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JULY 1990

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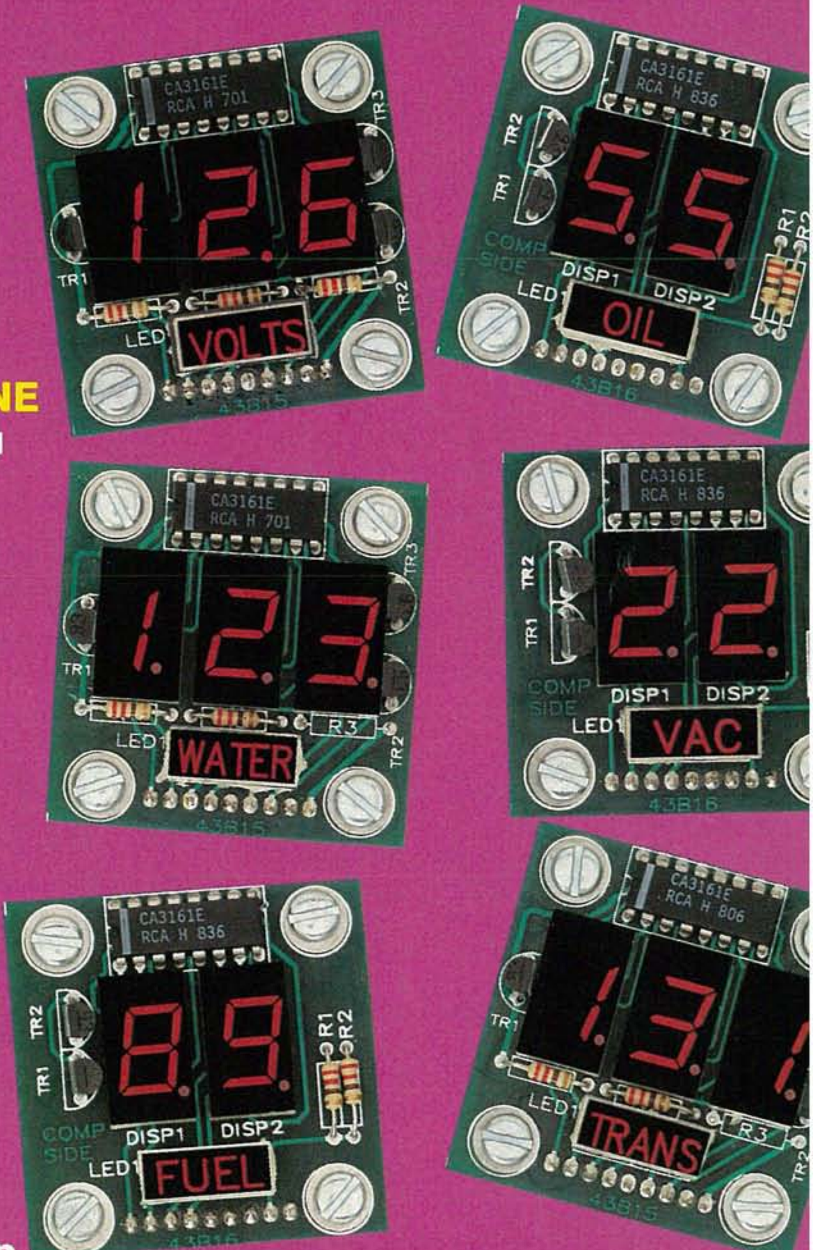

