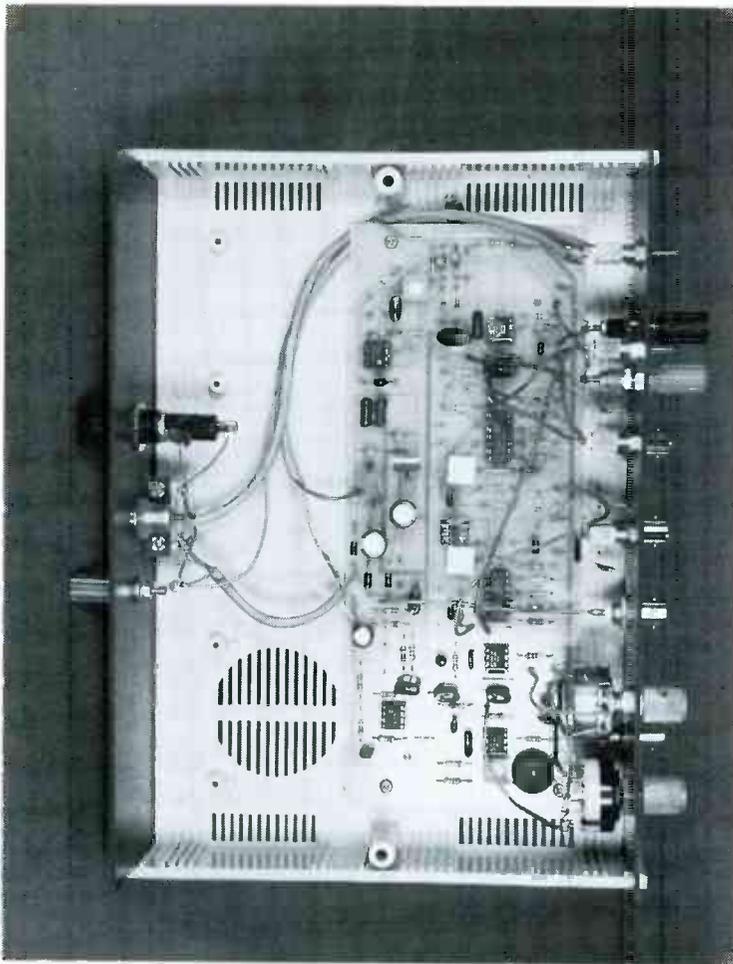


FIG. 4—THE COMPLETED PROTOTYPE. Notice how the incandescent bulb (LMP1) is protected from damage by a rubber grommet.

IC3-pin-1 side of R20. Adjust R22 for a minimum reading on the scope CRT or voltmeter. Insert a jumper in the C12 side of the JU1 jumper block. You may be able to squeeze 1 or 2 dB more null from the system by shifting the DMM to the DVM binding posts (J6 and J7), setting the meter to its 200 mV DC range, setting S4 to $\times 10$, and trimming the adjustments of R22 and R30.

Checkout and use

Connect a scope or DMM set to read AC volts to output jack J1. Rotate S1 and R10; the output signal voltage should vary accordingly. Remember that the controls are attenuators, not gain controls, so maximum signal occurs in the counterclockwise position.

Check the INPUT P-P switch S2 by applying the signal from J1 to J2, setting S5 to "REF," and measuring the AC output at J3. The output signal should be maximum with S2 in the $<20V$ position and minimum in the $>20V$

position. It's important to note that if the input signal to J2 goes much higher than 20V peak to peak, and S2 is in the $<20V$ position, clipping will begin to occur.

You can use the analyzer's calibrator to check all remaining functions. Connect a coaxial cable from J3 to J2. Set all toggle switches to the upright positions, and connect your DMM to J6 and J7 set to read DC volts or millivolts, as required. Now, if the THD signal reads 24.0 mV, which is 0.024V, and you switch the S5 to "REF," the DMM should then read 2.40V, or a number very close to that. When the resulting fraction (0.024/2.4) is multiplied by 100 it should produce a THD percent figure of one percent.

Figure 5 shows the test setup for THD measurements. Say that we are measuring percent THD of a 50-watt amplifier that's connected to an 8-ohm power resistor load. By ohms law, it will take 20 volts across 8 ohms to produce 50 watts. Now let's say

continued on page 59

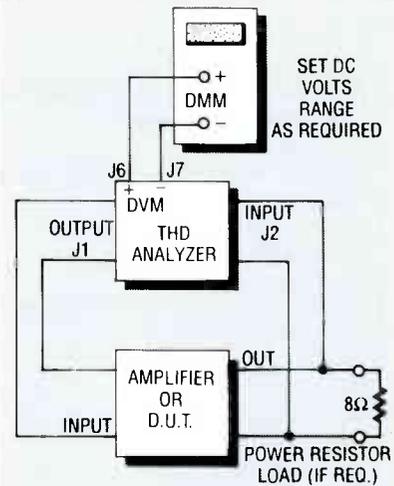


FIG. 5—BLOCK DIAGRAM OF TEST setup. Most THD measurements can be made in this manner.

THD MEASUREMENT

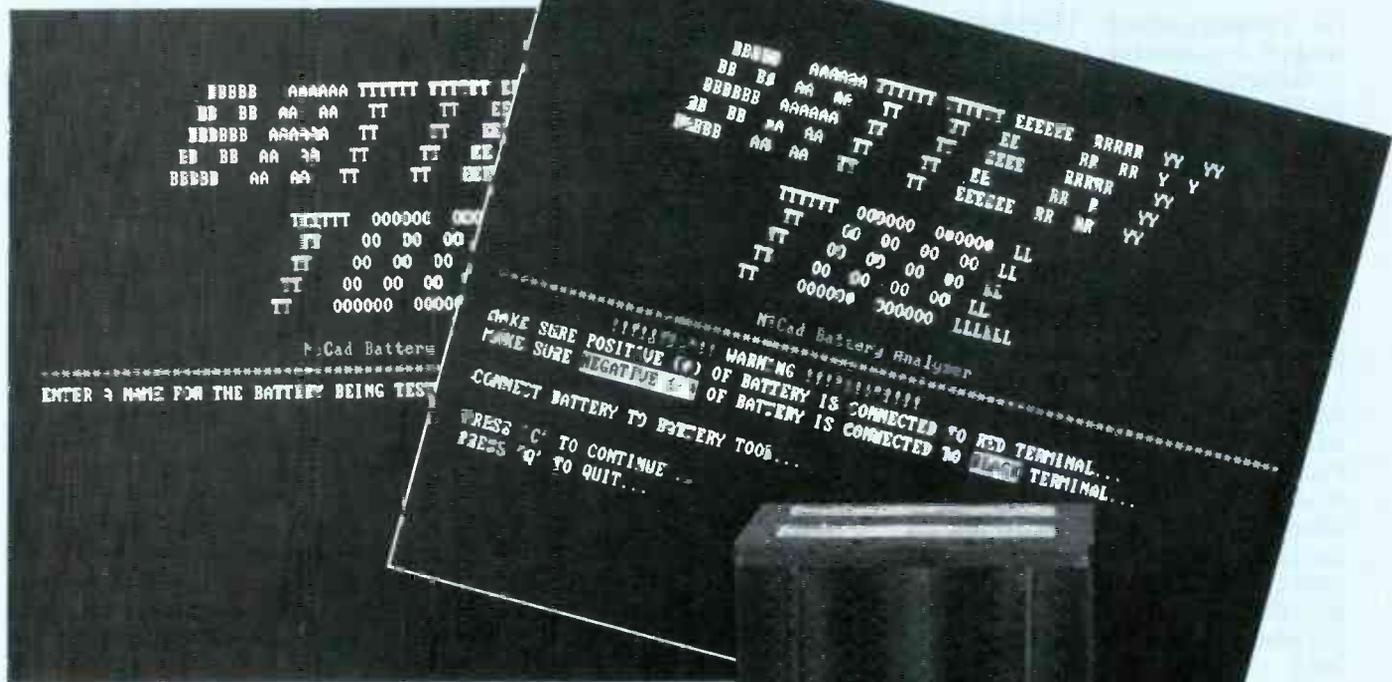
When a pure or undistorted sine wave is applied to a circuit containing vacuum tubes, transistors, or op-amps, which is used to provide linear transfer of the signal, some degree of distortion always appears at the output.

As the near-perfect sine wave travels through the device under test (DUT), its shape is altered due to inherent nonlinearities within the circuit. Waveform alteration is the equivalent of adding harmonics, or multiples of the fundamental frequency, in varying phases and amplitudes to the fundamental signal. It can be shown mathematically and by measurement that these spurious harmonic components are vested within the output signal's waveshape.

Spectrum analyzers are used to sweep over the frequency range of interest, separating the fundamental and its harmonics into individual signals. It provides a CRT display of these various signals, including odd and/or even harmonics in their proper amplitudes and frequency locations relative to the fundamental. Similar instruments use digital signal processing techniques rather than a sweep method to provide more in-depth data including phase angles.

Wave analyzers are essentially tuned filters that include a measurement window that is manually frequency shifted through the range of interest. It offers meter-read-out amplitude measurements of the various harmonics relative to the fundamental frequency.

THD analyzers are used to notch out the fundamental from the DUT's output signal leaving only the harmonic components intact. It then measures the sum total of the residual signals in terms of their RMS or average values, and compares them to the overall amplitude of the output signal which is taken as a 100 percent reference. The ratio of the THD measurement to the reference, multiplied by 100, equals the percent THD. R-E



BUILD THE BATTERY TOOL



Get the most out of your rechargeable batteries with this microcontroller-based battery discharger.

FRED EADY

TIMES HAVE CHANGED—YOU'D PROBABLY BE SURPRISED AT THE number of devices containing some sort of rechargeable battery that you use on a regular basis. Cordless phones, mixers, radio-controlled gear, emergency flashlights, camcorders—and even vacuum cleaners—are just a few examples. The list goes on, but let's just say that rechargeable batteries are popular because of their convenience and reusability. Because you pay more for rechargeable cells, and depend on them for extensive use, it is imperative that you get maximum performance from them. But you can't do that unless you understand their physical nature.

The secret to rechargeable battery life and performance is proper conditioning and use. To condition a battery, you must discharge the internal cells to a pre-

determined voltage that is well below the operating level of most electronic equipment and that is beyond the "knee" of the discharge curve. Ni-Cd batteries exhibit a linear discharge rate over the majority of their discharge cycle. However, at some point just before full discharge, the voltage drops off sharply. That sharp downturn in voltage is called the "knee" (see Fig. 1).

Conditioning allows charged electrode material, that is not normally used, to be discharged or "exercised" to prevent premature battery-voltage droop, or kneeling. The premature voltage droop, or premature knee, is commonly mistaken for the battery malady known as "memory." Memory is virtually impossible to create during typical battery use. It takes laboratory-grade equipment and multiple precise charges and discharges to create

the memory effect. The performance degradation you perceive as battery memory is actually due to the fact that not all of the charged electrode material in the cells of the battery is available for use by your equipment. That is, the battery has not been cycled, or discharged, sufficiently.

To properly facilitate the cycling process, the battery discharge current and end-point battery cutoff voltage must be carefully monitored to avoid damaging the cells. There are three ways to accomplish this: First, you purchase expensive laboratory-grade equipment specifically made for the purpose. Second, you can set aside a day and cycle the battery manually. But third, you can use the inexpensive, easy to build Battery Tool.

The Battery Tool is a micro-controller-based instrument that performs a controlled, user-determined, constant-current discharge on any type of rechargeable battery. Battery voltage can be as high as 18 volts, and the maximum discharge current can be set as high as 1.5 amperes. These maximums will accommodate most consumer batteries now in use. The Battery Tool monitors battery voltage and regulates the user-selected load current during the entire discharge cycle. Using the accompanying terminal program, you can determine such real-time parameters as 50% battery life voltage, 0% battery life voltage, battery capacity, knee voltage, and battery voltage under load. The Battery Tool also provides elapsed time and initial no-load battery voltage readings.

Since a history of battery performance is vital to determining when the battery is fully discharged or will not be able to provide useful service, the Battery Tool terminal program can save all of the above parameters to a disk file for retrieval and comparison later. The data collected during discharge can also be used to plot a typical battery discharge curve. If you're like most electronic experimenters, you have a gaggle of Ni-Cd's and chargers lying around. The Battery Tool can help determine if they are good or bad and, if they are good, what their capabilities are. Another plus for the Battery

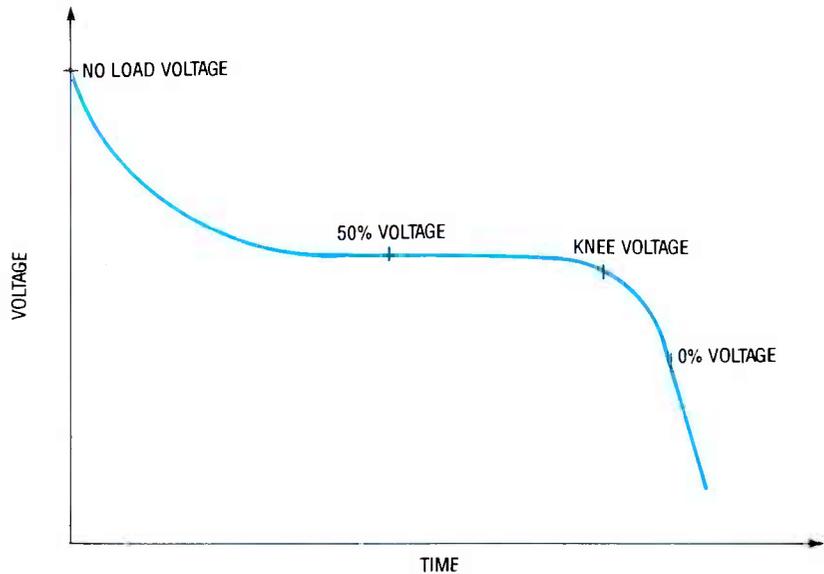


FIG. 1—TYPICAL RECHARGEABLE BATTERY CURVE. Proper conditioning entails controlled nondestructive discharging of the cells to a predetermined voltage that is well below the operating voltage of most electronic equipment.

```

BBBBB  AAAAAA  TTTTTT  TTTTTT  EEEEE  RRRRR  YY  YY
BB  BB  AA  AA  TT  TT  EE  RR  RR  Y  Y
BBBBBB  AAAAAA  TT  TT  EEEE  RRRRR  YY
BB  BB  AA  AA  TT  TT  EE  RR  R  YY
BBBBBB  AA  AA  TT  TT  EEEEE  RR  RR  YY

```

```

TTTTTT  000000  000000  LL
TT  00  00  00  00  LL
TT  00  00  00  00  LL
TT  00  00  00  00  LL
TT  000000  000000  LLLLLL

```

NiCad Battery Analyzer

TEST DATE ==> 12-31-1990

```

TEST CURRENT      ==> 1500 mA
ELAPSED TIME      ==> 01:14:29
50% CAPACITY VOLTAGE ==> 9.25
0% CAPACITY VOLTAGE ==> 6.94
KNEE VOLTAGE      ==> 9.10
BATTERY CAPACITY  ==> 1850.00 mA-hours
NO-LOAD VOLTAGE   ==> 10.55 Volts
CUTOFF VOLTAGE    ==> 7.20 Volts

```

TEST RESULTS FOR BATTERY 8pack
PRESS ANY KEY TO RETURN...

FIG. 2—A COMPLETED BATTERY TOOL TEST. All of the parameters are saved in a file to compile a history of battery performance.

Tool is that you can build it for less than \$100.

What does it all mean?

Figure 2 shows a completed Battery Tool test. Note that all of the parameters are included and saved in a file. The idea is to compile a history of battery performance. As the battery wears out, or if you accidentally abuse it, you can retrieve the history and determine just how much wear or damage has resulted. By using the Battery Tool, you'll never again have to guess about the condition of a particular rechargeable battery.

Let's talk about what all those

real-time event readings tell you. The "test current" is the amperage drawn from the battery during the test. "Elapsed time" is the time it took to run the test. The "50% capacity voltage" represents both the average overall battery voltage during a test and the voltage at the point where half of the battery's useful charge is left. The 50% value is dependent upon the cutoff voltage you specify. Use your best judgment or, better yet, consult the manufacturer's recommendations when selecting your battery's cutoff voltage.

The "0% capacity voltage" is a calculated measurement that

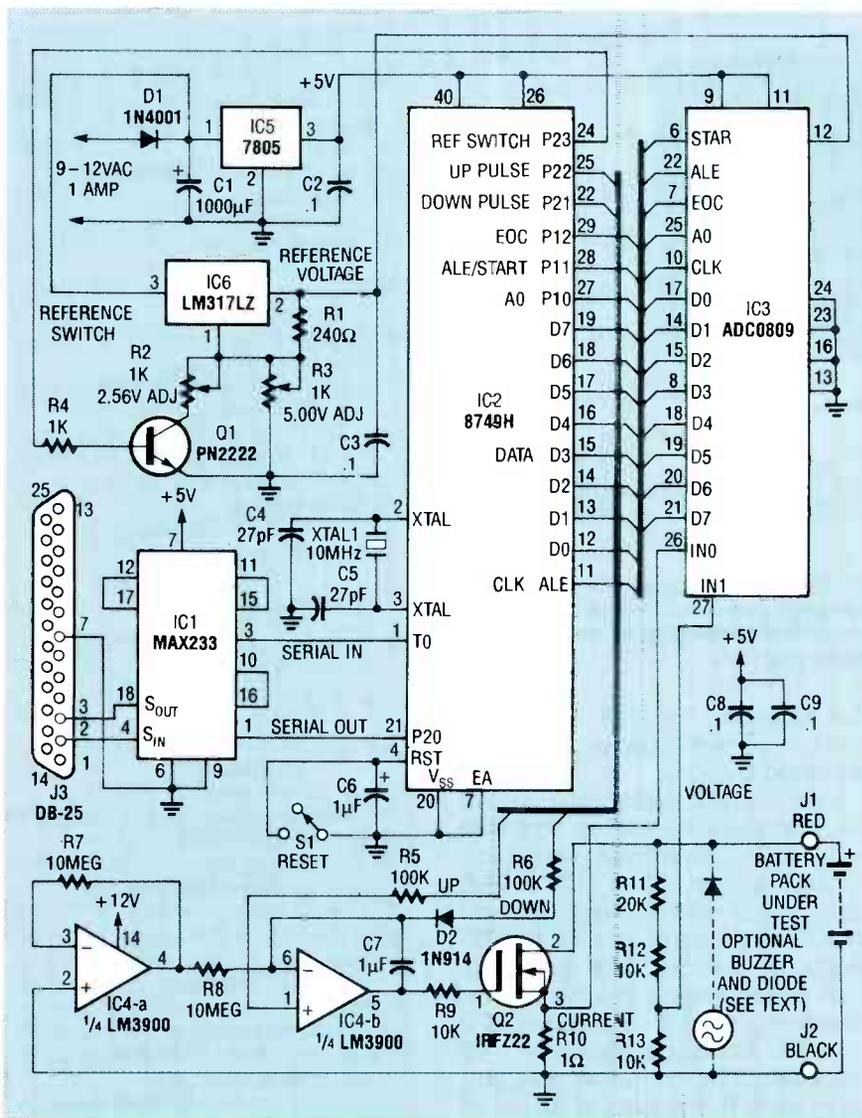


FIG. 3—THE BATTERY TOOL IS BASED ON AN 8749H microcontroller that performs serial I/O, analog-to-digital processing, and battery monitoring functions. A MAX233 converts TTL voltage levels to RS-232-C voltage levels and vice versa to simplify the serial interface between the Battery Tool and the terminal program.

Theory of operation

As shown in Fig. 3, the Battery Tool is based on IC2, an 8749H microcontroller, running at a clock speed of 10 MHz. The 8749H performs serial I/O, analog-to-digital processing, and battery-monitoring functions, as well as supplying the clock source for the analog-to-digital converter by executing a program contained in its internal EPROM. The 8749H is reset via S1 and C6. Note that we ran a story on an 874X-series microcontroller programmer (see **Radio-Electronics**, November 1991).

A MAX233, IC1, converts TTL voltage levels to RS-232-C voltage levels and vice versa to simplify the serial interface between the Battery Tool and the terminal program. Note that no external charge-pump capacitors or power supplies are needed to generate the necessary negative RS-232 voltages as with other RS-232 devices.

An ADC0809 8-channel, 8-bit analog-to-digital (A/D) converter (IC3) monitors voltage levels from the battery under test. Microcontroller IC2 initiates a voltage or current measurement by selecting IC3's channel 0 (IN0, pin 26) for current readings or channel 1 (IN1, pin 27) for voltage readings by applying a low or high respectively to pin 25 (A0) of IC3. Depending upon whether current or voltage is to be measured, IC2 also selects the correct reference voltage for pin 12 of IC3 by turning reference-switch transistor Q1 on and off—Q1 is turned on for current measurements and off for voltage measurements. The reference voltage—either +5.00 volts for voltage measurements or +2.56 volts for current measurements—is generated by potentiometers R2 and R3, resistor R1, bypass capacitor C3, and variable voltage regulator IC6 (an LM317LZ).

To initiate a reading, IC2 simultaneously applies a high pulse to IC3's ALE and START pins 22 and 6. Once IC3 reads the appropriate voltage input at either pin 26 (current) or pin 27 (voltage), it performs an internal A/D conversion. When conversion is complete, IC3 signals IC2 that the 8 bits of converted analog data on its bus are valid by raising pin 7 (EOC, or End Of Con-

version). IC2 then sends the data to the terminal program via the RS-232C interface. The terminal program then calculates the battery capacity in ampere-hours. That says under normal temperature and load conditions, the cell should be able to deliver the rated current for 1 hour. That may be true for new cells, but wear and misuse can reduce the performance figure. The Battery Tool gives you the real-world performance figures so you can most effectively use the chemical energy supplied by the battery. The Battery Tool calculates battery capacity every 60 seconds using the user-defined load current versus time.

The "battery no-load voltage" is the voltage measured with the battery at rest with no resistive load applied. Its only purpose is to give the user an indication of what the battery voltage is before loading.

projects the probable voltage under load that would be read when all usable battery energy is depleted. The projected reading is based on conventional Ni-Cd battery formulas involving the 50% calculation. The zero-capacity condition should occur after the knee has formed.

The "knee voltage" defines the voltage point at which the characteristic knee will occur. The value is calculated by taking into account the 50% battery voltage versus time.

The "battery capacity" is just that. That is, if you were to look at your particular cells closely you would find a manufacturer's capacity rating or rated cell capacity. On a AA Ni-Cd cell that's usually between 450 to 550 milli-

ampere-hours. That says under normal temperature and load conditions, the cell should be able to deliver the rated current for 1 hour. That may be true for new cells, but wear and misuse can reduce the performance figure. The Battery Tool gives you the real-world performance figures so you can most effectively use the chemical energy supplied by the battery. The Battery Tool calculates battery capacity every 60 seconds using the user-defined load current versus time.

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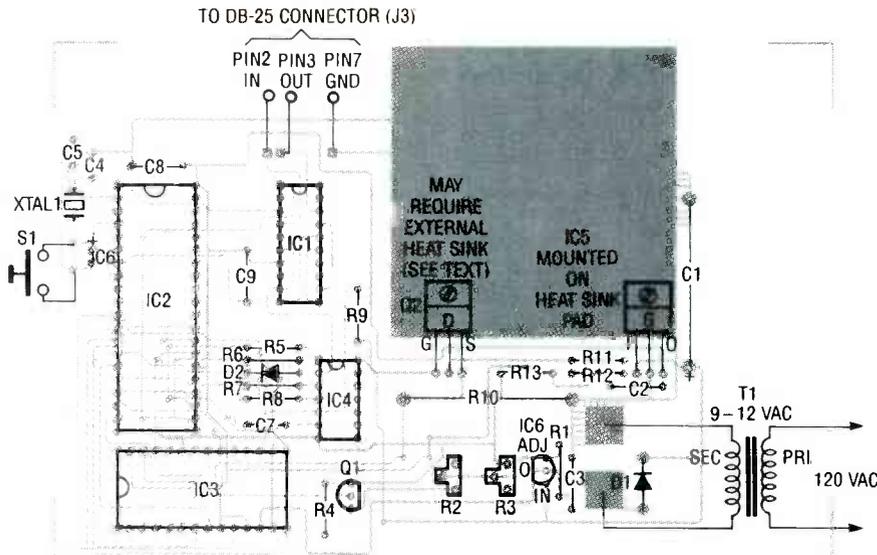


FIG. 4—PARTS-PLACEMENT DIAGRAM. MOSFET Q2 can be bent over and mounted on the heatsink pad along with IC5 if you intend to monitor batteries with four cells or less but must be insulated from the pad. If you will be monitoring battery packs with more than four cells, Q2 requires more substantial heatsinking (see text).

version). The data that is sampled by IC2 is either used by IC2 or sent in raw 8-bit form to the terminal program via IC1 for further processing.

Because IC3 can measure only voltages, it is necessary to derive current readings from known voltages and resistances. Since we are looking for a resultant current, voltage and resistance must be constants. Ohm's Law says that current is equal to voltage divided by resistance, or $I = E/R$. So, if we are measuring current, and IC3 measures 1 volt across R10, which in our case is 1 ohm, Ohm's Law says that $I = 1/1$, resulting in 1 amp flowing through R10. The 8-bit representation of 1 volt generated by IC3 causes IC2 to vary the resistance of MOSFET Q2 and regulate the load current.

Because, as mentioned before, IC3 is a voltage-measuring device, voltage measurements—as opposed to current measurements—are more straightforward. Resistors R11–R13 make up a low-power precision voltage divider that is placed across the battery's positive and negative terminals. The voltage-divider resistances were selected with two design points in mind: First, to draw insignificant current from the battery under test, and second, to divide the battery voltage by 4. In this application IC3 has a voltage-measurement range of 0 to +5 volts DC. That restriction would severely hamper the usefulness of the Battery Tool, so

the R11–R13 voltage divider is used to prescale the output data provided by IC3.

Note that IC3 can resolve to 256 discrete steps including step 0 (0 volts DC). When the reference voltage at pin 12 of IC3 is +5 volts, each voltage step resolved by IC3 is +5 volts divided by 256 steps, or 0.0195 volts per step. The prescaling enables IC3 to effectively read a minimum of 0 volts DC and a maximum of +20 volts DC. The terminal program processes the 8 bits of sampled data and computes the corresponding battery voltage which is displayed to you in real time. The maximum allowed battery voltage is also controlled by the terminal program. Also, IC2 uses the voltage data to determine if the preset cutoff voltage has been reached. If the battery under test exceeds 18 volts, the terminal program immediately removes the resistive load from the battery and halts the test.

With respect to current readings, each digital step is 0.01 volts, because of the 2.56-volt reference, so a maximum current of 2.56 amperes can be sensed. The limiting factor as to how much load current can be applied is dependent upon the power dissipation capacity of power resistor R10. The terminal program limits the operating test current to 1.5 amperes, which falls safely within the 5-watt dissipation rating of R10.

It would be impossible to get

PARTS LISTS

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

- R1—240 ohms
- R2, R3—1000 ohms, potentiometer
- R4—1000 ohms
- R5, R6—100,000 ohms
- R7, R8—10 megohms
- R9—10,000 ohms
- R10—1 ohm, 5 watts, 1%
- R11—20,000 ohms, 1%
- R12, R13—10,000 ohms, 1%

Capacitors

- C1—1000 µF, 16 volts, electrolytic
- C2, C3, C8, C9—0.1 µF, ceramic
- C4, C5—27 pF, ceramic disk
- C6—1 µF, 16 volts, tantalum electrolytic
- C7—1 µF, metal film

Semiconductors

- IC1—MAX233 RS-232 driver
- IC2—8749H microcontroller
- IC3—ADC0809 8-channel 8-bit A/D converter
- IC4—LM3900 quad op-amp
- IC5—7805 5-volt regulator
- IC6—LM317LZ adjustable regulator
- D1—1N4001 diode
- D2—1N914 diode
- Q1—PN2222A NPN transistor
- Q2—IRF222 MOSFET

Other components

- S1—SPST momentary pushbutton switch
- XTAL1—10 MHz crystal
- J1, J2—red and black banana jacks (or whatever best suits your needs)
- J3—female DB-25 connector
- Miscellaneous:** PC board, case, 18-gauge wire, heatsink (see text), 9-12 VAC 1-amp transformer, ribbon cable, hardware, IC sockets, solder, etc.

Note: The following items are available from Fred Eady, 1320 Anchor Lane, Merritt Island, FL 32952:

- Kit of parts with a programmed microcontroller and PC board (not including connectors, heatsink, and case)—\$89.00 + \$2.50 S&H
- Programmed microcontroller only—\$20.00 + \$2.50 S&H
- PC board only—\$25.00 + \$2.50 S&H
- Software on a 5¼-inch disk—\$5 postpaid

any accurate voltage or current measurements from any battery if the load current was not maintained at a constant value. Remember that if any of the three values used in Ohm's Law change, all others are affected. So, to get maximum measurement accuracy, IC2, IC4, and Q2, along with resistors R5–R9, blocking diode D2, and capacitor C7, form a low-drift ramp-and-hold circuit.

Here's how that circuit works. The first gate of IC4 (IC4-a) provides a very low input bias current to the input of the second gate, IC4-b. The bias gate elimi-

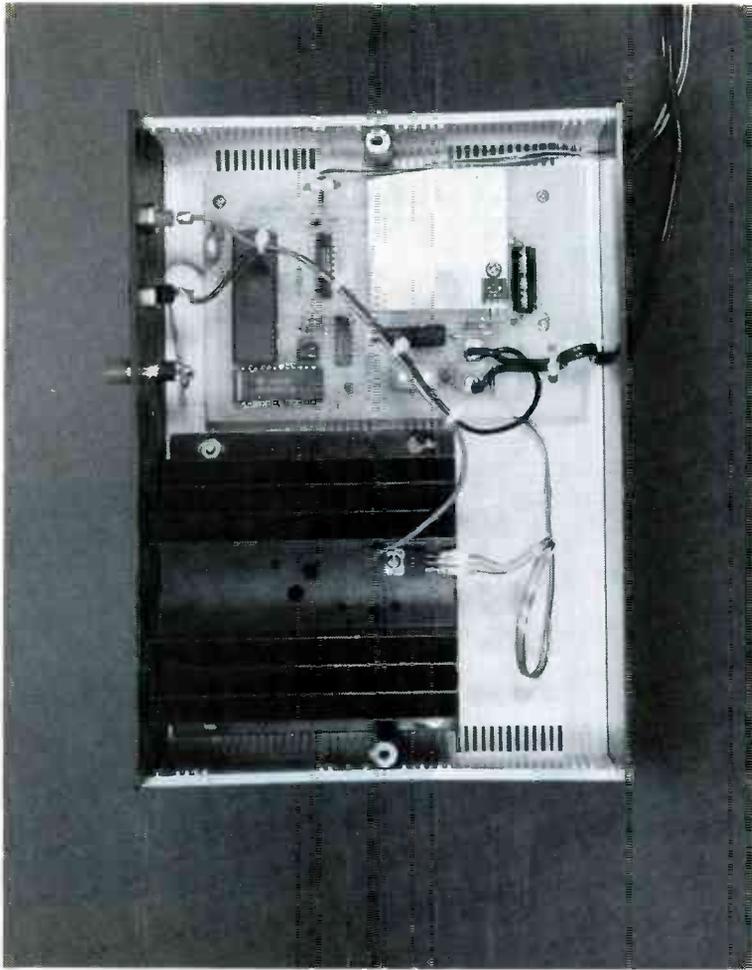


FIG. 5—THE AUTHOR'S PROTOTYPE. Notice how MOSFET Q2 is mounted on a separate heatsink. (You certainly don't need such a big heatsink; use whatever you have on hand, which is what the author did.)

nates the need for FET transistors and special-purpose integrated circuits normally needed for sensitive ramp-and-hold applications. The matched amplifiers found in the LM3900 op-amp are also helpful in this area.

Microcontroller IC2 supplies either a high or low TTL voltage level to resistors R5 and R6 via output port pins 22 and 23. (Note that, in Fig. 3, R5 is marked "up" and R6 is marked "down.") When a low TTL level is applied to both R5 and R6, the ramp and hold circuit is in the hold state. Thus the voltage at IC4 output pin 5 is stable. The higher the quality of capacitor C7, the less voltage drift at pin 5. Applying a TTL high to R5 while holding R6 low causes the voltage at pin 5 of IC4 to rise. Conversely, applying a TTL high to R6 while holding R5 low decreases the voltage at pin 5 of IC4.

The output voltage at pin 5 of IC4 is fed through R9 to the gate

of Q2, an insulated-gate MOSFET power transistor; think of Q2 as simply a high-wattage potentiometer whose wiper is the voltage supplied by IC4. As the voltage on the gate of Q2 increases, the resistance between Q2's drain and source decreases, and vice versa. A high-wattage precision voltage divider is formed by Q2 and precision power resistor R10. By Ohm's Law, we know that current is constant in a series of resistances while voltage differs at each resistance node. Now comes the good part: if we measure the voltage across the 1-ohm precision resistor and control the voltage drop across it using Q2, we can produce a constant load across a battery independent of the battery's voltage and operating temperature.

In summary, the user tells IC2 via the terminal program what load current to place on the battery under test. Microcontroller IC2 ramps the battery up to the

selected current by reading the voltage drop across R10 that is monitored by IC3. The sampled voltage drop is compared to the user-selected load-current value (actually a converted voltage drop value) sent to it by the terminal program. If the sampled voltage drop (current) reading is too high, a "down" command is sent to the ramp and hold circuit thus increasing the resistance across the drain and source of Q2, thereby reducing the voltage drop across R10. That of course has the effect of lowering the current across the precision voltage divider formed by Q2 and R10. The opposite is true if the comparison is too low. The process takes place hundreds of times per second providing a varying resistance able to track a varying voltage, resulting in a constant current independent of the battery voltage.

Construction

Using the supplied foil patterns, you can make your own PC board. If you would prefer not to make your own, a professionally prepared PC board is available—see the parts list. Following Fig 4 as a guide, begin assembly by installing voltage regulator IC5, rectifier diode D1, filter capacitor C1, and decoupling capacitor C2. Note that IC5 should be bolted down to lie flat against the heat-sink pad on the PC board. Temporarily connect a 9–12 VAC, 1-amp source to the pads indicated in Fig. 4 and apply power; there should be +5 volts DC at the output (pin 3) of regulator IC5. Remove power and install IC6, R1–R4, Q1, and C3, observing proper orientation of Q1 and IC6.

To perform reference-voltage calibration, connect a jumper between the end of R4 that is *not* connected to the base of Q1 and ground. Grounding R4 will assure that Q1 is off and allows the adjustment of R3 for +5.00 volts at the output of IC6; apply power and make the adjustment. After adjusting R3, disconnect the grounded end of the jumper and connect it to the +5-volt output of IC5; that turns Q1 on and places potentiometers R2 and R3 in parallel. Adjust R2 for a reading of +2.56 volts DC at the output (pin 2) of IC6. Recheck both the +5.00- and the +2.56-volt

adjustments until you can alternate between them by moving the jumper without further adjustments to either R2 or R3. Remove power and the jumper before proceeding any further.

Install components IC2, XTAL1, and C4–C6. You may also temporarily connect reset switch S1 at this time. Once again apply power and, using a logic probe, check for oscillation at pin 11 of IC2; if it doesn't oscillate, check power connections, the clock circuit (consisting of XTAL1, C4, and C5), and make sure S1 is not closed. If pin 11 is oscillating, check to see that the oscillation stops when S1 is closed. Oscillation at pin 11 of IC2 indicates that the IC is operating properly.

Complete the board by mounting IC3, IC4, R5–R13, C7, and D2. Recheck the reference voltages at pin 12 of IC3. Mount IC1 and assemble the serial cable according to your needs. Most of you will use a DB-25 IDC (Insulation Displacement Connector) connector and 3 strands of ribbon cable connected between the points indicated in Fig. 4 and pins 2 (serial in), 3 (serial out), and 7 (signal ground) of DB-25 connector J1.

Note that MOSFET Q2 must be heatsinked. If you intend to monitor batteries with four cells or less, Q2 can be bent over and mounted on the heatsink pad along with IC5. BUT, if you do that, Q2 *must* be insulated from the pad because its metal tab gets connected directly to the positive terminal of the battery under test, while the 7805's tab is at ground potential. If you will be monitoring battery packs with more than four cells, Q2 requires more substantial heatsinking than just the foil pad. In that case, you can either mount Q2 on the board, along with a suitable heatsink, or mount it off the board on a heatsink and wire it to the appropriate PC pads as was done with the prototype shown in Fig. 5. Keep in mind that the larger the heatsink, the cooler the MOSFET runs, and the more stable the MOSFET's operation will be.