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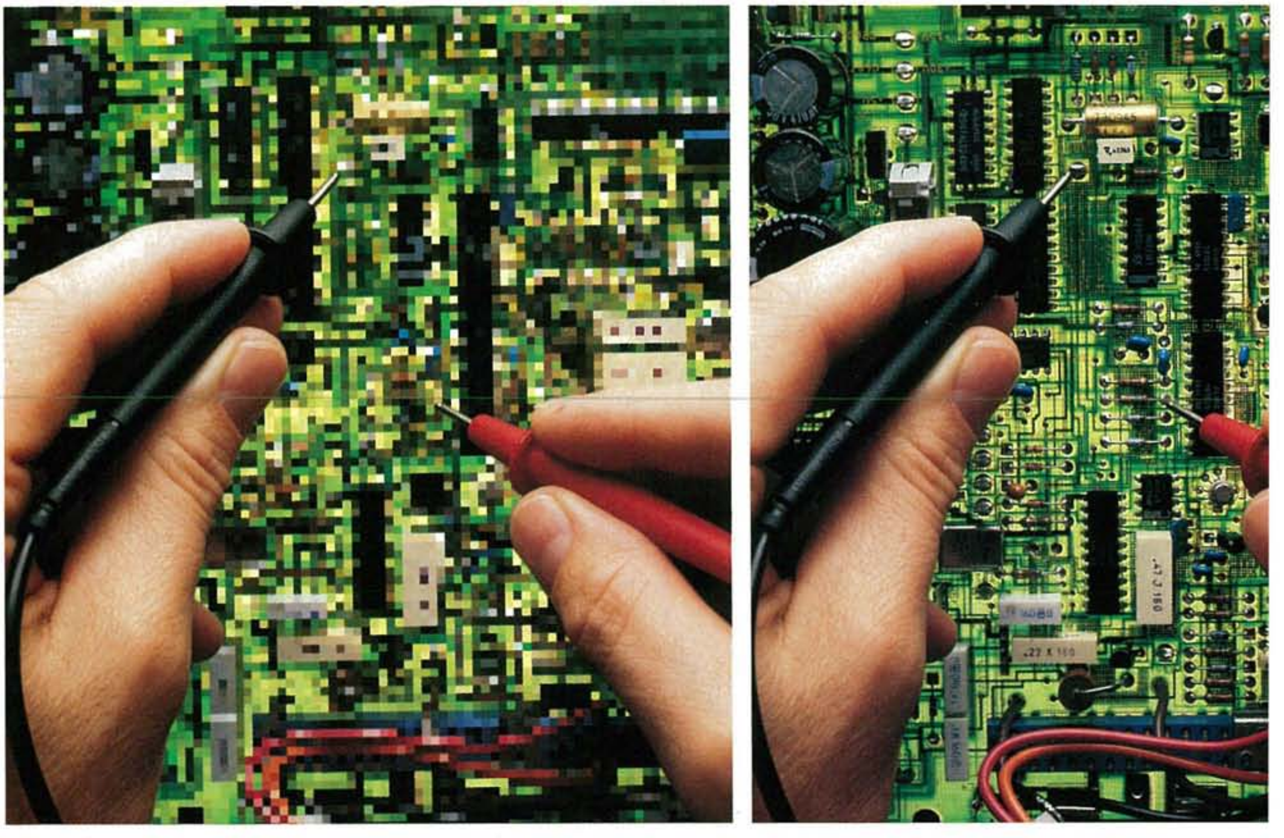

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CIRCLE 121 ON FREE INFORMATION CARD

July 1990

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Vol. 61 No. 7

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DEPARTMENTS

PAGE 31

PAGE 75

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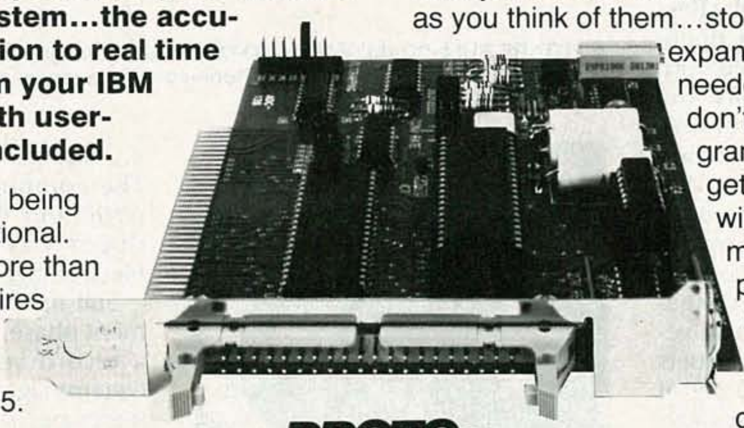

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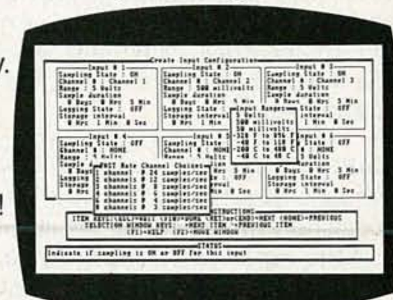

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CIRCLE 189 ON FREE INFORMATION CARD

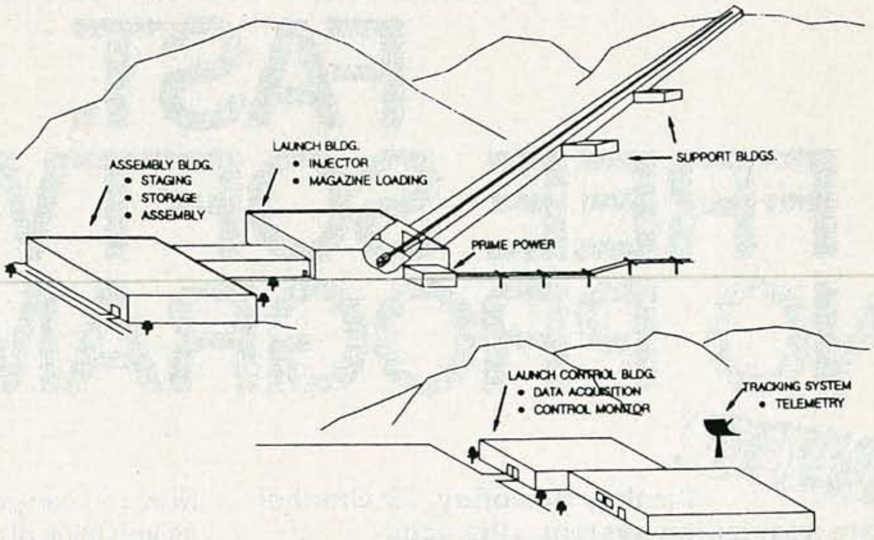
WHAT'S NEWS

New earth-to-orbit launcher will use electromagnetism

A new technology that might be used to launch small satellites from earth to orbit, currently being developed by Sandia National Laboratories (Albuquerque, NM), uses electromagnetic induction and involves no sliding electrical contact between the projectile and the barrel. Providing an alternative method to rockets for the launching of satellites up to 1,000 pounds, it could have potential military and commercial applications.