Install a solder lug on the heatsink tab of Q2 and solder a length of 18-gauge wire from the lug to a connector of your choice; the connector is for the positive ter-

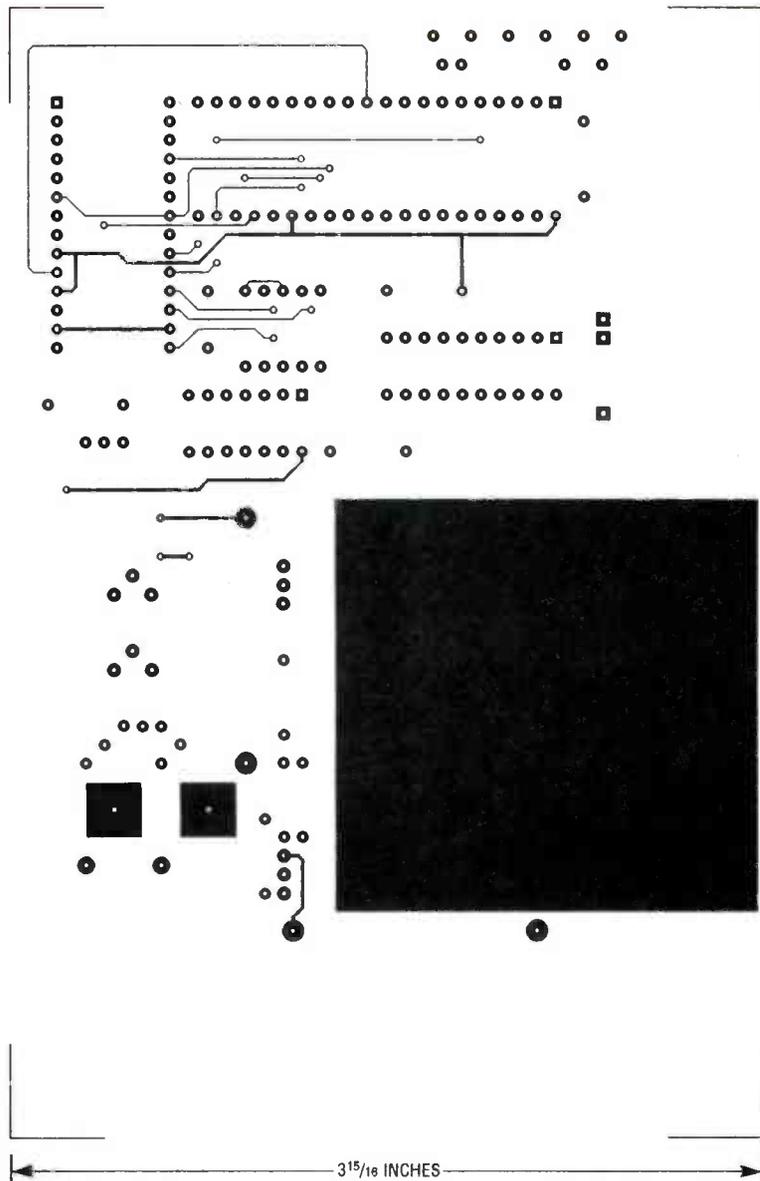
minal of the battery under test. The prototype uses standard red and black banana jacks for the battery receptacles, although you can use whatever you like. Solder a second piece of 18-gauge wire from the ground pad on the printed circuit board to the other battery connector.

You can install the Battery Tool in a suitable case if desired. The prototype is housed in a 10"×8"×3" 2-piece plastic case. The banana jacks and the reset switch are mounted on the top panel, although the layout is not critical. The serial cable and AC power cable can enter the rear of the case. As shown in the schematic, you can install the optional diode and buzzer across the input jacks to indicate that

the battery under test is connected with the wrong polarity.

Using the Battery Tool

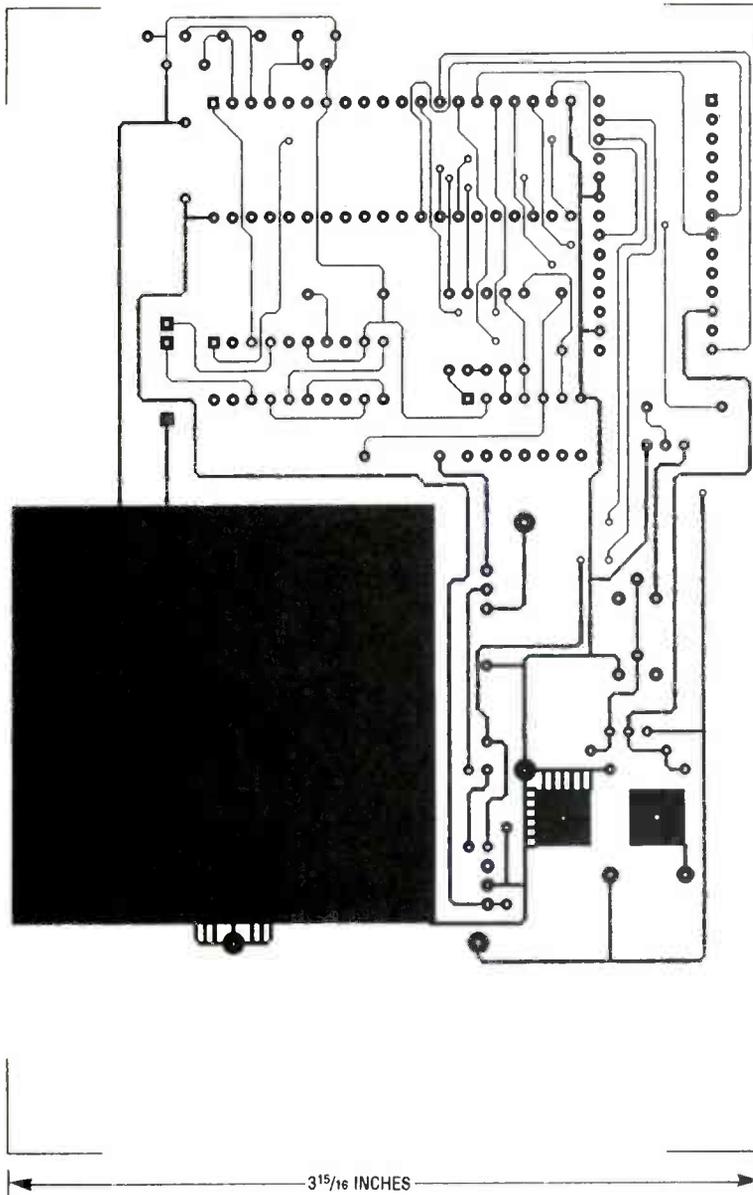
Use of the Battery Tool is simple. The terminal program called TOOL.EXE, which is available on the RE-BBS (516 293-2283, 1200/2400, 8N1) as part of a self-extracting ZIP file called BATTOOL.EXE, prompts you through the entire process. (After downloading the file, simply type "BATTOOL.EXE," and the file will unzip itself.) The ZIP file also contains the code for the microcontroller (TOOL.ASM), in case you want to program your own, although a programmed microcontroller is included in the parts kit. All of the software is also available on a 5¼-inch floppy



COMPONENT SIDE of the Battery Tool PC board.

THD ANALYZER

continued from page 52



SOLDER SIDE of the Battery Tool PC board.

disk (see the parts list), for those of you with no modem.

Run the terminal program, apply power to the Battery Tool, connect the battery you wish to test, and enter the battery cutoff voltage and load current. Within 20 seconds you should see an elapsed-time indication followed by a full screen of real-time events that were described earlier. When the battery is discharged to the cutoff voltage you specified, the discharge process is halted, the load is removed from the battery under test, you are prompted for the correct time, and the final data is saved to a file. If for some reason the battery under test cannot supply your selected current, the terminal program notifies you and halts the test.

The Battery Tool can be used to simulate a particular device by determining how much current the device draws, and dialing that load current into the Battery Tool and running a cycle on the related battery. Another use involves determining just how much charge or life is left in a battery. Using the history you compile on a certain battery, you can connect the battery in question to the Battery Tool, ramp up to the current specified by the history, and note the voltage at that point. Using the historic voltage readings, you should be able to determine how far into the discharge cycle you are. If you depend on rechargeable batteries, the Battery Tool will be a worthwhile tool. R-E

we drive the input of the amplifier with a 1-volt pure sine wave and we obtain the 20 volts required at the output. Since 20 volts RMS is 56 volts peak-to-peak, S2 must be set to >20V. With S5 in "THD" position a reading of 1.4 mV (0.0014V) DC is obtained. In the "REF" position we read 2.00V. Always read the range on the DMM that affords the best resolution. Now make the calculation: $0.0014/2.00 \times 100$ equals 0.07 percent THD.

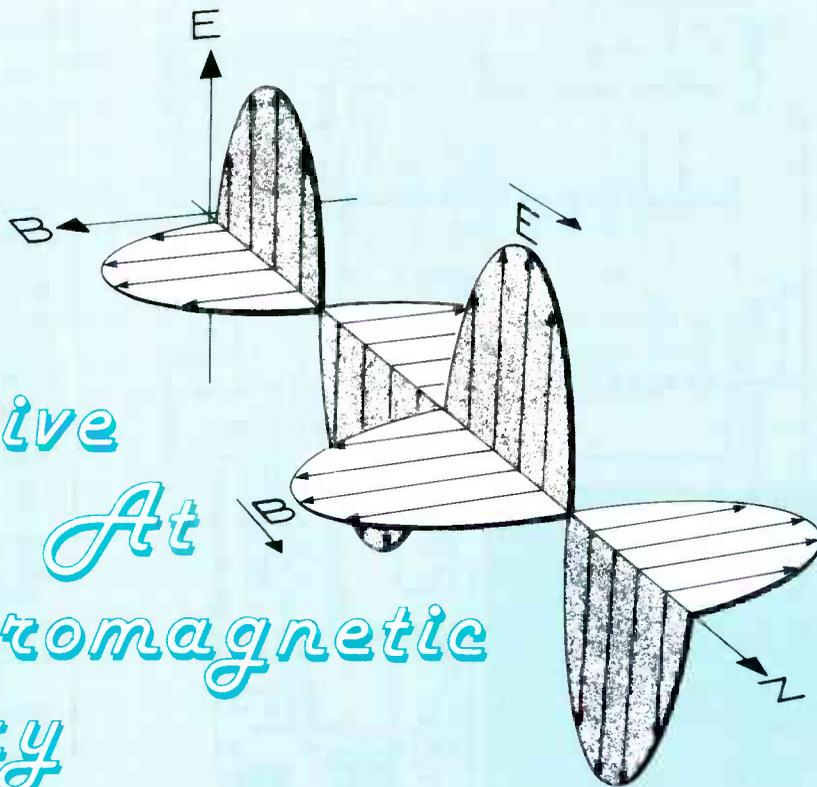
Voltage amplifiers are measured in the same manner, but without the requirement of a load resistor. Such amplifiers will probably show lower THD voltage readings. If the THD voltage is too low on the DMM's mV range, set S4 to "×10." In this case, however, divide the displayed THD voltage by 10. For example, 0.8 mV on the meter is read as 0.08 mV, since it was amplified 10 times to 0.8 mV.

If the measured THD percent is three times or more greater than the analyzer's measurement "floor," no correction of the measured value is required. If it's less than three times, a good approximation of the true THD percent is given by the formula $D(DUT) = \sqrt{D^2(\text{measured}) - D^2(\text{floor})}$. That means if you measure a pre-amp's THD at 0.005%, and the measurement floor is 0.004%, the true THD of the preamp is 0.003%.

Depending upon the depth of the notch and how closely the RC's in the oscillator's frequency selective network are matched, the "floor" should typically be 0.003 to 0.005%. You can check the "floor" value in the same way you measured the 1% THD calibrator, explained earlier. Instead of using the calibrator signal, feed in a maximum signal level from output J1. If you use the ×10 position, it may be necessary to connect J8 to an external earth ground.

Finally, you should know that THD measurements above 10 percent are less accurate than those below 10 percent, since the reference includes distortion plus the fundamental—not just the fundamental. R-E

An Intuitive Look At Electromagnetic Theory



In the concluding installment of this series, we discover the relationship between changing magnetic and electric fields.

WILLIAM P. RICE

PREVIOUSLY WE DISCUSSED STATIC electric and magnetic fields in empty space and in materials. This month we'll see some effects of changing fields and find out how the **E** field and **B** field are so closely related.

The changing electric field

Recall that the divergence of a field that is the curl of another field is always zero since the curl describes apparent rotation rather than spreading out around a point. Ampere's law $\nabla \times \mathbf{H} = \mathbf{J}_f$, as developed so far, says that the free current density is just such a field. Taking the divergence gives

$$\nabla \cdot (\nabla \times \mathbf{H}) = \nabla \cdot \mathbf{J}_f = 0.$$

Because electric charge is always a conserved quantity, any net free charge diverging about a point must do so at the expense of the density of free charge at that point

$$\nabla \cdot \mathbf{J}_f = -\partial \rho_f / \partial t.$$

This implies that $-\partial \rho_f / \partial t = 0$ which says it is impossible to change the free-charge density; a conclusion easily disproven by experiment. Maxwell noted this and concluded that a term must be missing from Ampere's law. One way to obtain that term is to write

$$\nabla \cdot (\nabla \times \mathbf{H}) = \nabla \cdot \mathbf{J}_f + \left[\frac{\partial \rho_f}{\partial t} \right] = 0.$$

Using Gauss' law, plus the fact that differentiation is not dependent upon the special coordinates, the above term can be written within the divergence as

$$\nabla \cdot \mathbf{J}_f + \left[\frac{\partial (\nabla \cdot \mathbf{D})}{\partial t} \right] =$$

$$\nabla \cdot \mathbf{J}_f + \nabla \cdot \left[\frac{\partial \mathbf{D}}{\partial t} \right].$$

Ampere's law now reads

$$\nabla \times \mathbf{H} = \mathbf{J}_f + \frac{\partial \mathbf{D}}{\partial t}.$$

Ampere's law, as stated above, says that a magnetic field with

apparent rotation is present around a small region when either an electric current or a changing electric field is present in that region. This is one of Maxwell's equations.

The changing magnetic field

Experiments by Faraday showed that electric charges in a coil of wire were subjected to a force whenever a **B** field enclosed by the coil changed. That force could be described by a vector equation and an associated field in a manner similar to static charge and constant current cases. However, that would be an unnecessary complication since, as it turns out, the Lorentz force law

$$\mathbf{F} = q[\mathbf{E} + (\mathbf{v} \times \mathbf{B})]$$

completely describes the force on a charge.

Faraday showed that the work per unit charge, called the electromotive force **E**, in the coil was related to the time-rate of change of the magnetic flux Φ enclosed by the coil according to

$$E = -\frac{d\Phi}{dt} = -\frac{d(\int \mathbf{B} \cdot d\mathbf{s})}{dt} \text{ (volts) ,}$$

where \mathbf{s} is the area of the coil, and the current induced in the coil is $I = E/R$. The negative sign is a result of the standard use of the right hand rule and of energy conservation. Rather than apply the right hand rule directly, it's easier to use Lenz's law to determine the direction of the electromotive force.

Lenz's law says that E , and hence I , will be in a direction in such a way to produce a magnetic field that tends to oppose the change in flux. If the negative sign were not included, the equation would say that an increase in flux would increase E , thus increasing the flux thus increasing E , and so on, giving an infinite amount of energy from an infinitely small change in Φ ! The opposition is not complete since the induced current dies away rapidly due to the resistance once the driving flux is held stable. However, in superconductors, $R=0$ and the induced current continues.

E is independent of the cause of the flux change. Flux change can occur in two basic ways:

1. The source of \mathbf{B} could be moved, or in some way, the direction or magnitude of \mathbf{B} could be changed as in Fig. 1-a or
2. The coil could be moved, rotated, or the area of the coil changed as in Fig. 1-b.

As long as the time-rate of change of the enclosed flux is the same, the same amount of electromotive force results.

The fact that an \mathbf{E} field is associated with the force on an electric charge can be used to account for this force. The work per unit charge required to move the charge from point a to point b was discussed previously. Moving the charge around the closed coil and relating this to Faraday's result gives

$$\oint \mathbf{E} \cdot d\mathbf{L} = E = -\frac{d(\int \mathbf{B} \cdot d\mathbf{s})}{dt} \text{ (volts) .}$$

The charge doesn't have to be confined to a conductive coil, the equation is valid for any closed path. The curl of \mathbf{E} is found by taking the limit of the ratio of

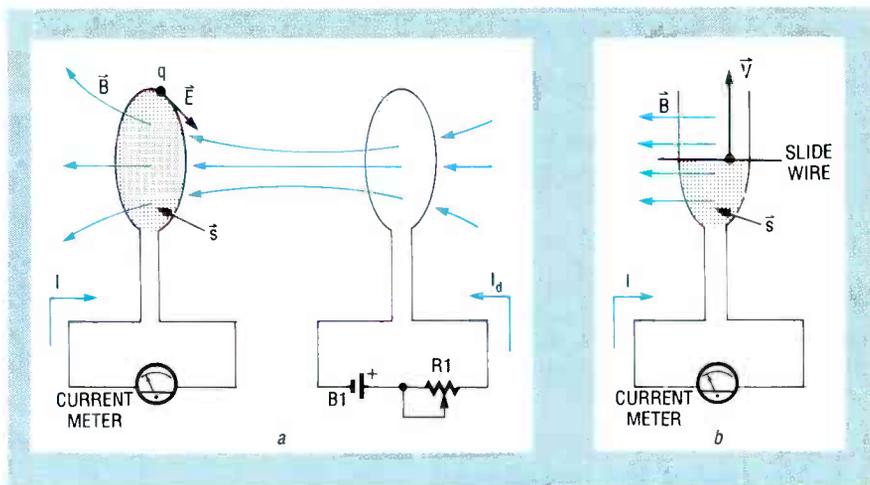


FIG. 1—A CHANGING ENCLOSED MAGNETIC FLUX induces an electromotive force. In (a), the driving current I_d is increased resulting in an increasing \mathbf{B} field or flux in the area \mathbf{s} , which induces an electric field \mathbf{E} . This current produces a magnetic field that tends to oppose the change in \mathbf{B} . In (b) the \mathbf{B} field is held steady. The area of the coil and thus the flux enclosed by the coil is increased by moving the slide wire with velocity \mathbf{v} . A charge on the slide wire experiences a force $\mathbf{F} = q\mathbf{v} \times \mathbf{B}$ resulting in current I . This current produces a magnetic field that tends to oppose the increase in enclosed flux.