In the new launcher, the projectile passes through a series of cylindrical coils that form a contactless barrel. Just before firing, a pneumatic device sets the projectile spinning, for aerodynamic stability. The firing is under electronic control: One after another, coils are energized by a heavy capacitor discharge, accelerating the armature forward down the length of the flyway. Between each coil, a high-speed optical-fiber sensor measures the precise position and velocity of the projectile and instructs the computer to fire the next coil at the right instant to provide maximum effect. The launch mass for a full-scale earth-to-orbit projectile would include an iron or other magnetizable armature, a removable aeroshell, small rocket motor, and the payload. An existing mockup resembles a small rocket or a very large artillery shell, with the tapered aeroshell streamlined to reduce atmospheric friction.

A sophisticated code called "WARP 10" has been used to support the experiments. The code has successfully predicted the results of all of the experiments made so far. Its predictions for scaled-up versions of the electromagnetic launch system are making scientists extremely optimistic that the larger systems will also be successful.



A FUTURE FULL-SCALE EARTH-TO-ORBIT electromagnetic launch system might look like this. The flyway, consisting of hundreds of stages, is built up the side of a hill to present a 30-degree launch angle.

SANDIA EXPERIMENTER Ronald Kaye inserts a projectile into the breech of a six-stage electromagnetic launcher, which is being developed as a possible alternative to rockets for frequent launches of small payloads.

The electromagnetic launcher would provide enough velocity—about 4.5 kilometers per second at the end of the flyway—to send the main part above the earth's atmosphere (the armature would drop away shortly after launch). Once the projectile was above the atmosphere, the aeroshell would drop away and the rocket motor would step up the velocity about another 4.5 km/sec, to achieve orbit velocity. The combination of electromagnetic and rocket techniques reduces costs and risks for the electromagnetic launch.

Still in the exploratory development phase, the work has achieved a record velocity for contactless electromagnetic launchers of 1 kilometer per second with a 160-gram projectile. Experiments are now underway with a larger, six-stage launcher that fires a 4-kilogram (10-pound) projectile that is 5½ inches in diameter. Subsequent development stages will focus first on still larger launchers. After that, the concept would be scaled up further by adding more stages to the launcher, increasing the length of the flyway along which the launch mass is accelerated. For earth-to-orbit launch, the flyway would consist of multiple stages, each powered by its own capacitor bank, and elevated at a 30-degree angle. The technology seems especially promising for the economical launching of large numbers of relatively small objects into earth orbit. **R-E**

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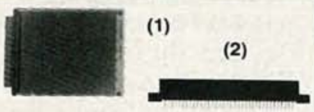

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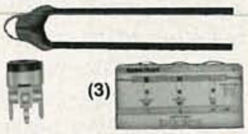

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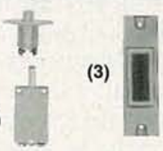

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CIRCLE 78 ON FREE INFORMATION CARD

VIDEO NEWS

DAVID LACHENBRUCH,
CONTRIBUTING EDITOR

• **Ghostbuster tests.** The first major American test of automatic ghost cancelling was pronounced a rousing success, and there were predictions that anti-ghost technology could be put into the FCC's broadcast standards before the year is out. The exorcism occurred in Atlanta, the site of the 1990 convention of the National Association of Broadcasters, where six television stations used the ghostbusting system developed—and now in use—in Japan. As reported here (**Radio-Electronics**, November 1989), the system employs a "training pulse," broadcast in the vertical interval (in Atlanta it was line 18), which instructs specially equipped TV sets to remove ghosts and accept the true image. Observers of the demonstrations at the convention were impressed with its performance. Set-top tuners equipped with ghostbusters are currently selling in Japan for $700–$1,000, but more-integrated, chip-based systems built into television sets are expected to be much cheaper. Although other ghost-canceling systems have been proposed—notably by AT&T, Zenith, and the David Sarnoff Research Center—the Japanese system now has the inside track because of the successful Atlanta tests and its proven quality in everyday use in Japan.

• **Laserdisc shortage.** When laser optical videodiscs' popularity slumped almost to nothing a few years ago, who would have thought they would become so popular in 1990 that there would be a severe shortage of programs? Thanks to the influence of the compact disc, the laserdisc now has become the preferred playback medium of videophiles. With about 10 brands of players either on the U.S. market or about to enter it, and player sales expected to double this year to 250,000, disc manufacturers are hurrying to try to relieve the shortage. The latest to go into videodisc pressing in the United States is Sony, whose Digital Audio Disc Co. plant in Terre Haute, IN, is adding videodiscs to its compact-disc manufacturing ability.