$\oint \mathbf{E} \cdot d\mathbf{L}$ to the area enclosed as the coil is shrunk down around a point.

$$\nabla \times \mathbf{E} = \lim_{ds \rightarrow 0} \frac{d(\int \mathbf{E} \cdot d\mathbf{L})}{ds} = \lim_{ds \rightarrow 0} \frac{d\left[\frac{d(\int \mathbf{B} \cdot d\mathbf{s})}{dt}\right]}{ds}$$

The summation by integration over the surface $\int \mathbf{B} \cdot d\mathbf{s}$ does not depend upon time, so the derivative with respect to time can be taken inside the integral

$$\nabla \times \mathbf{E} = \lim_{ds \rightarrow 0} \frac{d\left[\int (d\mathbf{B}/dt) \cdot d\mathbf{s}\right]}{ds}$$

The limiting value of the ratio is the time-rate of change of \mathbf{B} at the point so

$$\nabla \times \mathbf{E} = -\partial \mathbf{B} / \partial t \text{ (V/m}^2 = \text{T/s).}$$

The ∂ symbolism stresses the fact that the concern is only with the time-rate of change of \mathbf{B} and not how \mathbf{B} changes from one point in space to another. This is Faraday's law and is one of Maxwell's equations. It says that a changing magnetic field is associated with an electric field whose apparent rotation about a point is proportional to the time-rate of change of the magnetic field. Since the curl is not zero, an electric field associated with a changing magnetic field is therefore not conservative.

Gauss' law plus Faraday's law gives a complete picture of an electric field. It has a divergence due to electric charge at a point

and it has curl due to changing magnetic field at a point. If there is no charge there is no divergence; if there is no change in the \mathbf{B} field, there is no curl. If we place \mathbf{E} field test instruments (electric charges q) near a point with a changing \mathbf{B} field, the charges tend to circle around the point. In any case, the force on a charge q is given by the Lorentz force law.

Inductance

In the case of a static \mathbf{B} field, inductance was defined as $L = \Phi/I$. Fig. 2 shows a coil with changing current I . A voltage E will be induced that tends to oppose the

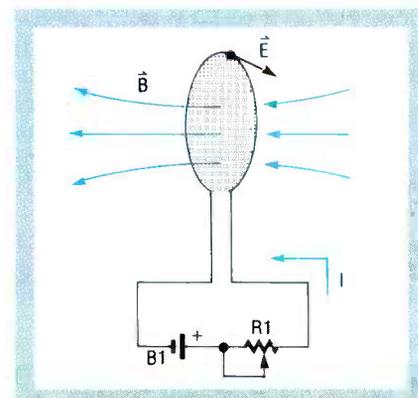


FIG. 2—SELF INDUCTANCE OF A COIL. As the current I changes the magnitude of \mathbf{B} , the magnetic flux Φ enclosed by the coil also changes proportionately. An electromotive force and associated \mathbf{E} field results that tends to oppose the change in I and keep the flux constant. The inductance is the ratio of the change in flux to an infinitesimal change in current. It is related to the geometry of the coil and any material present within that coil.

change in I , and hence Φ . For the case of changing current, the inductance is more properly defined as a measure of the ratio of the change in flux to an infinitesimal change in current. So by Faraday's result

$$L = \frac{d\Phi}{dI} = -E \frac{1}{dI/dt}$$

To produce this current, the external voltage across the coil must be $V = -E$. therefore

$$V = L \frac{dI}{dt}$$

In the case of two flux-linked coils (Fig. 1-a), the mutual inductance M of the arrangement is defined by

$$E = -M \frac{dI_d}{dt}$$

where I_d is the drive current in one coil and E is the electromotive force or voltage measured across the other coil.

Roots of Einstein's relativity

Suppose the coils are stationary and the \mathbf{B} field is changed in such a way that there is a certain time-rate of change of enclosed flux, as in case 1 described earlier. The \mathbf{E} field has some curl and the force on a stationary q is $\mathbf{F} = q\mathbf{E}$. Suppose instead that the coil, or some part of it, is moved in a \mathbf{B} field, as in case 2, so that there is the same time-rate of change of enclosed flux. A charge q in the coil is moved with a velocity \mathbf{v} , so it must be that q experiences a force $\mathbf{F} = q\mathbf{v} \times \mathbf{B}$. In either case, from the perspective of the coil, the physical effects on q are the same, implying that electric force and magnetic force are really manifestations of the same underlying phenomenon—the electromagnetic force. That is an essential fact of electromagnetic theory that led to Einstein's theory of relativity.

Towards a complete picture

Faraday's law relates an electric field to a changing magnetic field; Ampere's law relates a magnetic field to a changing electric field. A changing electric field is accompanied by a changing magnetic field and vice versa. The four Maxwell's equations give a complete picture of the \mathbf{E} and \mathbf{B} fields.

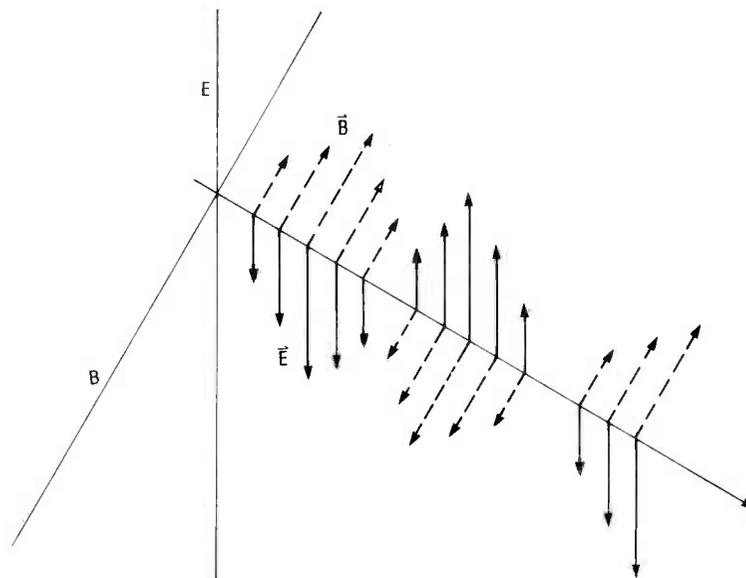


FIG. 3—AN ELECTROMAGNETIC WAVE in empty space. A few of the \mathbf{E} -field vectors, shown as solid arrows, and \mathbf{B} -field vectors, shown as dashed arrows, that simultaneously change magnitude at each point as the wave propagates through space.

The simplest example is in empty space where $\mathbf{H} = 1/\mu_0 \mathbf{B}$, $\mathbf{D} = \epsilon_0 \mathbf{E}$ and there are no free charges so $\mathbf{J}_f = 0$. Then

$$\nabla \times \mathbf{B} = \mu_0 \epsilon_0 \frac{\partial \mathbf{E}}{\partial t}$$

and since $\nabla \cdot \mathbf{B} = 0$, the magnetic \mathbf{B} field is completely characterized. Also by Faraday's law

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

and Gauss' law $\nabla \cdot \mathbf{E} = \rho_f/\epsilon_0 = 0$, the electric \mathbf{E} field is completely characterized.

Electromagnetic waves

Maxwell found that because of the symmetry in the equations, the combined electric and magnetic fields could propagate as waves. It's not easy to see how that comes about without getting involved in heavy mathematics. An electromagnetic wave, however, can be pictured as the simultaneous variation of the electric-field vector and magnetic-field vector at each point in a region of space through time. Fig. 3 shows the changing \mathbf{E} and \mathbf{B} fields as the wave propagates in empty space.

Maxwell calculated the velocity of an electromagnetic wave and found it to be a constant in close agreement with the measured speed of light. That along with a rather large number of experiments, notably those performed by Hertz, led to the conclusion that visible light was but a small range of wavelengths of electromagnetic waves.

R-E

FURTHER READING

There are many available books on electromagnetics. The following are just a few the author suggests:

1. Griffiths, David J., *Introduction To Electrodynamics*, Prentice-Hall Inc., 1981. An undergraduate text with many intuitive insights into vector calculus and electromagnetic theory. Equations are in rationalized mks units as used here.
2. Jackson, J. D., *Classical Electrodynamics*, John Wiley & Sons, 1975. A standard graduate-level text complete with all the heavy mathematics. Equations are in Gaussian cgs units which have certain advantages in theoretical work.
3. Schey, H. M., *DIV, GRAD, CURL, and All That*, W. W. Norton & Co., 1973. A short, mathematically informal text on vector calculus. Includes useful ideas that help build intuitive pictures of vector operations. This book also discusses the electrostatic field.
4. Visscher, Peter B., *Fields and Electrodynamics A Computer-Compatible Introduction*, John Wiley & Sons, 1988. Presents electromagnetic theory from Maxwell's equations formulated in computational algebra. Lists available demo programs that display the evolution of fields.
5. Maxwell, James Clerk, *A Treatise On Electricity and Magnetism*, Vol. I and Vol. II, Dover Publication, Inc. Republication of the third and final 1891 edition. Electromagnetic effects are described by use of mathematical quantities called quaternions and the now discredited elastic ether model rather than the modern idea of vector fields and empty space. Useful for historical and reference purposes.



ELECTRONIC FUSE

How do you troubleshoot power-related problems without blowing fuse after fuse? Just use our electronic fuse!

T.L. PETRUZELLIS

THE ELECTRONIC FUSE IS A SENSITIVE fast-acting adjustable circuit breaker that will quickly become one of your most useful bench-top accessories. If you have been stumped by a faulty electronic circuit and consumed a number of costly or hard-to-locate fuses, you will appreciate this inexpensive circuit breaker. All you have to do is connect the electronic fuse to the device under repair, and then adjust the current threshold control to the value you need anywhere from $\frac{1}{10}$ to 10 amperes.

Additional applications for the electronic fuse include charging circuits for marine/mobile/aircraft systems, as well as new circuit designs. The electronic circuit breaker could be used after the design of a new circuit to help choose the correct value fuse. The electronic circuit breaker is connected in place of the original fuse of the device under repair or test. If the breaker

"trips," a red LED will light and power is cut off. When you're ready to continue, simply press the reset button.

Circuit description

As shown in Fig. 1, two test leads are connected in series with the normally closed relay contacts of RY1, a 12-amp fuse (F1), and the two-turn primary of T1, a torroid transformer. The secondary of T1 is wound underneath the primary on the half-inch torroid. The secondary coil is 100 turns of 30-gauge magnet wire with a total resistance of 8 to 10 ohms. The secondary is connected to a high-low RANGE switch (S1). The switch connects to a resistor network to provide stability and ease of operation. The low range permits values from $\frac{1}{10}$ to 6 amperes, and the high range includes values from 1 to 10 amps, with overlapping between ranges. Capacitors C1 and C2 form a high-frequency fil-

ter to help reduce spikes and line noise.

Op-amp IC1-a amplifies and rectifies the AC input and applies it to IC2-a, an LM339 comparator, which is used to adjust the threshold, or current, via potentiometer R4. A clamp is formed by D3 which holds the input of IC2-b to a constant level. A filtered DC output is amplified by IC2-b and fed to Q1, a 2N3904 transistor. The transistor changes the output of IC2-b to the proper level and polarity in order to trigger SCR1. When the input current exceeds the threshold set by R4, the SCR will turn on. The relay will now open and LED1 will indicate that the circuit has been "tripped." The LED will remain on and the power to the device under test will remain off until the reset button (S3) is pressed.

Current consumption for the electronic fuse is about 10–15 mA at idle and about 100 mA when

PARTS LIST

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

- R1—107,200 ohms
- R2—442,000 ohms
- R3—387,000 ohms
- R4—165,000 ohms
- R5, R6—300,000 ohms
- R7—50,000 ohms, audio-taper potentiometer
- R8—1500 ohms
- R9—12,000 ohms
- R10—18,000 ohms
- R11—13,000 ohms
- R12—4700 ohms
- R13—2000 ohms
- R14, R15—1000 ohms

Capacitors

- C1—200 pF, 50 volts, ceramic
- C2—100 pF, 50 volts, ceramic
- C3, C4—1 μ F, 50 volts, electrolytic
- C5—100 μ F, 50 volts, electrolytic

Semiconductors

- IC1—LM358 low-power dual op-amp
- IC2—LM339 quad comparator
- D1—D3—1N914 diode
- D4—1N4004 diode
- LED1—red light-emitting diode
- SCR1—NTE 5404 silicon-controlled rectifier

- Q1—2N3904 NPN transistor

Other components

- T1—hand-made transformer (see text) on 0.5-inch powdered-iron torroid core
- S1—DPDT toggle switch
- S2—SPST toggle switch
- S3—normally closed pushbutton switch

- F1—12-amp fast-blow fuse

- RY1—DPDT relay, 12-volt coil, 12-amp contacts (or use two sets of contacts in parallel, see text)

Miscellaneous: PC board, project case, fuse holder, alligator clips, 30-gauge magnet wire, 24-gauge stranded wire, 16-gauge stranded wire, PC-board scrap for wire spool, hardware, solder, etc.

Note: The following items are available from T.L. Petruzellis, 340 Torrance Avenue, Vestal, NY 13850:

- PC board only—\$8.25
- Kit of parts including the torroid core and wire (you have to wind it yourself), IC's, and project case (does not include a power supply)—\$44.95

Specify wires with alligator clips or 3-prong female power outlet (see text). Add \$3.00 S&H. NY residents must add 7% sales tax. Please allow 4–6 weeks for delivery.

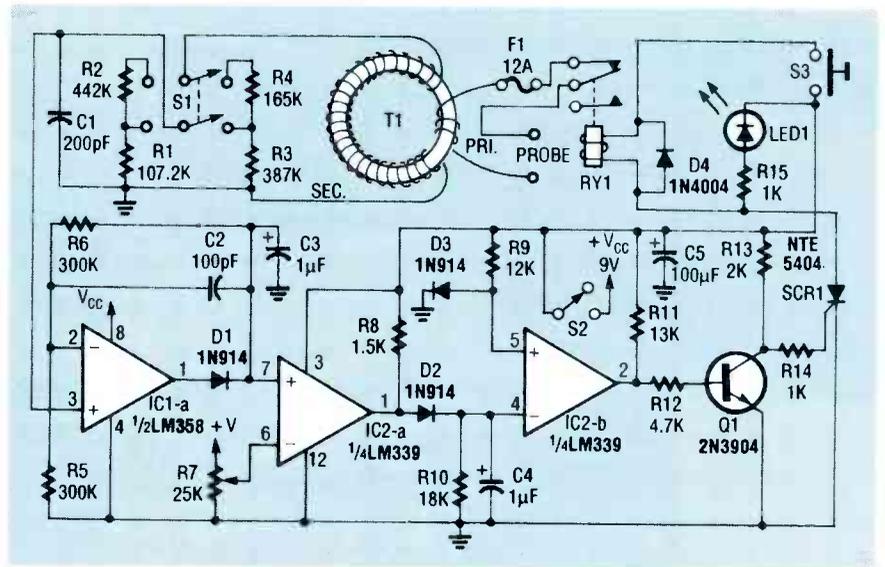


FIG. 1—THE ELECTRONIC FUSE is almost like an adjustable circuit breaker, where you can adjust the trip point anywhere from 0.1 to 12 amps.

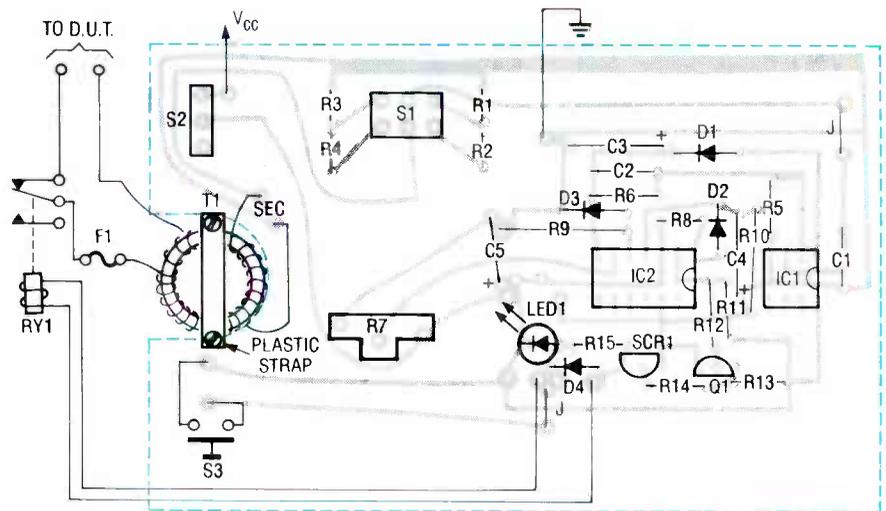


FIG. 2—PARTS PLACEMENT DIAGRAM. Because various controls are mounted directly on the PC board, you may have to drill tiny pilot holes on the circuit board in the center of each control location, place the unpopulated circuit board directly on top of the case, and then transfer the holes before installing the components on the board.

the relay is pulled in. Both integrated circuits are single-supply types, so any 12-volt battery or power supply can be used.

Construction

Everything except the relay and fuse are mounted on a PC board, for which we've provided a foil pattern—you can also buy a pre-made board if you like (see the parts list). If you use the PC board, you'll have to drill the holes in the case cover very accurately in order to accept the switches, LED, and potentiometer directly from the circuit board. One way to deal with this problem is to drill a tiny pilot hole on the circuit board in the center of each component location that

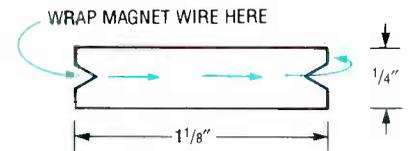


FIG. 3—THIS WIRE SPOOL allows easy winding of the torroid transformer (see text).

must come through the top cover. Then place the unpopulated circuit board directly onto the top cover and transfer the holes. This problem should be dealt with before installing the components on the board. Figure 2 shows the parts-placement diagram.

The torroid transformer was



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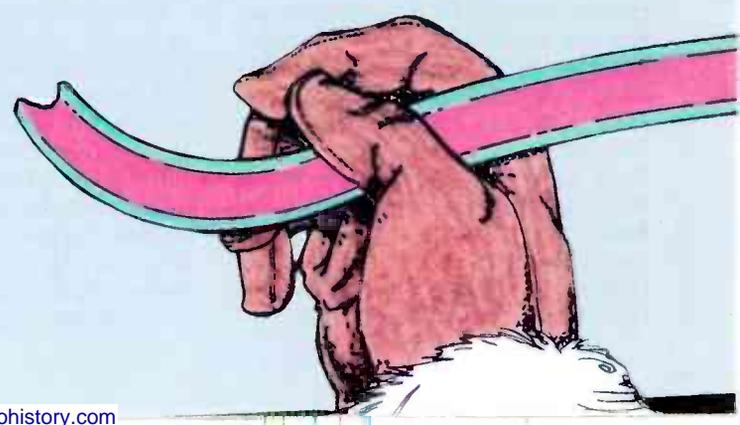
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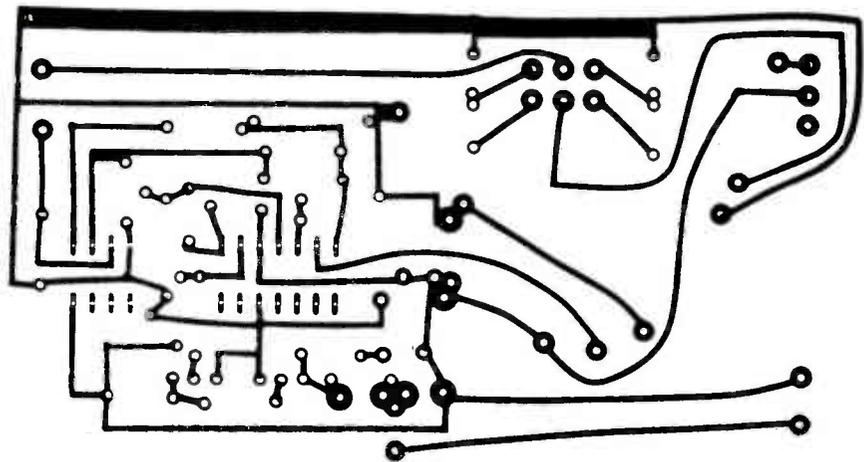
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constructed from a 0.5-inch powdered-iron torriod. A wire spool was made from a scrap of PC-board material, about 1¼-inches long by ¼-inch wide with V-shaped notches cut at both ends (see Fig. 3), and 30-gauge magnet wire was wound on the spool between the two notches. The spool was then pushed in and around the core of the torriod (like a sewing needle) forming a 100-turn coil (T1's secondary) all the way around the entire torriod core (you unspool the wire as you make the turns). The ends of the 30-gauge magnet wire were stripped and carefully soldered to 24-gauge wires. Five-minute epoxy was then brushed over the secondary coil. After the glue dried, the two splices were glued to the edge of the torriod with another spot of epoxy to reduce the stress on the 30-gauge wires.

The primary coil was wound over the secondary using two turns of 16-gauge wire with insulation heavy enough for about 12 amps. Heavy linecord can be used for the primary if you like. The torriod was placed over the square notch on the end of the PC board (as shown in Fig. 2), and attached to the board with a plastic strip placed over the torriod and fastened with two screws. One of the 16-gauge wires was connected in series with the 12-amp fuse; the other end of the fuse was connected to an alligator clip. The other 16-gauge wire was connected to one end of RY1's normally closed contact. The remaining relay contact was connected to another alligator clip. Note that the relay used in the prototype is a double-pole unit with the contacts wired in parallel to handle higher current. Figure 4 shows the prototype.

A later version of the electronic fuse replaced the alligator clips with a chassis-mounted female power receptacle. The device under test is plugged into the outlet on the electronic fuse and a 12-amp fuse is placed in the fuse holder of the device being tested. The electronic fuse, set at the fuse value of the device being tested, will then fully protect the faulty circuit until you have located the problem. Then simply replace the original value fuse in the circuit you just repaired.



FOIL PATTERN for the electronic fuse PC board.



FIG. 4—EVERYTHING EXCEPT the relay and fuse are mounted on the PC board.

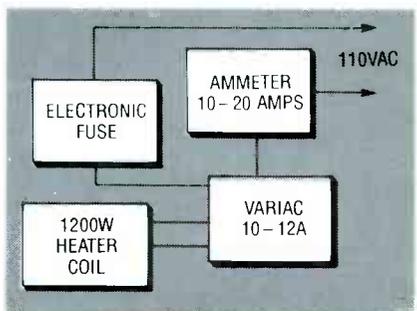


FIG. 5—CALIBRATION IS PERFORMED using a 1200-watt heating element coil connected to the output of a variac (see text).

Operation

Operation of the electronic fuse is quite simple. The alligator clips connect to the fuse holder of the device under test, essentially substituting the electronic fuse for the fuse that was in the original circuit. First choose the high- or low-sensitivity position of S1; the low range covers ½ to 6 amps and the high range covers 1 to 10 amps with overlap between the two ranges. Next adjust R7 for

the current setting that best represents the desired fuse value. Turn on the power switch S2, and reset the electronic fuse by pressing S3. Now turn on the device being tested; if LED1 lights, the "fuse is blown" and you must reset the circuit by pressing S3. Continue to troubleshoot until the repair is completed.

Calibration of the Electronic Fuse was performed by using a 1200-watt heating element coil, but an electric fry pan or toaster could be used instead. The thermostat in a fry pan must be turned up to maximum or disabled. The heater is connected to the output of a variac and the input of the variac is connected in series with an ammeter and the electronic fuse (see Fig. 5). The variac output is slowly stepped up in small increments. A calibration sheet is placed under R4's adjust knob.

Calibration must be done for both the high and low ranges. Begin by selecting the low range, and turn R4 clockwise to about midway. Next turn on the variac and adjust for about 1 amp, then rotate R4 to the trip point. Place a pencil mark on the calibration sheet, back down the variac, and reset S3. Bring up the variac to the point you just marked for one amp, and watch the meter to ensure that you are drawing one amp as the breaker "trips." Now proceed with the next value, adjust R4 past midway, set the variac for two amps, and rotate R4 down to the trip point. Repeat the procedure for each fuse value in the low and high ranges. R-E

HARDWARE HACKER

Standards resource information, more on FM stereo chips, fractals & chaos update, home energy monitoring, and current-transformer ideas.

DON LANCASTER

Let's start things off with a bunch of updates to some of our previous topics. That along with several answers and random comments to a few of our more asked helpline calls...

FM stereo broadcasters

That *Rohm* BA1404 FM stereo transmitter chip sure has been popular, and a dozen sources now exist for kits via ads in **Radio-Electronics**, in *Nuts & Volts*, and elsewhere. The micropower and low-cost chip was originally intended to ease adding a CD player to your car radio. You just unplug your regular antenna, insert a module containing the BA1404 into the radio, and plug your old antenna into the new module.

Presto. Instant and hassle-free high-quality stereo access to your car audio system. The fact that the chip made a really great wireless broadcaster was an afterthought.

But there are problems with some of the kits. Some do not use a crystal for the 38-kHz stereo pilot subcarrier, and that can lead to drift and adjustment hassles. A suitable 38.4-kHz crystal is cheaply available from *Statek*.

A second problem is that many premium FM receivers are synthesizer-controlled these days, and they *demand* a frequency that is *exactly* on channel. Older and cheaper FM receivers had an AFC analog frequency lock that could grab any old frequency and follow it as it drifted around.

Can you *directly* crystal-control a broadcast-quality FM transmitter? Not really, because you are asking for something that is both ultra "stable" and instantly able to accurately "drift" over a wide frequency range as it is being modulated.

Instead, you normally would use an *indirect* method to stabilize your FM transmitter. You should add a small varactor diode (say 10 pF) across your tank so that you can tune your

tank circuit by using a DC control voltage. Details on that are in *Rohm's* ap-notes. Then, you divide down your output frequency to average out your modulation and compare it against a reference. A DC control voltage is then derived to hold the frequency. Phase-lock-loop style.

I'm checking out several suitable circuits, so stay tuned. Or else send me your favorite solution to this on-going circuit hassle. What's really needed here is a low-cost, low-power, single-chip synthesizer.

Alternators as steppers

Yes, they definitely do work, and an amazing number of hackers have already picked up on that on their own. The important uses now include animation stands and computer-controlled wood routers. One videotape I received was quite impressive.

This is an interesting example of *synchronicity*. If the time is right for something, it should emerge from dozens or hundreds of apparently independent sources. By the same token, attempting to patent your "new idea" is almost certainly futile, again because of synchronicity.

Word has it that rewinding your alternator gives you by far the best results. Try something around twenty feet of #26 wire *per pole* and straddle only one single pole (instead of the usual three) with each winding.

The driver circuits that I showed you purposely held back on the power to keep you from burning things up on your first cut. Naturally,

you'll go to higher power and properly current-limited two-level drivers as you improve your designs.

Video time codes

I forgot to tell you that the SMPTE vertical-interval time code is usually sent on lines 13 and 15 of your field retrace. In retrospect, the code is horribly klutzy and incredibly inefficient. Owing mostly to its having to evolve from an earlier movie-film standard and from very primitive extraction electronics. Rear-view mirror style.

A bunch of newer time codes are now emerging. All incompatible, of course. Both *NEC* and *Sony* are pushing their own time standards on new consumer video products. More on these when I get a chance.

Our second most popular helpline topic (second only to caller ID) is on the new VCR time code. The one that lets you look up a magic number in a directory or a video guide and easily program your VCR for an unattended recording. It turns out that the two developers of the recording code are Daniel Quo and Henry Yen. More info on the use and distribution of the code is available through *Gem Star Development Corp.*

At present, their code is "secret." Naturally, that won't last for long, and you can expect either complete technical details or else a fully open substitute to evolve shortly. Consult the usual suspects.

To me, it makes infinitely more sense to derive a simple code based on channel, time, date, and duration. One that anyone can apply and use. Most computer manufacturers have learned long ago that open is the *only* way to go.

Witness Adobe System's fortune skyrocketing when they released the *black book* showing how their super secret type-1 PostScript fonts were encrypted. In reality, their highly touted encryption was an outright joke. Why? Because any computer-literate seventh grader could trivially

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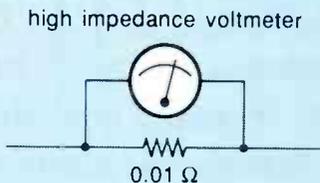
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crack their code with a little patience and zero insider knowledge. But that's another story. See my *Ask the Guru II* reprints for details. And I do stock some black books here.

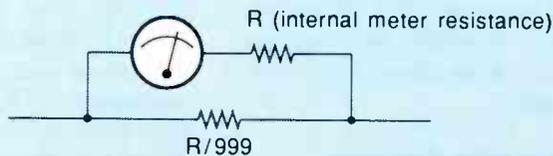
Fractals and chaos

One of the shortcomings of James Gleick's popular *Chaos: The Making of a New Science* was that it was a tad shallow in spots. It would lead you up to lots of great stuff, and then leave you with nowhere to go. That has now been cured in spades through *Chaos: The Software* from Autodesk. The \$59.95 software package uses a color VGA on any IBM PC or clone. It includes stunning and spectacular interactive demos of Julia sets, Mandelbrot sets, chaotic pendulums, strange attractors, chaos games, fractal forgeries, toy universes, and bunches more.

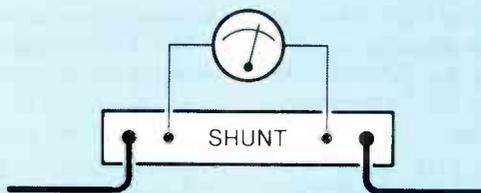
One major emerging use for the fractals is in video compression. The *Iterated Systems* people have just introduced a unique series of new products. These include their *POEM Fractal Factory* and *POEM Fractal Slide Projector*. Amazingly, they use *software only* to decompress a full



- (A) The standard way of measuring a DC current is to place a very small valued shunt resistor in series with your power load. The voltage drop across the shunt and Ohm's Law will tell you the current. In this example, an 0.01 Ohm shunt gives you a tenth of a volt out for a measured current of ten amperes.



- (B) If an ordinary meter is used, its internal resistance must be included in the calculation of the shunt value. As shown here, to convert an 0-1 DC milliammeter with an internal resistance of R into an 0-1 DC ammeter, you have to add an external shunt of R/999 Ohms. Note that the term "shunt" applies to the meter, and not to the load being measured.



- (C) When ultra-low shunt values or high currents are involved, a four terminal Kelvin measurement scheme should be used. This prevents unavoidable drops across the power connections from trashing your readings. Four terminal techniques are also used for remote load regulators and in superconductor research.

FIG. 1—SOME OF THE FUNDAMENTALS involved in DC current measurement.

animation in real time—and at compression rates approaching 100:1. Sadly, the compression process is very slow and requires expensive and custom hardware and software. Their new compression scheme is ideal for such uses as CD ROM. Much more info on all of these topics does appear in my *Hardware Hacker II* and *Hardware Hacker III* reprints.

Current and current sensing

Accurately sensing or measuring an electrical current can get tricky. Especially when AC is involved or when breaking the primary circuit is a no-no. Let us do a quick review of several of the current-sensing fundamentals and see which hacking opportunities it leads us to.

In general, there are two main methods of sensing current. With the *direct* method, you will place an ap-

propriately low resistance or an impedance in series with your load and then measure the voltage drop across that impedance. With the *indirect* method, you try to accurately measure the strength of the magnetic field created by a conductor carrying your load current.

Figure 1 shows us three stock direct-current ammeter schemes. In 1-a, a low-value resistor known as a *shunt* is placed in series with the load. You then measure the voltage drop across it with a "perfect" high-impedance voltmeter. For instance, an 0.01-ohm shunt will give you a tenth of a volt out for ten amps in.

Shunts can be anything from a piece of paper clip (thank's to Steve Ciarcia) to precision and temperature-compensated devices. Sources of shunts include *Simpson*, *Triplett*, and various advertisers found in

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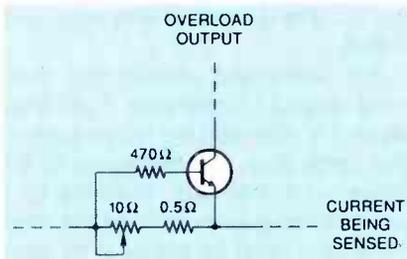


FIG. 2—THIS SIMPLE CURRENT LIMITER is adjustable over a 50-mA to 1-ampere range. Use the collector current to pull down a reference or otherwise reduce your input current or source voltage.

those *Measurement & Control* and *Sensors* trade journals.

It gets slightly trickier when you use a shunt to increase the range of an ordinary milliammeter, rather than a "perfect" high-impedance voltmeter. Details per Fig. 1-b. Say you have an 0-1 DC milliammeter of internal resistance R . Your shunt to convert it into a 0-1 DC ammeter should have a value of exactly $R/999$. Such that the combined parallel resistance of your shunt and the meter resistance ends up precisely $R/1000$.

The amount of voltage drop across your shunt will depend on the input current, your shunt resistance, and Ohm's law. The lower the R value of your meter, the less voltage drop you will get across your shunt when you measure high currents.

Since all high-current shunts are extremely low impedances, you have to be very careful that voltage drops across your meter and all your load connections do not inadvertently get included in your measurement.

That leads us to the *four terminal* or *Kelvin* connection shown in Fig. 1-c.

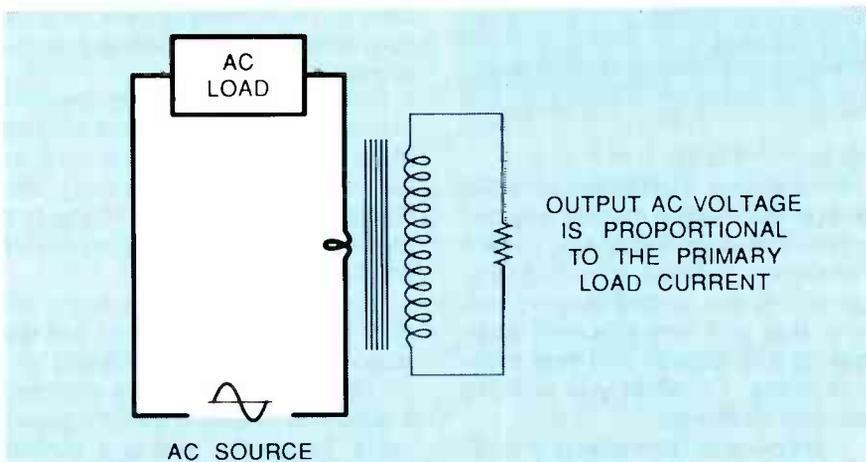


FIG. 3—A CURRENT TRANSFORMER is just a transformer that has a very low-impedance primary (often ONE turn or less) and a high step-up ratio. The voltage across the secondary is proportional to the primary current.

You measure only the voltage drop across a precisely known *portion* of your shunt. That guarantees any external high-current connections are *outside* of the voltage drop being accurately measured.

A variation on the four-terminal technique can let you use a voltage regulator remote from its load. By feeding back your voltage-sensing leads, you could include your main current drops *inside* your regulator and get more precision results. The trick, of course, is to make absolutely certain that none of the load current travels through the sensing leads.

A simple *current limiter* is shown in Fig. 2. It's adjustable over a 50-milliampere to a 1-ampere range. It is based on a silicon NPN transistor needing a 0.6-volt drop before it conducts. Whenever your transistor starts conducting, its collector current gets used to pull down a regulator or whatever, thus safely limiting your current.

As Fig. 3 shows us, current sensors for AC circuits often use a *current transformer*. That is a special transformer with a very low-impedance primary and having a high step-up ratio. The AC voltage that is delivered to the load resistor is proportional to the primary current.

There are some very important rules for current-transformer use. The load must *never* be disconnected from a current transformer! Dangerous and possibly lethal voltages could result. Also obviously, you must never disconnect the primary in any live circuit. Only the specified load resistor can be used or calibration will suffer.

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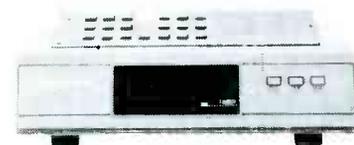
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Often, the primary can simply be a single wire through the core of the transformer. If you do use a single wire, some care is needed to get an accurate and repeatable reading. The wire should go straight through the exact center of your current transformer. It should extend straight and normal for a few inches in either direction. It must not be allowed to move or vibrate.

On the other hand, sensitivity and accuracy can be improved by using several primary turns. But there may

not be room in the core.

If the current-transformer core can be opened in some manner, you can connect or disconnect your current transformer without physically disconnecting the current-carrying load wire. That gets very important when making any service and test measurements. Or when you want to avoid an electrician.

A *snap around ammeter* is one example of an openable core. When you snap around your wire to be sensed, you are closing the core and complet-

ing a current-transformer magnetic circuit.

Two important points: You must snap around a *single* wire. If you snap around a wire and its return path at the same time, the two currents will largely cancel out, leading to a useless measurement. And the magnetic path must be identical for each snap. Thus, your core must snap together exactly and precisely. The same way each and every time.

I've found three good sources for low prices and eminently hackable current transformers. They include *Amecon*, *CR Magnetics*, and *Toroid Corporation*. The latter two offer toroidal current transformers, similar to Fig. 4. They are priced in the ten- to twenty-dollar range. Some models include built-in LED safety monitors.