The videodisc's comeback started, ironically, with the ballyhoo for an unsuccessful product—Compact Disc-Video—a name coined by Philips and its affiliate Polygram in hopes that the magic of the CD boom would rub off on videodiscs. The two companies retreated in early 1990, and the name reverted to laserdisc. But today's players take advantage of most recent laserdisc's compatibility with audio CD's, and almost all of the new players can play CD's as well as LD's. The new laserdisc players also have copied from Super VHS, by using Y/C (luminance and chrominance) outputs to plug directly into "S-connectors" on high-resolution TV sets.

• **Full-Motion CD-I.** The *C*ompact *D*isc-*I*nteractive (*CD-I*) system has added something new that makes it far more significant as a consumer product: full motion. The system espoused by Philips and Sony has suffered in the past in comparison with Intel's *D*igital *V*ideo *I*nteractive (*DVI*) system. The addition of full motion to the digital CD-I system makes it a very potent potential product of the 1990's. A standard 5-inch compact disc recorded in the CD-I mode now can provide up to 72 minutes of full-motion digital video plus digital audio. As demonstrated recently by Philips, the picture quality of the CD-I disc was virtually indistinguishable from videotape. The system is scheduled for marketing next year in the U.S. and Europe. It also has the potential to become an important movie-carrying medium. As a digital-video system, the same disc can be played on the American and Japanese NTSC system, the European PAL system, or any other color TV system.

While the Intel DVI system is designed for playback using a computer (and isn't intended to be a consumer product), CD-I uses a player that resembles an audio CD player. Philips says that DVI takes several hours to record an hour of video, but CD-I can record in real time—requiring only an hour to record an hour of video. Philips' enthusiasm about CD-I is best summarized by a quotation from a company official: "CD-I is what publishers have been waiting for since the 1450's, when Johann Gutenberg produced the first printed version of the Bible. We have pushed CD-I full-motion video far beyond DVI. There is no discussion any more." R-E

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RING MY PHONE

There is not enough line current to ring the telephone bells in our house. Either we're too far out or there are too many phones on the line. Is there any other way I can get the phones to ring?—G. Myers, Meridian MS

Before we start on this, and by the way the answer is yes, let me tell you that I haven't heard of a problem like this in a long time. In these post-divestiture days, most phones have gone a long way from the original Western Electric 2500 series. CMOS has replaced most of the circuitry in the old phones and I haven't seen a real carbon granule in years.

The popular lore and certain legends have it that the telephone line voltage is fixed at a value written in stone. Nothing could be further from the truth. It has never been promised by the telephone company that you'll find 50-volts DC on-hook, 5-volts DC off-hook, and a 90-volt AC ringing voltage.

All the phone company guarantees is that the phone circuit is a 20-milliamp line. As a historical note, that's interesting because 20-milliamp current loops have been around for a long time. But this isn't helping you solve your problems.

The development of CMOS-based telephone parts has resulted in a sort of revolution in telephone design. Given a 20-milliamp limit, most phone manufacturers have been able to design multi-featured telephones that draw their power directly off the phone line. Just about the only use for batteries is to preserve memory in phones that let you store numbers.

Several semiconductor manufacturers make chips that are designed with your specific application in mind. An example of those is made by AMI (3800 Homestead Road, Santa Clara, CA 95051 (408) 246-0330). The chip you need is their S2561—a dedicated telephone-ringer IC that can be powered directly off the phone line. You can use a battery if you're afraid of loading the line.

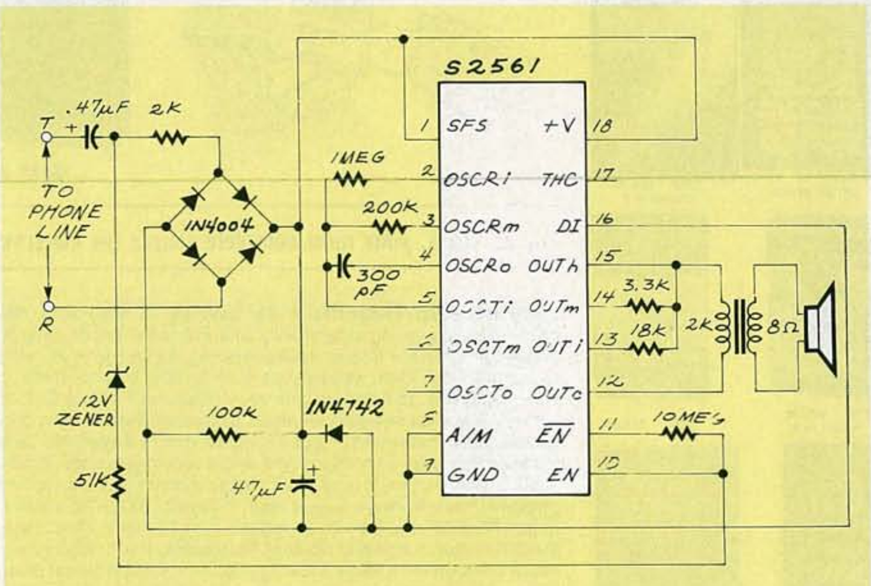

FIG. 1

The chip doesn't need much support to make it work, and everything you could want to know about it is described in the data sheet. The circuit in Fig. 1 shows you what has to be done to put the IC to work. You can use it to drive a small speaker, since the chip puts out up to 50 milliwatts when you power it off 10 volts. As an alternative, you can feed the output to an amplifier and get even more gain.

TOUCH TONE DECODER

I've been trying to design a circuit that would decode Touch Tone frequencies and display them on LED's. So far, the best I've been able to do is less than what I want. Can you point me in the right direction?—W. Brown, Golden CO

Once upon a time, doing something like that was a real pain in the neck, since you had to do analog decoding of the frequencies in the high and low groups used for DTMF (*D*ual *T*one *M*ulti *F*requency) tones. Fortunately, this is America, and capitalism usually fills any consumer needs that show up in the marketplace—and that is even true in the world of semiconductors.

Several manufacturers make DTMF decoders, including such well-known names as National, AMI, and Mostek. I'm not listing any of the chip numbers because each of those companies have several of them and which one you use depends entirely on what you want to do. Call or write them and get yourself a handful of data sheets.

What all of the decoders have in common, though, is that they decode only the incoming frequency and put out a binary equivalent. If you want to build something that can display a dialed number, you're

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☐ Appliance Servicing	☐ TV/Audio/Video Servicing	☐ Cellular Telephone
☐ Locksmithing	☐ Telecommunications	☐ Digital Electronics Servicing
☐ Building Construction	☐ Robotics	☐ Basic Electronics

Name ____________________ Age ______

Street ____________________

City/State/Zip ____________________

Accredited Member National Home Study Council   3-070 going to have to work out a circuit that can store the number being decoded and then be able to display at least ten digits—more if you use access codes.

Several of these circuits have appeared on the pages of **Radio-Electronics** over the years and, of course, there are some chips, such as National's MM74C9XX series, that make the job really simple. It's possible to design a circuit to do the job with two or three IC's, a handful of passive parts, and the displays themselves.

50-Hz TAPE SPEED

I have a European cassette recorder that was designed to run at the correct speed with 50-Hz AC. Is there any way, without changing the pulleys and belts, to have the machine run correctly in the USA?—F. Peterson, Brampton ONT

There's a way to do anything, but that doesn't make everything worth doing. You could have the machine run at the correct speed by building a 50-Hz AC generator capable of putting out as much power as is required by the recorder. But that is not a trivial task.

Some machines have a dual-pulley system, so that the speed can be adjusted by moving the belt from one groove to another. If that isn't true in your case, the next step would be to contact the manufacturer and see if they can sell you a replacement pulley for 60-Hz operation. The voltage can be taken care of with a small transformer, as I'm sure the machine doesn't use a great deal of power.

I know you're really looking for a different kind of answer but, believe me, this is the best way to do it. You may think of having to change pulleys as a pain in the neck, but it's a piece of cake compared to the brain damage involved in designing circuits from the ground up. And, in any event, opening up the machine and changing a pulley isn't really that big a job. It's easy, sometimes, to get so involved in something you're trying to do that you forget what you were trying to accomplish when you first started.

CGA TO VGA

I have an IBM-compatible computer and have just upgraded my display from CGA to VGA. Since I already own a good CGA monitor, it seems a shame to have to junk it and spend the money necessary to get a VGA monitor. Isn't there something simple I could do to my CGA monitor to make it compatible with my VGA card?—F. Ischer, New York, NY

Believe it or not, there's a simple way you can do that. It takes some work but it can be done. Remove the power cord from your CGA monitor and attach it to a VGA monitor. When you're finished, the new monitor will work perfectly.

But seriously folks, there's no other way.

I suppose it's possible to modify all of the circuitry in the CGA monitor to handle VGA, but I'm sure it's not an easy thing to do. And even if you were able to do it, I'm not sure the phosphor in the picture tube has a long enough persistence to be usable for VGA. A safe bet would be no.

VGA scan frequencies are about double those of CGA, and you would have replace so many parts in the CGA monitor that you'd more than likely have nothing of the old one in use except the case. Nobody likes saving a buck more than I do, but this is definitely one of those times when it's better to rob the piggy bank than warm up the soldering iron.

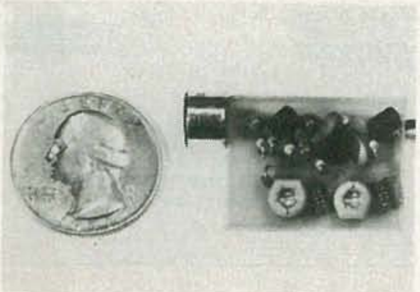
TELLING SCR'S FROM TRIACS

I recently bought a bag of mixed SCR's and Triacs. Since the parts aren't easily marked, I'm having a hard time telling the SCR's from the Triacs. Do you have some simple circuit I can use?—D. Koetting, St. Louis, MO.