But by far the most hackable current transformer I have ever seen is the *Amecon* LD-50 load detector. That beauty costs under three dollars in quality. Samples are available.

Now for the unusual part. Their LD-50 comes apart so you can install it snap-around style, without breaking your primary load wire. Wires of #8 size or smaller are acceptable.

With a 50-ohm load, the LD-50 produces 50 millivolts per ampere and is useful over a 5- to 50-ampere range. Which is ideal for most home power monitoring uses.

Home energy monitoring

Most people can save hundreds of dollars a year on their power bills, simply by finding out what electricity gets used when and by whom. And then attacking the worst of the power gobblers in a logical and a cost effective way. Step number one in this process is one or more current sensors connected to your home computer or microcontroller.

Probably the one single greatest obstacle to wide acceptance and use of home energy monitoring involves the hassles of current sensing. You do not want to rewire your house, hire an electrician, or go to any expensive and fully approved devices.

Figure 5 shows you one home energy monitor scheme that I call the *isopod*. A fully insulated and split tennis-ball shaped pod gets snapped around one insulated line of a power cable. Inside the pod is a current transformer and some black magic chips. Possibly from such outfits as *Dallas Semiconductor*, *Maxim*, *LSI*,

or one of the other good guys.

The isopod derives all the power it needs from the sensed current. A separate control receiver/transmitter is located a safe few feet away. The control box uses a lower-frequency radio waveform to interrogate your isopod. If properly addressed, the isopod responds by returning a high-frequency code burst equal to the current presently being measured. Finally, the control box intercepts the data burst and converts the sensed current into standard serial data that a computer can understand.

As shown, the isopod would only measure and monitor current. That should be good enough for typical home energy monitoring uses. But, by carefully synchronizing the start of your data burst to the a positive-going current zero crossing, your control box could measure its own voltage to determine the lag or lead and your actual real and reactive power.

Several channels could be made available by using different isopod addresses. That solves the dilemma of simultaneously monitoring both legs of the normal 220-volt, center-ground home power system. Or of monitoring individual breaker lines.

You can probably snap the pod directly onto your incoming power leads ahead of the meter—up on the roof where they are easily open and accessible. The tiny extra power "stolen" from your utility would add half a cent to a \$200 monthly power bill. And the potential utility benefits in load shedding and load leveling would be much higher.

I can think of lots of other uses for a cheap and fully isolated, snap-on current sensor. Safely measuring high-voltage industrial systems can be one obvious use. Getting info onto or off of a rotating shaft or moving machine is a second.

And last summer I had a slightly but infuriatingly intermittent frost sensor in my heat pump. It sometimes insisted on switching over to high emergency heat during the middle of an Arizona desert summer afternoon.

The several wasted service calls and the perfectly good parts that were unnecessarily replaced could have been eliminated by several snap-on isopods that monitored and recorded what was going down.

But why don't you tell me instead? For this month's contest, just tell me

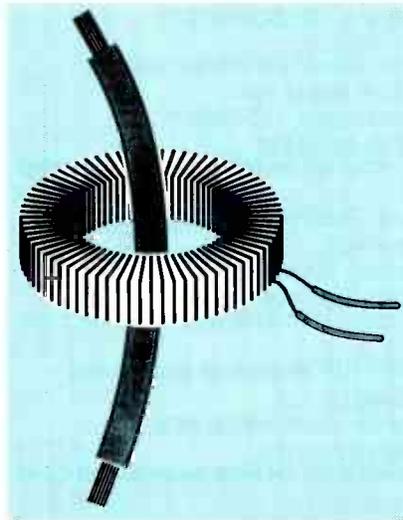


FIG. 4—A TOROIDAL CURRENT transformer is economical and accurate. It is also self-shielding. But you physically have to disconnect and thread the primary wire through the core center.

what you would do with one or more isopods. Or else contribute somehow to our home-energy dialog. There will be all of those usual newly revised *Incredible Secret Money Machine* books going to the dozen best entries, with an a great expense-paid (FOB Thatcher, AZ) *tinaja quest* for two going to the best of all. Be sure to send your written entries directly to me at *Synergetics*, and not to **Radio-Electronics** editorial.

Getting standards info

Where do you go to get a copy of EIA standard RS-232? Two obvious places to start include the *Encyclopedia of Associations* on the reference shelf of your local library. Or, for government standards, the

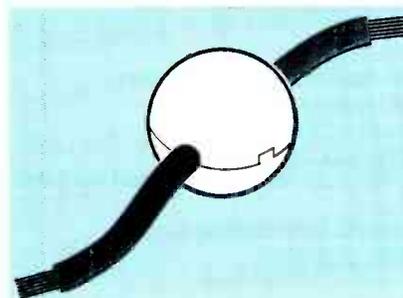


FIG. 5—THE "ISPOD" CONCEPT greatly simplifies home energy management. The isopod clamps on one of your incoming power cables. Inside is a current transformer and some micropower electronics. On any addressable VLF radio inquiry from a nearby control module, the isopod returns your present current consumption as a UHF radio signal. Response is synchronized to current zero crossings so that both real and reactive power can be remotely measured.

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main *Federal Information Center* phone number of (800) 359-3997.

To make things easier for you, I've gathered up most of the standards associations and resources of hacker interest together for you into our resource sidebar for this month.

Two quick notes. *ANSI* is just the American arm of the international *ISO*. They are pretty much one in the

same. And the *US National Bureau of Standards* has long ago changed their name over to the *National Institute of Science and Technology*, or *NIST*.

Actually, RS232 has been largely replaced by the MacDonald interface. Jerome R. MacDonald is the senior member of a design team in the dairy science division of the *US*

Department of Agriculture who came up with a fast, convenient, error-free, and fully networkable serial communication setup.

The great MacDonald interface is presently up for *Electronic Industries Evaluatory (EIE)* status. Thus, the old MacDonald farm interface is now an EIE I/O.

New tech lit

From *Hitachi*, there's an *Audio and Video IC Data Book* chock full of unusual video camera, digital audio, and broadcast satellite chips. And from *Silicon Systems*, a pair of newer data books on *Communications Products* and *Storage Products* chips.

Free user samples of the TPIC2801 intelligent power drivers plus an Application Report are available from *Texas Instruments*. This one is particularly useful for various automotive and solenoid driver applications.

Trade Winners now has a US phone and address. This Hong Kong answer to *Computer Shopper* gives you direct access to far-eastern computer and electronic sources.

The monthly *EPRI Journal* is full of power ideas, ranging from solar, to energy conversion, to cold fusion, to cogeneration. It is free to utilities or anyone associated with the media, but \$29 per year otherwise. *EPRI* also has lots of videos and reports.

The *Alternate Energy Sourcebook* is a combination catalog and resource file offered at a refundable \$14 from *Real Goods*. On their catalog side, you will find such goodies as solar panels, pumps, DC lights, and such. On the resource side are tech articles by Amory Lovins and directories to electric vehicle clubs.

How to Automate your Home is a new self-published manual by David Gaddis and offered through *Home Automation USA*. Well done.

I've newly revised and reprinted the second edition to my *Incredible Secret Money Machine*, and now have autographed copies in stock for you. And for those of you interested in Display PostScript, I have now posted a freeware *GhostScript* clone to my *GENie* PSRT board. Included are special Ghostscript fonts and the full source code. You'll also find *Hardware Hacker* and *Blatant Opportunist* preprints here, along with bunches of goodies not available elsewhere.

R-E

DRAWING BOARD

Automotive charging systems.

ROBERT GROSSBLATT

I know that the shortest distance between two points is a straight line but that's not the way things work in life. Nothing ever goes according to plan—things keep coming up and getting in the way no matter how careful you are. We were supposed to talk some more about digital scopes and get into the hardware side of things. Well, that's not going to happen until next time. Something else came up.

A few months ago I answered a letter in the *Ask R-E* column from a fellow who was rebuilding an old British motorcycle (see **Radio-Electronics**, August 1991). He was looking for an alternative to Lucas electrical stuff—always a good idea, by the way—and wanted a way to build a voltage regulator. Since I've rebuilt a '65 Triumph Bonneville and a '68 Jaguar, I was naturally the person to talk to.

Since that letter appeared, we've received an unbelievable amount of mail asking for a foil pattern and ways to handle vehicles that have a slightly different charging system. Since there's no room for that in the *Ask R-E* column, we'll take care of it here. So bear with me... we'll get back to digital scopes next time.

At its most basic level, a car or motorcycle electrical system needs only two things: a battery to start the engine and a way to keep the battery charged. It's amazing how something so fundamentally simple can be so much of a hassle.

Once upon a time, the recharging part of the electrical system was a DC generator that was turned by the engine. The faster it turned, the more current it produced and, since overcharging a battery is what we technically refer to as a "bad thing," some way had to be found to control the amount of current produced by the generator. The voltage regulators for generators were inherently crude since the generator itself is an inherently crude device.

There's not much of a difference between a car generator and the hand-cranked generator used by Tom Edison to demonstrate his first light bulb. The faster you turn it, the more current it produces and the current limits are completely determined by the construction of the generator. This meant that the only way to regulate the amount of current being sent to the battery (and the car's electrical system) was to put something between the output of the generator and the rest of the car.

Voltage regulators designed for use with generators have to be really beefy because they often have to handle a lot of current. Remember that the amount of current produced by the generator is directly related to the engine RPM. Most of the regulators are essentially relays that constantly make and break the connection between the generator output and the rest of the electrical system. The amount of current fed from the generator to the battery is determined by how often and for how long the contacts are closed.

Since generators, and the regulators that control the current they produce, are a really stupid charging system, the car and motorcycle manufacturers jumped on alternators as an alternative (really sorry about

that), as soon as they became available. Alternators are AC generators and their basic characteristics make them much more attractive for use in an automotive charging system.

For starters, alternators have a much higher output at lower RPM and they're much easier to control. The best way to think of how an alternator works is to compare it to a transformer. As you can see in Fig. 1, there are two separate windings in an alternator. The main winding is the one that produces the AC current but the amount of current it can produce is controlled in two ways. The number of RPM sets the maximum possible current, but the amount actually produced (up to the maximum) is determined by the amount of current flowing in the second, or field, winding. The greater the current in the field winding, the more current you'll get out of the main winding.

The AC current produced in the main winding is rectified by a full-wave bridge made of six diodes and the resulting DC is fed to the rest of the car's electrical system. In order to regulate the current put out by the alternator, you don't (as with the generator) chop the output, but simply regulate the amount of current flowing in the field winding. A voltage regulator for an alternator has to monitor the state of the battery and send enough current to the field so the alternator will keep the system voltage somewhere around 13.5 to 14 volts.

If the battery voltage is really low, the regulator will sense that and cause the alternator to put out enough juice to charge the battery back up. Since the regulator is driven by the battery voltage, as the battery's charge increases, the regulator will lower the output of the alternator. That's certainly much better than the older generator system because the regulator is a low-current device and is therefore cheaper to manufacture and a lot more reliable.

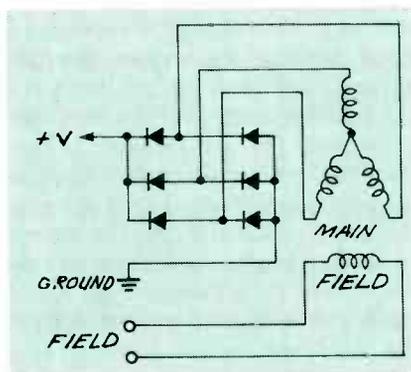


FIG. 1—YOU CAN THINK OF AN alternator as a transformer with two separate windings; the main winding and the field winding.

Most modern alternators have a regulator built inside them. That may or may not be such a great idea since it means the alternators are going to be more expensive and a lot more difficult to repair. For those of us that have vehicles with alternators and external voltage regulators, there's no reason why you have to be a helpless slave to using the manufacturer's regulator. You can easily build a much more versatile one for a couple of bucks and thumb your nose at the often arrogant people behind the parts counter.

Nothing is standard and the way a part can be used is directly proportional to the number of terminals it has. Since an alternator-based electrical system is basically simple, I've got to admire the amount of creativity the vehicle manufacturers have shown in making things as complex as they are.

A basic alternator has four connections as shown in Fig. 1. The field winding has two ends and so does the outputs of the full-wave bridge. Before you can build your own voltage regulator, you first have to determine how the manufacturer has wired these four terminals since the design of the regulator is different for each one.

It's a safe bet that the two main outputs of all alternators are wired the same—the positive output goes to the hot side of the battery and the negative output goes to the system's electrical ground. However, what most likely causes the problem is what the manufacturer has done with the field winding.

There are three possibilities:

1. *A pulled-up field*—In this setup, one side of the field is connected to the positive side of the battery and the voltage regulator moves the other side closer to and further away from ground.
2. *A grounded field*—One side of the field is tied to ground and the regulator moves the other side closer to and further away from the system's positive voltage.
3. *A floating field*—Both sides of the field windings are brought out to terminals on the alternator and the manufacturer wires them into the system using one of the first two methods.

At the risk of sounding like a disclaimer at the bottom of a glitzy ad, it's extremely important to know exactly how your charging system is set

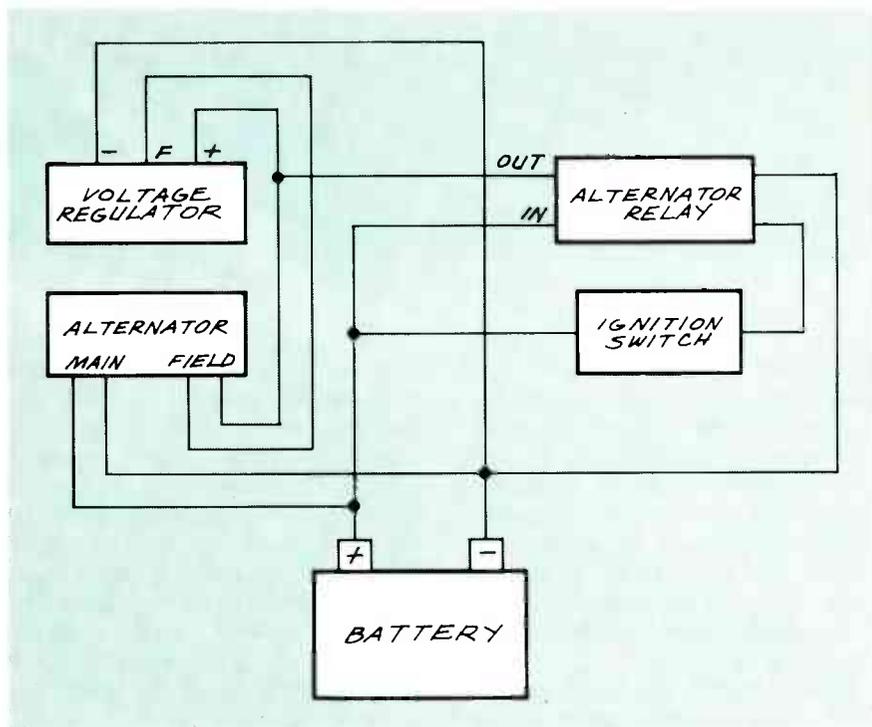


FIG. 2—HERE'S THE BASIC CHARGING-SYSTEM LAYOUT for a pulled-up field system.

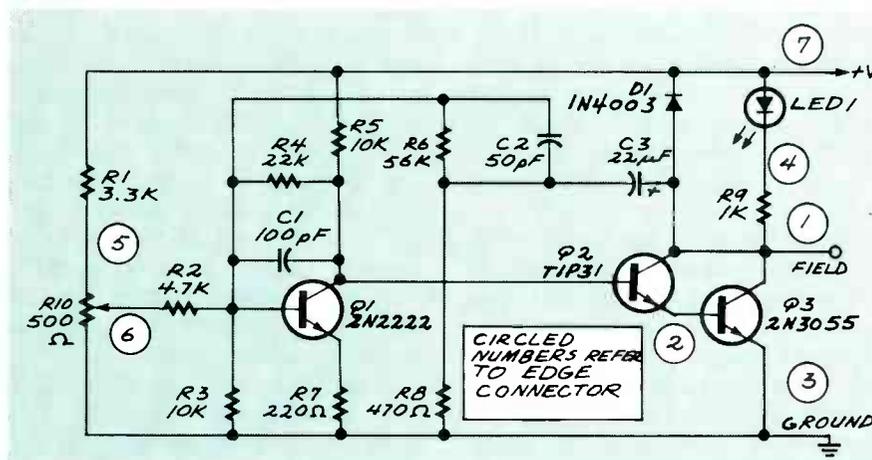


FIG. 3—THIS IS THE REGULATOR NEEDED for a pulled-up field. The circuit monitors the state of the battery through a resistive divider and causes the voltage to change at the field terminal.

up because a mismatch between the voltage and the alternator will cause a lot of damage. It's a given that the regulator will blow up but that's not too bad because you can build another one. The real problem comes from the fact that your alternator can get destroyed as well. That's not even too bad a problem if only the diodes have been trashed since you can replace them for a minimal cost too—but if you've burned out the coils in the windings, you're looking at a whole lot of bucks.

Before we get on with this, let me tell you that I've seen several alternators that had both sides of the field

brought out to terminals but still had one of them tied internally to +V or ground.

Be warned.

Most British vehicles—both cars and motorcycles—use a pulled-up field and the basic charging system layout is shown in Fig. 2. One side of the field is tied to the positive side of the battery through a relay that's energized when the ignition is turned on. The relay is needed because a permanent connection would mean that the alternator's field windings were connected across the electrical system all the time and, since they usually have a resistance of about

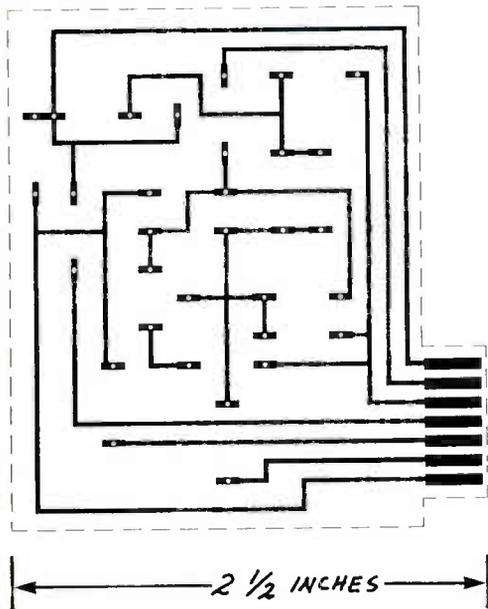


FIG. 4—THE FOIL PATTERN for our regulator circuit. It's shown here actual size.

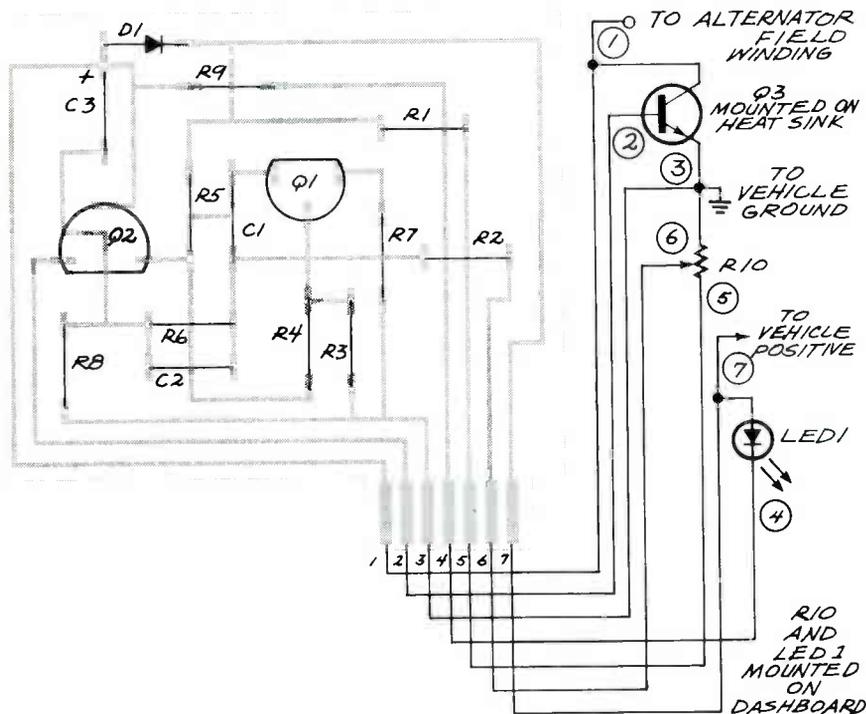


FIG. 5—PARTS-PLACEMENT DIAGRAM. Remember that Q3 should be mounted off the board on a heatsink and R10 and LED1 can be mounted on your dashboard.

four ohms, the battery would drain completely in no time at all. Not a good thing.

The circuit in Fig. 3 is the regulator needed in this case and it's designed to work with a pulled-up field. As you can see, the basic action of the circuit is to monitor the state of the battery through the resistive divider made up of R1, R2, R3, and potentiometer R10, and to cause the voltage to change at the terminal marked "FIELD."

When the ignition is turned on, current flows through R5, turns on the home-made Darlington pair consisting of Q2 and Q3, and this sends current to the field windings of the alternator. When the engine starts and the alternator begins delivering current to the system, the resulting voltage is sampled through R2 and, at a point determined by the setting of R10, Q1 begins to conduct and drops the voltage at the base of Q2. That

continued on page 79

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DECEMBER 1991

Efficiency and amplifier design

LARRY KLEIN

An audio amplifier of any design can be considered a sort of complex electronic valve between the AC wall outlet and your speakers. The audio-signal voltages from the program sources serve as control signals that vary the much larger power-supply voltages and currents provided by your local public utility.

The power-supply section of an amplifier has the task of converting the AC supplied by a wall outlet to a direct current of the desired voltage and current capabilities. Limitations in a power supply's ability to deliver voltage and current ultimately determine the amount of output power available to drive speakers. Of course, another potential limitation is the amount of current that the output transistors can handle. But today's high-power output transistors are relatively cheap compared to heavy-duty power-supply transformers and heat sinks—and certainly less bulky.

Power supply performance

What demands do we make on a power supply besides that of converting AC to DC? Ideally, it should be able to instantaneously supply all the current and voltage needed by the output transistors to produce the desired output wattage in the speaker load: A standard—if not particularly cost-effective—way to achieve that goal is to build in a power supply designed to stand up under any signal contingency. That means a massive power transformer with heavy low-resistance windings (around an appropriate core) capable of supplying the needed current, one or more heavy-duty bridge rectifiers, and very large filter/reservoir capacitors that are kept charged to a high-voltage level to cope with transient peak voltage/current demands. A few audiophile amplifiers are built that way, and their owners take pride in the fact that they can't be lifted without risk of a hernia.

The operating theory of a conventional power supply is somewhat similar to that of the standard home hot-water heater. A large storage tank of water is maintained at a high temperature against the time that several family members might decide to take a shower and/or run both the dishwasher and the washing machine. To guarantee enough hot water reserve for several persons to shower comfortably (assuming they don't do it together), the storage tank would have to be bigger, the heating elements larger, and/or the water hotter. The need to hold large amounts of water at a constant high temperature despite the intermittent usage makes the typical hot-water heater a thermally inefficient waster of both space and fuel. There are high-efficiency, on-demand, tankless hot-water systems available on the market, but for some reason they've never become popular.

Toward higher efficiency

Supposing an amplifier designer set himself the goal of designing a more efficient and cost-effective power supply that would nevertheless provide all the power needed for musical contingencies: How would he go about it? In much the same way that some hot-water system manufacturers did: He would have the power supply "turn on" only when required, and to the degree that it is needed, rather than running continuously at full output. Such an approach has significant advantages. Much of the thermal inefficiency of conventional amplifiers arises from the fact that the power output transistors are required to handle the full potential of the power supply even when the amplifier is being driven to a very low output level, or when there is no output at all! Current flow through the output transistors creates the need for the large finned heat sinks that line the rear or side panels of conventional power amplifiers. The heat

sinks radiate that wasted power and thereby protect the output devices against thermal breakdown and stabilize the operation of other circuit elements that are affected by high temperatures.

Super efficiency

Amplifiers with "smart" or tracking power supplies monitor the audio signal level and continuously adjust the power-supply voltage to the levels needed to support the required output level. There are several high-efficiency designs that use this technique. Soundcraftmen's "Vari-Portional" circuit was probably the first to reach the market. The Vari-Portional circuit uses a fixed-level, low-voltage power supply plus an "on-demand" signal-controlled high-voltage supply.

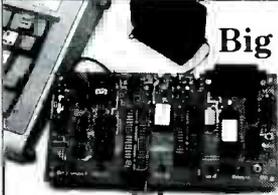
Because of music's low average signal level, the amplifier operates as a low-power unit using its low-voltage supply 90% of the time. This means that the dissipation (heating) of the output stage is substantially reduced, since dissipation is directly proportional to the voltage applied across the output transistors. And even when a momentary signal peak turns on the high-voltage supply, its moment-to-moment voltage level is raised no higher than necessary to handle the signal peak, rather than being constantly fully on as with conventional output circuits. Two other, smaller companies that use similar smart power supplies come to mind: QSC and Crest.

About 10 years ago, Bob Carver introduced a "magnetic-field" power amplifier that startled the audio world by its ability to produce a total of 400 watts from a 9-pound, 6½-inch cube. It included several innovative design concepts that both reduced the size of its internal components and increased efficiency to unprecedented levels. The unconventional "magnetic field" power transformer operates with a solid-state phase-controlled

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Triac in series with its primary. The Triac controls the voltage reaching the primary of the transformer in the same way that Triacs in light dimmers adjust the voltage reaching a lamp bulb—except that it does so it under electronic rather than manual control. An isolating photocoupler sensing element responds to voltage variations at the transformer secondary caused by changes in power demand, and adjusts the phase angle of the Triac to allow more or less AC to reach the transformer primary. At the transformer secondary there are up to four separate bridge rectifiers that supply $\pm 25, 50, 80,$ or 125 volts to the output stages, also depending on the signal level.

The extraordinary efficiency of the Carver design is due both to the varying AC input to the "magnetic field" power transformer and the to the varying levels of power-supply voltage, *both* of which are controlled by the moment-to-moment amplitude of the audio signal.

A final note: I've not meant to imply in my discussion that high-efficiency in amplifiers necessarily correlates with their sonic quality—any more than it does in speakers. But, as with speakers, if you can get efficiency *plus* all the other desired properties, then it seems to me that high efficiency (meaning reduced size, cost, and heat radiation) is obviously the way to go.

R-E

DRAWING BOARD

continued from page 77

causes the Darlington pair to turn off and cuts the current sent to the field windings. The alternator output will drop off which also turns off Q1.

The voltage sampled by R10 will always be a fixed proportion of the system voltage but the ratio can change due to heat and other factors. Remember that the engine area of a bike or car is a really harsh environment. If you find that to be a problem for you, replace R2 with a 8 ± 10 volt Zener diode.

The fundamental switching action of the regulator circuit gets help from the positive feedback supplied by C3 and R6. When the Darlington starts to turn off, the voltage at its collector increases and some current flows through C3 and R6. The current at the base of Q1 is the sum of the tapped system voltage through R10 and the feedback supplied through C3 and R6. That speeds up things to get to the point where Q1 will turn on and turn off the Darlington pair and shut down power to the field. When that point is reached, C3 dumps the rest of its charge through R7 and R8 and the current flow in the field windings drops to zero. Diode D1 protects the Darlington pair from being damaged by the induced voltage that appears

when the field current collapses.

The knee of the voltage regulator is determined by the setting of R10. By adjusting the position of the potentiometer, you can change the voltage setting of the car's electrical system. The LED will provide a peace-of-mind indicator to let you know that the circuit is working, but a flashing light can be annoying so, if you put it on the dashboard, use a small LED.

The foil pattern for our regulator circuit is shown in Fig. 4. The reason for the multitude of connection points is because Q3 should be mounted outside the case on a heatsink for cooling. The board was also designed to have LED1 and potentiometer R10 mounted outside the case. If you're going to use the regulator in a car, it's nice to have them right on the dashboard near the voltage indicator.

There are fingers on the PC board so the connections to the off-board components can be made with a handy-dandy edge connector on tenth-of-an-inch centers. If you can't find one, you can always use a header and some ribbon cable, but edge connectors are a lot easier. The parts-placement diagram is shown in Fig. 5. (Remember that this setup is for a pulled-up field.)

When we get together next time, I'll talk about grounded fields and make a few suggestions about what to do if you have—gasp, gasp—a vehicle with a generator.

R-E

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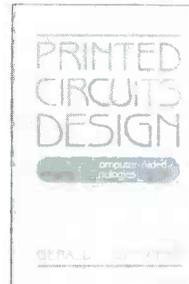
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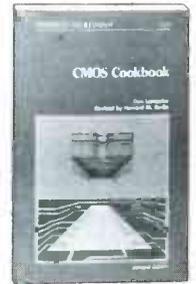
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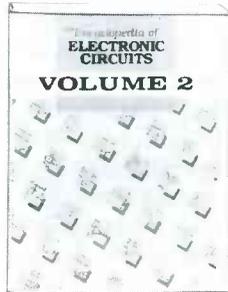
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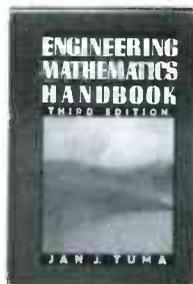
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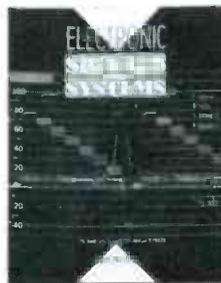
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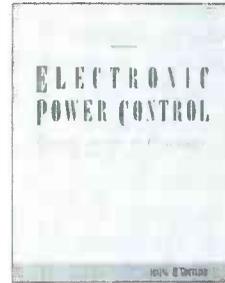
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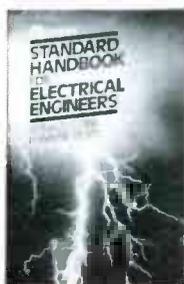
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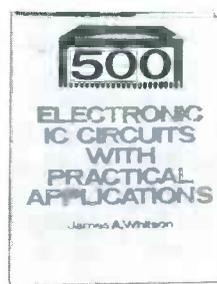
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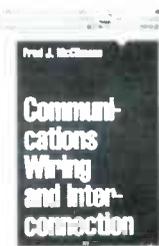
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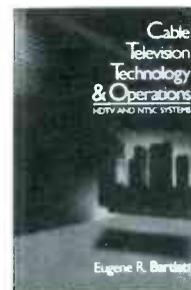
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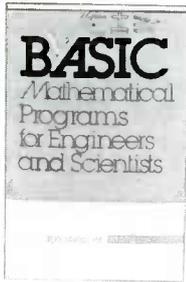


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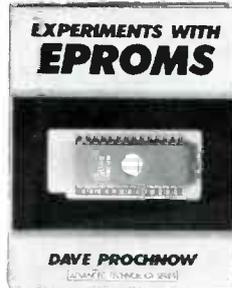
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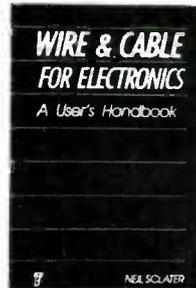
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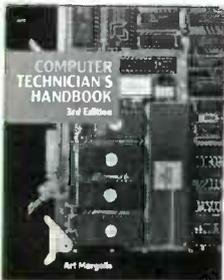
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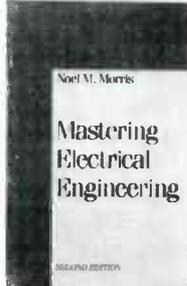
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COMPUTER CONNECTIONS

1991 Retrospective

JEFF HOLTZMAN

This is the last calendar issue of the year; let's take a look at what happened and make some educated guesses about where things are going in the personal computer industry.

1991 will be remembered as a turning point in the history of personal computing. It was the tenth anniversary of the IBM PC. In 1981, the 4.77-MHz 8088 microprocessor though hardly leading edge was certainly much more powerful than the Z80's and 6502's most of us were used to. Today's high-end PC's offer magnitude-of-order improvements over the original in bus speed, memory addressing, disk storage, video resolution, print resolution, and general expandability.

Back then, networking was hardly out of the research labs; today it is ubiquitous. It's no longer a question of when or how the business scene will become networked, but what to do with that capability now that we've got it. This will be a huge growth area between now and the start of the next millennia.

In 1981 the big companies were IBM, Apple, Microsoft, Borland, Ashton-Tate, and MicroPro. There was no Lotus, no Novell, no WordPerfect. IBM, Digital, and HP had no idea that their business would soon be under frontal assault from a cocky band of renegades and dropouts with strange ideas about democratizing computer power.

In 1981, the three most popular applications were word processing (then dominated by WordStar), spreadsheets (VisiCalc), and database management (dBASE). Computer-based graphics and desktop publishing did not exist. Since then the dominant products have changed, but the basic categories haven't, even though it's been apparent for years to researchers and visionaries that text, data, and graphics do not exist in isolation. There were numerous attempts throughout the

decade to integrate the various forms of data; so-called integrated packages (Symphony, Framework, Enable, Smart, Works) stuck a bunch of tools together, tried to give them a common look and feel, and couldn't understand why they failed, often miserably.

What was necessary was a paradigm shift, a whole new way of looking at the problem, one that did not create artificial analytical distinctions and subsequently wonder why things never came together.

This paradigm shift is now underway, due in part to the success of Windows 3.0. Not because it solves the problem, but because it provides a tangible framework in which to think about it.

Another related but distinct factor in this evolution has been the increasing success of object-oriented analysis, design, and programming. A central feature of all OO technology is a hierarchical classification scheme that often has a much closer correspondence with reality than prior schemes.

Whereas the holy grail of integration has consistently eluded the software community, the hardware folks have shown continuing success. Overall PC size, shape, and cost remained relatively constant the previous decade; but during that time, more and more power has been

crammed in. Chip density has increased by a factor of 1000. New design techniques (e.g., ASIC's) have all but eliminated the use of discrete logic, thereby decreasing required space, increasing functional density, decreasing required power, and increasing reliability. Breakthroughs are still required in battery power, portable display technologies, and optical read/write media.

Suppose you spent \$2500 in 1981, 1986, and 1991. What kind of system could you buy? Table 1 provides one comparison. Now take the amount by which each CPU-related category has increased. Bus width is four times greater, standard memory is 64 times greater, and CPU speed is about six times greater; $4 \times 64 \times 6 = 1536$. In other words, for the same amount of cash you can now buy 1536 times the raw computing power you could a decade ago. To factor inflation, you might push that number up to 2000.

But you're still running 1981-paradigm software.

Product watch

Accelerator cards were popular for awhile in the mid '80s. Typically you installed an accelerator card in an XT expansion slot, removed the CPU, and ran a cable to the CPU socket. The accelerator consisted of a 286 CPU with some cache memory, and

TABLE 1—PC EVOLUTION

Subsystem	1981 (Z80/4 MHz)	1986 (80286/8 MHz)	1991 (80386/20 MHz)
Bus width (bits)	8	16	32
Standard memory (KB)	64	640	4096
Maximum memory (KB)	64	16384	16384
CPU speed (MHz)	4	8	25
Mass storage (MB)	0.160	20	200
Video resolution	80 × 25 text	640 × 350 (EGA)	1024 × 768 (Super VGA)
Print resolution	80 character text	9 pin graphics	300 dpi (laser/ink jet)

in a few cases, conventional memory. These cards had numerous problems, including difficult installation, occasional software incompatibility, and cost. The accelerator-card market pretty much dried up when 286 and 386 motherboard prices dropped to reasonable levels. By installing a whole new motherboard, you could get better, more reliable performance than with an accelerator card. Even so, my old XT (my *kids'* old XT I should say) still runs a Microsoft Mach 20 accelerator card with no reliability or compatibility problems.

Now a rash of second-generation accelerators (2GA's) has surfaced, this time for upgrading a 286 to the 386SX level. They're designed much more elegantly than the first-generation devices. But are they worthwhile?

To answer that question, I requested evaluation units from several manufacturers. Two responded in time; one declined, stating that the company was trying to hold costs down. Anyway, Cumulus and Evergreen sent in units for review.

My test machine was an AST Premium 286, a 10-MHz unit with two megabytes of memory that my wife uses for graphics work under Windows. I was interested in upgrading the machine for two reasons: to increase raw CPU performance, and to increase memory handling flexibility. (A 386 under DOS 5.0 or with an external memory manager can map memory into unused holes in the address space between 640K and 1MB, and load device drivers and TSR's there.) The AST is also used as a network print server and for CD-ROM access, so loading device drivers up high would return a big chunk of conventional memory.

To make a long story short, both devices worked. Benchmark results show slight performance gains that match manufacturers' claims (10–15%). In practice, speed felt about the same, due to the fact that the 2GA's run at the system's original clock speed. On the other hand, memory handling flexibility increased drastically. With either 2GA installed, I now boot with more than 600K of memory, versus about 450K before.