The following method is an easy way to solve your problem: An SCR is a DC device, and a Triac is an AC device. The former conducts one way only, while the latter conducts both ways. A battery and bulb let you find out which are which. Put the bulb in series with the battery and connect the two leads to the large legs of the device.

Use a piece of wire to momentarily connect the third leg to each large leg, one at a time. If the bulb doesn't light, reverse the battery polarity and do it again. If you can't get the bulb to light at all, the part is either dead or another kind of device. If it lights one way only, it's an SCR, whereas if it lights both ways, it's a Triac. **R-E**

Radio-Electronics mini-ADS



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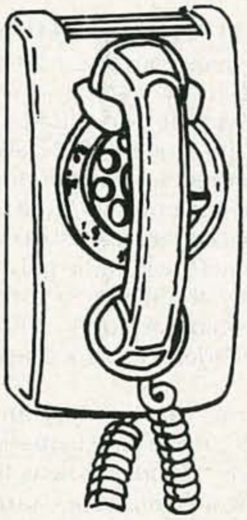

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LETTERS

AMATEUR SCIENTIST'S WISH

This is just a quick note to let you know how much I enjoy Don Lancaster's "Hardware Hacker" column. The topics presented are extremely interesting and diverse. I only wish more such information, articles, and publications were available to the amateur scientist, inventor, and general tinkerer. Many years ago—well before my time—a number of publications existed for the amateur experimenter. But today, unfortunately, only two really useful regular columns (that cover fields other than computers and electronics) exist that I know of: **Radio-Electronics'** "Hardware Hacker" and *Scientific American's* "The Amateur Scientist."

On another note, the gremlins attacked your April column by substituting iridium (sic) for indium in the 117 alloy. I volunteer to purchase all the 20% iridium alloy anyone will sell me at $78.00 per pound, and I'll retire rather quickly!

ROBERT N. WILLIS
Stone Mountain, GA

Your wish has come true. This September, the magazine you have been asking for will be available. It's called **Science Probe, The Amateur Scientists Journal**, *and it does exactly what you're looking for. Just scan the titles on the first issue (its cover is shown above)—"Lightning—How to Capture it With Your Camera;" "Killer Bee Identification—An Electronic Device that Makes Identification a Snap;" "Miniature Tracking Transmitters—Two Tested Radio Transmitters that Anyone Can Build;" and "Aerial Photography from Kites—Tips and Gadgets that Make it Possible." And then there's a wide range of special departments to grab your interest. They include "Science Fair News," "Communications Facts," "Field Reports," "Computers," "The Scientist," and much, much more.*

They will be sending out subscription materials as soon as they're available. But if you want to start today, you can become a Charter Subscriber right now. It will be starting with four issues a year. The cover price in the U.S. will be $3.50 per issue, and you can order your 4-issue subscription for only $9.95. Write to Science Probe!, *Subscription Dept., P.O. Box 54098, Boulder, CO 80321-4098. Be one of the first to enjoy this unique publication!—Editor*

PROPER STORAGE PROCEDURES

Each month when I receive my copy of **Radio-Electronics**, I look forward to seeing what new toys and sweets Don Lancaster has in his "Hardware Hacker" column. I'm always looking for new information or a different view on how to do things, and he always has some great input!

I was disturbed by something in the April "Hardware Hacker." On page 59, we are told to use *Tupperware* to store ammonium-persulfate. Nothing was mentioned about labeling the container! Chemicals should *never* be stored in unmarked containers, and in the case of *Tupperware*, both the lid and the container should be labeled. Remember, someone else coming upon the container doesn't have the knowledge of what's inside.

PHILL LEYVA
Hollister, CA

POLARITY POINTERS

Like many people, I tend to get behind in my reading, and just recently had the opportunity to catch up on the January 1990 issue of **Radio-Electronics**. I enjoyed the article entitled "Telephone Mute Switch," the device that's used to turn off the stereo or TV when the phone rings. However, there was one point that I feel should have been emphasized to the readers constructing the project.

Tip and ring are very important, but the article failed to mention that the project is *polarity* sensitive. If tip and ring are wired backwards in the user's house, which is very common in older homes, the phone will remain off-hook forever. To avoid that, check the line for polarity. If no dial tone is heard when the project is connected, simply reverse tip and ring, the red and green wires mentioned in the article.

ERNEST SCHMELTZER
PCU, Inc.
Midland, TX

IN PRAISE OF THE MAC

The article concerning Microsoft Windows in December's *Editor's Workbench* was interesting in its discussion of the graphic interface. Although I've never used Windows, I'm an old window-hacker on my Mac. It surprises me that after four years of development the DOS world has yet to implement a consistent, high-quality graphic interface for its machines.

The command line interface is clearly obsolete, a holdover from the days when personal computers had 64K (or less) of memory. Even the original 128K Mac successfully demonstrated the graphic interface. Practically all new software is menu-driven, but the blank screen of DOS is always waiting.

As stated in the article, the Mac is a finely crafted piece of equipment. When I launch a new program, I feel confident that it will run on my machine with no need for tinkering, and that the basic menu commands will look as I expect them to look and be where I expect them to be. That standardization means that a total novice can do useful work with an afternoon's training. I consult documentation only when using the more esoteric features of an application. Usually, the on-line help is more than sufficient. A great deal of the pleasure that I derive from working with the Mac is in appreciation of the elegance of the "overall architecture" of the entire integrated software/hardware system.

I really don't understand the mixture of patronizing amusement and grudging respect that the Mac commands from DOS users. The article opens with a reference to "toys like the early Macintosh"; later, it offers considerable praise for that "toy." I think that since the Mac is simple and fun to use, and DOS is demanding of the user, that the Macintosh is not taken seriously: "No pain, no gain."

I can attest to the Mac's power. I recently attended a seminar that demonstrated a new instrumentation software package called LabView. An application that fully implemented the standard Mac interface communicated with an oscilloscope,a microphone, a thermal sensor, QuickBASIC, and the Excel spreadsheet—no surprises there. The bonus was in the interface: An on-screen image of a custom control panel was drawn by the user, with toggle switches, slide controls, rotary knobs, etc. Those controls actually operated the program. Data was displayed in a user-designed graphic format. What's more, *not one line of code was typed!* All programming was done by selecting icons that represented functions, devices, and subroutines, and drawing lines between them. Labels and function parameters were typed. In the space of ten minutes, we had run data acquisition and spectrum analysis on a sound sample, crunched a selection of the analysis in Excel, and displayed a color bar chart. And the compatibility was excellent. The seminar was conducted on Macintosh II's with large, high-resolution color monitors. The demo disk ran equally well without any tinkering on a low-end MacPlus.

Apple *is* thick-headed in its pricing and marketing practices. The Mac is not cheap, but it does avoid the hidden costs associated with open architecture—buying boards, hardware compatibility, etc. I feel safe buying a second-hand Mac because the probability that anyone has opened the case and touched the hardware is very small.

As far as tinkering goes, if I want to modify hardware, I'll use an inexpensive "classic computer." If I want to sit right down and get to work, I'll use the Mac.

I'd like to build some stuff to attach to my SCSI port, but hobbyists and hackers are seriously neglected. It would be a great service to a sizable (and growing) population of users if **Radio-Electronics** would address that issue occasionally. Connectivity is a hot issue. Expand our horizons!

MICHAEL J. SCHENK
Baltimore, MD

Do You Know the ABC's of Home Theater?

If you're looking to recreate the movie theater experience at home, home theater is just what you're looking for. The integration of large screen televisions, videodisc players, VCRs and surround sound processors is one of the most exciting trends in today's consumer electronics world. The following quiz will tell you how much you know about home theater. Score 10 points for each question you answer correctly.

1. True or false: Only large screen televisions can be used in home theater systems.

2. Which of the following are types of televisions used in home theater systems?
(a) Rear projection
(b) Direct view
(c) Front projection
(d) Combination television/monitors
(e) Virtually any type of television can be used in a home theater system

3. True or false: Television programs have never been broadcast in Dolby surround sound.

4. Which of the following are necessary to experience surround sound?
(a) A universal remote control
(b) A surround sound processor
(c) Two extra speakers
(d) None of the above

5. Videodisc players that play all sizes of videodiscs and compact discs are called
(a) All-in-one players
(b) Multi-players
(c) Continuation players
(d) Combination players

6. What is a television set without a tuner that accepts input from such sources as a VCR, videodisc player, home computer, and a video game?
(a) Monitor
(b) Large screen television
(c) Viewer
(d) All the above

7. Videodisc players offer consumers two different formats: one with few special effects, and another that allows such added features as frame search, freeze-frame, and multi-speed play. Those formats are:
(a) CLV and CAV
(b) DBA and DBD
(c) CNV and CVA
(d) SLO and FAS

8. How many projection televisions were sold in 1989?
(a) 50,000
(b) 110,000
(c) 265,000
(d) 1,000,000

9. True or false: Surround sound decoders must be incorporated in a home theater system for the system to work properly.

10. How many speakers are required for surround sound?
(a) 2
(b) 5
(c) 4
(d) 1

TURN IT ON IN THE 90s

Electronic Industries Association
Consumer Electronics Group

Answers: 1-False. Screen sizes from 31 inches and up can be used effectively in home theater setups. 2-E. 3-False. Many movies are broadcast in Dolby surround sound. 4-B, C. 5-D. 6-A. 7-A. 8-C. 9-False, although the full effect of the home theater environment is not felt unless surround sound is incorporated. 10-C.

EQUIPMENT REPORTS

Tektronix 2214 Digital/Analog Oscilloscope

A unique combination of features makes this scope ideal for physical-system measurements.

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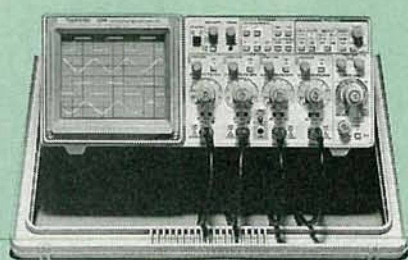

WHAT DO YOU GET WHEN YOU CROSS A 20-MHz, 4-channel oscilloscope with four digitizers and an RS-232 interface? You get the 2214 Digital/Analog oscilloscope from Tektronix (P.O. Box 500, Beaverton, OR 97077).