Mechanics

Due to obstructions around the CPU socket, both boards required mechanical socket extenders. Cumulus does not sell these adapt-

ers; Evergreen does. Cumulus primarily targets IBM and Compaq PC's, which the company claims do not require socket adapters. Other than that, installation is simple: just remove the 286 and pop in the adapter. You may also have to play with a couple of jumper settings.

The Cumulus board, shown in Fig. 1, is about twice the size of the Evergreen board; I had to rearrange some expansion cards to accommodate either. If your CPU socket is in line with a slot that requires a full-length expansion card, or if there is little clearance between the CPU and your hard disk drive, forget about using one of these 2GA's.

The cards differ in their support of math coprocessors. You can install a

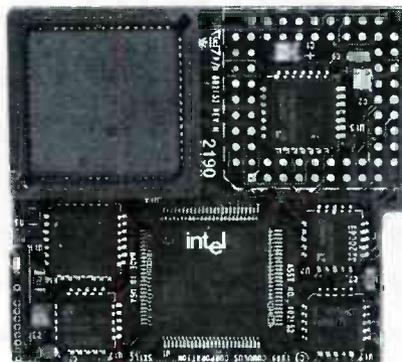


FIG. 1—THIS ACCELERATOR CARD from Cumulus converts your 286 to 386SX operation for about \$300. The empty socket can hold a 387SX.

387SX right on the Cumulus card, but you must run a separate \$25 flex cable to the 287 socket. The Evergreen requires a separate \$99 adapter to run a 287. Evergreen also sells several accessories, including a clock adapter (\$10) that increases 287 speed to 25 MHz, 25-MHz 287's (\$99), socket adapters (\$10 for 1/8", \$35 for 1/4"), and AMI BIOS upgrades (\$30), which may be required if your old BIOS has tight timing loops.

The base price of the Evergreen is \$199; the Cumulus goes for \$299. I wouldn't be surprised to see those prices decrease, because full 16-MHz motherboards are now available for \$250–350.

Choosing between the two, I liked the Evergreen's compact size and elegant design, but the Cumulus provides slightly better benchmark performance, comes with Windows 3.0 and a 386 memory manager, and has better coprocessor support. On

the other hand, Evergreen sells socket adapters, Cumulus doesn't, and I suspect it's hard to find those things on the open market.

How to choose between a 2GA and a 386SX motherboard: The motherboard will be more trouble to install and will cost more, but not by much in either case. In addition, it will be more reliable and compatible, and will give much better performance.

The bottom line is that a 2GA is a cheap way to upgrade to 386SX memory-handling capabilities. If you're looking for a real performance increase, look elsewhere. If freeing up some memory will suffice, one of these second generation accelerators can do the trick.

Book Nook

Last year at this time I wrote about two meaty Abacus books, *PC System Programming* and *Turbo Pascal Internals*. Now comes *Windows System Programming*, which consists of 700 pages and a floppy disk of source code. Sixteen chapters cover text output, dialog boxes, graphics, colors and bitmaps, the multiple document interface (MDI), DDE, DLL's, printing, memory management, serial I/O, and more. The book is aimed at C programmers, and depends on use of Microsoft's Windows development tools. However, even if you don't program Windows in C, but instead are looking to understand more of what's going on behind the scenes, you'll be impressed with this book. It's quite readable, contains lots of examples, and provides much code that can be adapted to your own use. **R-E**

VENDOR INFORMATION

- Cumulus 386SX Card (\$299), Cumulus Corporation, 23500 Mercantile Road, Cleveland, OH 44122. (216) 464-2211. **CIRCLE 41 ON FREE INFORMATION CARD**
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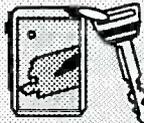
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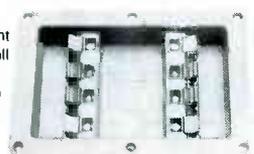


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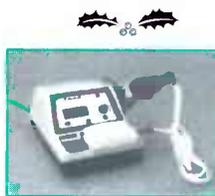


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SIA30K/60K



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Approx. 60 Sec.

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999SD

Model	999DA		999SD	
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Heater Power	30 Watt	60 Watt	60 Watt	60 Watt
Vacuum Pump	—	—	—	100VAC
Operating Voltage	12VDC	—	—	100VAC
Temp. Range	100-450°C 212-842 F	100-470°C 212-878 F	100-470°C 212-878 F	100-470°C 212-878 F
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- Utility components box • 10 foot tape rule • Electric tape • 6" long tweezers • 7" brush and scraper • 7" fine point probe • 7" slotted probe • Digital multimeter • Rosin core solder • Desoldering pump • Soldering stand • 30 Watt soldering iron with long life tip • 5.5" stainless steel scissors • Brush (to clean keyboard, monitor, etc.) • 2 piece needle file (round and flat) • 6" adjustable wrench • Heavy-duty utility knife • 5.25" bent needle nose pliers • 4.5" diagonal cutting pliers • 5.25" flat nose pliers • 5.25" needle nose pliers • 10 piece line color screwdriver set: **Slotted** - 1/8x3, 3/16x4, 3/16x6, 1/4x1 1/2, 1/4x4, 1/4x6; **Phillips** - 1/8x3 (#0), 3/16x3 (#1), 1/4x1 1/2 (#2), 1/4x4 (#3) • 6 piece precision screwdriver set (1/32, 3/64, 5/64, 3/32, 1/8, 9/64) • 8 piece hex key wrench set (fold type) (0.05, 1/16, 5/64, 3/32, 7/64, 1/8, 9/64, 5/32)

E8900 - CONTENTS:

- Brush • Mini flash light • Mini drill • Anti-static strap • Utility knife • Mini vacuum cleaner • IC extractor • 30 Watt soldering iron • Hobby vise • Soldering stand • Electric tape • Desoldering pump • 3 prongs holder • Rosin solder core • 5" flat nose pliers • 5" adjustable wrench • 5" long nose pliers • Utility components box • 5" bent nose pliers • 5 piece miniature file set • Long nose pliers with cutter • 3 piece soldering aid kit • Stainless tweezers • 11 piece screwdriver set • 4.5" diagonal cutting pliers • Electrical test screwdriver • Digital multimeter • Cleaning solution (60 cc) • 5.5" stainless steel scissors • Head cleaning fluid (18 cc) • 7 piece folding hex key wrench set • 9.5" 5-way crimping tool • 6 piece precision screwdriver set: **Slotted** - .09"x3", .19"x4", .15"x6"; **Phillips** - .09"x3" (#0), .19"x4" (#1), .15"x6" (#1) • 10 piece miniature combination wrench set (5/32", 3/16", 1/4", 7/32", 15/64", 5/16", 9/32", 3/8", 11/32", 7/16")

Order #	Price	Description	Weight
E8305	119.95	51 Pc. Pro Tool Kit	12 lbs.
E8900	199.95	92 Pc. Electrician's Tool Kit	17 lbs.

DIGITAL MULTITESTERS



M3800



Optional
RS232 Interface

M4650CR

M3800 FEATURES

- **Max. Display:** 1999 counts with automatic polarity indication • **Max. Input Current of AC and DC:** 20A (max. of 15 minutes) • **Overrange Indication:** "1" Figure only on the display • **Max. Common Mode Voltage:** 500Vdc/AC RMS • **Reading Rate Time:** 2-3 readings per sec. (approximate) • **Temp. for Guaranteed Accuracy:** 23°C ±5°C • **Temperature Ranges:** Operating 0°C to 40°C, 32°F to 104°F; Storage -10°C to 50°C, 14°F to 122°F • **Power Supply:** One 9V battery (Included) • **Size:** 3.5"W x 6.8"D x 1.4"H • **Unit Weight (Excluding carrying case):** 0.8 lbs. (Including 9V battery) • **Accessories:** Operating manual, 9V battery, test leads, spare fuse and carrying case.

M4650CR FEATURES

- **Max. Display:** 19999 counts with automatic polarity indication • **Max. Input Current of AC and DC:** 20A (max. of 15 minutes) • **Overrange Indication:** "OL" and "Bar graph flashing" figure on display • **Max. Common Mode Voltage:** 500Vdc/AC RMS • **Reading Rate Time:** 1-2 readings per sec. (approximate) • **Temp. for Guaranteed Accuracy:** 23°C ±5°C • **Temperature Ranges:** Operating 0°C to 40°C, 32°F to 104°F; Storage -10°C to 50°C, 14°F to 122°F • **Power Supply:** One 9V battery (Included) • **Size:** 3.4"W x 7.4"D x 1.3"H • **Unit Weight (Excluding carrying case):** 0.8 lbs. (Including 9V battery) • **Accessories:** Operating manual, 9V battery, test leads, spare fuse and carrying case. RS-232C Cable, Floppy Disk (Option)

Order #	Price	Description	Weight
M3800	34.95	3 1/2 Digit LCD Multitester	1.22 lbs.
M4650CR	109.95	4 1/2 Digit LCD Multitester	1.50 lbs.
RS232C	9.95	RS-232 Interface	3.5 oz.

TEST INSTRUMENTS

Fieldpiece.



HS25

DMM's For The
Test Bench Or
On The Go



ADK10

SPECIAL FEATURES - Dangerous voltage warning (HS23 and HS25): At >28V, meter beeps & red LED blinks. **Logic indicator (HS25):** Up/down arrows in LCD indicate logic states "hi" (>2.8V - 8V) or "lo" (<0.8V - 5V). **AC coupled. Frequency response** 20MHz, 25ns min. pulse width, input impedance 120K Ω - 10K Ω shunted by 100pF. **Pulse rise time (max)** 10 μ sec. **Pulse rep rate (max)** 1Mpps. **Overvoltage protection** 500Vdc or ac RMS. **Capacitance (HS23 and HS25):** 1 range: 200uF, accuracy 3%+5. Tested at 3V/40Hz. **Overload protection** to 500Vdc or RMS. Auto power off after 1 hour.

GENERAL SPECIFICATIONS - Display hold: Press "HOLD" button, display "locks" reading. Any range, any function. Heavy duty case design of hi-impact, fire retardant yellow Valox, fully "O" ring sealed. Meets MIL-T-28800 class II type A. **Size** (not including probes): 7.2"x1.9"x1.0". **Weight:** 185 grams. **Indicators:** Continuity (<150 Ω) indicated by a continuous "beep" within 100 msec. Low battery indicator in the LCD with 100 hours of battery life left. **Environmental:** Operating temperature -15° to 55°C, storage -40° to 60°C with batteries removed, RH<80% from 0°C to 50°C. Tempco <10% of applicable accuracy spec per °C (-15°C to 20°C, 30°C to 55°C).

Order #	Price	Description	Weight
HS21	79.95	Stick-Style DMM	1.06 lbs.
HS23	99.95	Stick-Style, Capac. to 200uF	1.06 lbs.
HS25	119.95	Stick-Style, Capac., Logic Probe	1.07 lbs.
ACH	24.95	Optional Clamp Head	4.6 oz.
ADK10	26.95	Deluxe Test Lead Kit	9.3 oz.

DUAL-TRACE OSCILLOSCOPES



S7020A

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Order #	Price	Description	Weight
S7020A	375.00	20Mhz Dual Trace Oscilloscope	21 lbs.
S7040A	630.00	40Mhz Dual Trace with Delayed Sweep	22 lbs.
SP100	49.95	100Mhz Probe Kit (Pair)	12 oz.
SP101	34.95	50Mhz Probe Kit (Pair)	12 oz.



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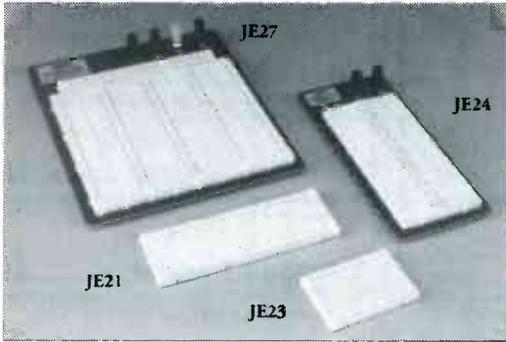
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Jameco Logic Pulser



- Compatible with TTL, DTL, RTL, HTL, HNL, MOS and CMOS ICs
- 1MΩ Sync input impedance • Pulser mode output current: 10mA • Square wave current output: 5mA • Audible tone

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Jameco Logic Probe



- Max Frequency 80MHz • Minimum detectable pulse: 10ns • 120KΩ input impedance • Max. supply voltage: ±25V
- TTL threshold: (Lo)+0.8V ±0.1V, (Hi) +2.3V ±0.2V • CMOS threshold: (Lo) 30% VCC ±10%, (Hi) 70%VCC±10%

MS104.....\$24.95

A.R.T. EPROM Programmer



- Programs all current EPROMs in the 2716 to 27512 range plus the X2864 EEPROM
- RS232 port • Software included

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- Erases all EPROM's • Erases 1 chip in 15 minutes and 8 chips in 21 min
- UV intensity: 6800 UW/CM²

DE4.....\$89.95

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TMS2532A.....	6.95	2764A-20.....	3.75	27256-20.....	4.95
TMS2564.....	5.95	2764A-25.....	3.19	27256-25.....	4.49
TMS2716.....	5.95	27C64-15.....	3.95	27C256-15.....	5.95
1702A.....	3.95	27C64-25.....	3.25	27C256-20.....	4.95
2708.....	4.75	271280TP.....	3.49	27C256-25.....	4.25
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2716-1.....	3.75	27128-25.....	7.75	27512-20.....	6.75
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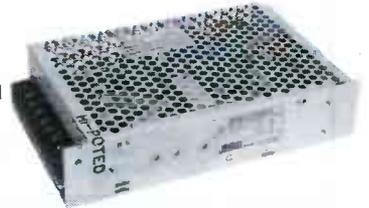


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+12VDC @ 1.2A

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7420	.29	.19
7432	.35	.25
7447	.89	.79
7474	.39	.29
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LM741CN	.29	.25
LM1458N	.35	.29
LM1488N	.45	.39
LM1489N	.45	.39
ULN2003A	.69	.59
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NE5532	1.19	1.09
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7812T	.45	.41

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41256-80	80ns, 256K x 1	2.19
41256-100	100ns, 256K x 1	1.95
41256-120	120ns, 256K x 1	1.79
41256-150	150ns, 256K x 1	1.69
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511000P-10	100ns, 1MB x 1	6.75

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XC556Y T1 3/4, (Yellow)	.16

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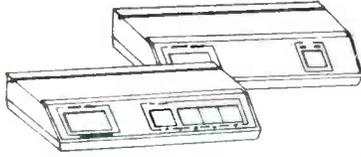
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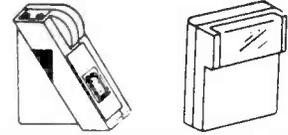
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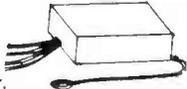
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Standard JUMBO
 Diffused T 1-3/4 size (5 mm)

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W/ built in flashing circuit
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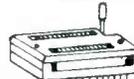
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CAT# NCB-D

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2.1mm D.C. power plug with center negative. White case.
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12 Vdc 200 ma.

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Pushbutton

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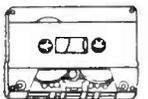
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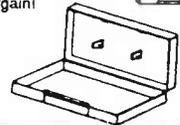
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LS3200	NEC	670 nm	3 mW	85 mA	2.2v	79.99
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														1-9	10+
LT7770	543nm (Green)	0.5mW	1.0mW	0.71mm	≤ 1.2 mrad	random	1750v ± 110v	6.5 mA	≤ 8 kV	81k Ω	37 x 350	200	II	799.99	749.99
LT7650	632.8nm (Red)	0.5mW	2.0mW	0.49mm	≤ 1.7 mrad	>100:1	1000v ± 100v	3.5 mA	< 7 kV	68k Ω	25 x 146	70	IIIA	529.99	479.99
LT7656	632.8nm (Red)	0.5mW	2.0mW	0.34mm	≤ 2.4 mrad	random	1050v ± 100v	2.8 mA	≤ 8 kV	82k Ω	22.5 x 118	60	IIIA	134.99	124.99
LT7655	632.8nm (Red)	0.5mW	2.0mW	0.49mm	≤ 1.7 mrad	random	1000v ± 100v	3.5 mA	≤ 7 kV	68k Ω	25 x 150	70	IIIA	144.99	134.99
LT7655S	632.8nm (Red)	1.0mW	2.0mW	0.49mm	≤ 1.7 mrad	random	1000v ± 100v	3.5 mA	≤ 7 kV	68k Ω	25 x 150	70	IIIA	159.99	144.99
LT7632	632.8nm (Red)	1.2mW	3.0mW	0.61mm	≤ 3.0 mrad	random	1300v ± 100v	3.5 mA	≤ 7 kV	81k Ω	20 x 210	70	IIIA	249.99	229.99
LT7621S	632.8nm (Red)	2.0mW	5.0mW	0.75mm	≤ 1.2 mrad	random	1300v ± 100v	5.0 mA	≤ 7 kV	68k Ω	30 x 255	140	IIIA	204.99	191.99
LT7634	632.8nm (Red)	2.0mW	5.0mW	0.75mm	≤ 1.2 mrad	>500:1	1300v ± 100v	5.0 mA	≤ 7 kV	68k Ω	30 x 255	140	IIIA	209.99	194.99
LT7621MM	632.8nm (Red)	5.0mW	15mW	1.0mm	≤ 2.5 mrad	random	1250v ± 100v	6.5 mA	≤ 7 kV	68k Ω	30 x 255	140	IIIB	359.99	334.99
LT7627	632.8nm (Red)	5.0mW	15mW	0.80mm	≤ 1.1 mrad	random	1900v ± 100v	6.5 mA	≤ 8 kV	81k Ω	37 x 350	200	IIIB	369.99	344.99
LT7628	632.8nm (Red)	5.0mW	15mW	0.80mm	≤ 1.1 mrad	>500:1	1900v ± 100v	6.5 mA	≤ 8 kV	81k Ω	37 x 350	200	IIIB	389.99	364.99
LT7627MM	632.8nm (Red)	10mW	30mW	1.2mm	≤ 4.0 mrad	random	1750v ± 100v	6.5 mA	≤ 8 kV	81k Ω	37 x 350	200	IIIB	479.99	444.99

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- Output: 3.5 mW
 - Wavelength: 670NM
 - Power Supply: 2xAAA Batteries (included)
 - Beam: Approx. 3" @ 100 yards
- Quantity Discounts Available

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- Size: 7" L x 5 1/4" W x 2 1/2" H

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Collimator Pen



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- Current: 90-150 mA
- Op. Volt.: 2.2-2.5V
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For static-sensitive applications. Dispenser packs, individually wrapped.

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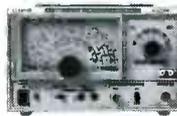
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