At first glance, the 2214 doesn't appear any different from a standard analog scope. The front-panel controls are laid out in an intuitively easy-to-use format. Above each BNC input connector is its corresponding input-coupling switch, attenuation selector or VOLTS/DIV switch, position control, and ×10 selector. To the right of the four vertical-amplifier controls are the time-base controls. The trigger controls are grouped together at the top right of the front panel, next to another group of controls for storage functions.

The front-panel layout is kept uncluttered in part by using a single push-button where you might expect more. For example, to select one of six possible trigger sources, a single push-button is used. Each time the button is pressed, a call-out above the button is back-lighted to indicate the choice.

Connectors that are used less frequently are relegated to the side panel. They include external-trigger and Z-axis inputs, and a trigger-level output. The Z-axis input doubles as an external-clock input when the scope is in its digital-storage mode. The hardcopy serial interface connector and its related parameter-selection switches are also located on the side panel.

Special features

The basic specifications of the 2214 may not seem too impressive at first: an analog bandwidth of 20 MHz, a bandwidth in digital-storage mode of 8 MHz. Such specifications, however, tell only part of the story. The 2214 offers a number of features that make it stand out as an excellent tool in electromechanical and process-control applications, for which it was designed.

One of the interesting features worth noting is that the scope can operate at a wide variety of speeds. Its roll mode can be used to slowly display up to 500 seconds of on-screen data. Such a display can often make the data easier to comprehend. Alternately, the digitizer can be clocked from an external source at any rate from DC to 8 MHz.

The 2214's horizontal timebase is variable even in the storage mode. Waveforms—even frozen captured signals, which consist of 16K data samples—can be expanded by up to a factor of 50 to let you zoom in for close examination. All 16K sample points are visible on the screen in the expanded mode. All four channels, and all 64K samples, can be displayed simultaneously.

You can freeze and store the signals from any or all channels and

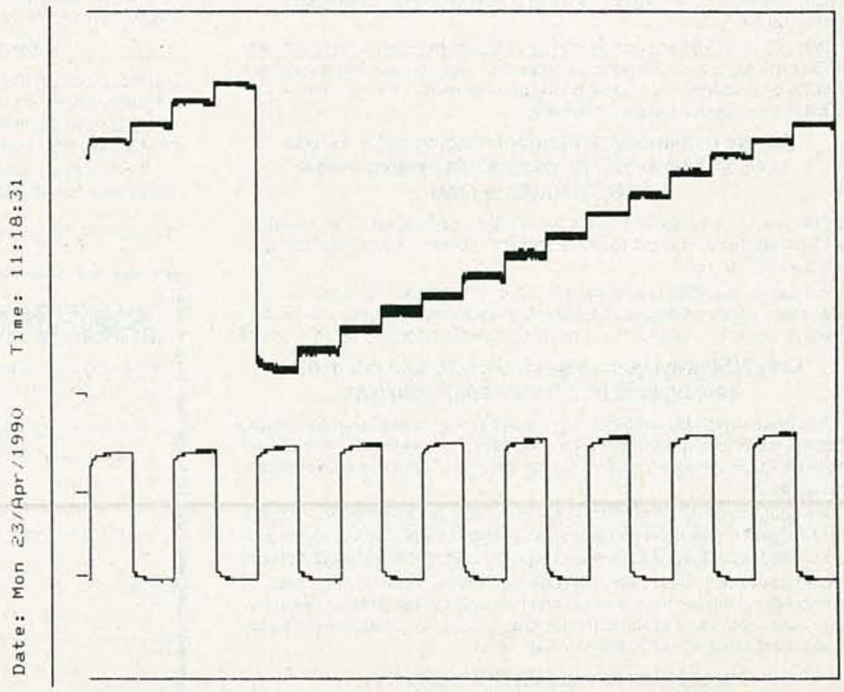

Fig. 1

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can view both "live" and stored signals at the same time. For example, a reference signal can be stored on screen while live inputs are monitored.

Any of the four input channels can serve as a trigger source, as can a signal at the external trigger input. Positive- and negative-slope triggering is available, as is a "BiSlope" mode that can obtain stable triggers for both positive and negative signals. That's useful if you cannot predict the polarity of signals you wish to acquire. The trigger level you select is available at an output jack for display on either a DMM or on one of the scope channels itself.

Hardcopy output

An RS-232 interface is built into the 2214. You can output stored waveforms directly to plotters that support the HPGL (*H*ewlett-*P*ackard *G*raphics *L*anguage) or, alternatively, an Epson-compatible dot-matrix printer. A sample printout is shown in Fig. 1. The printer can easily be used to emulate a chart recorder. In that mode, acquired signals are continuously output to the printer, resulting in a four-channel chart-recorder-like output. Speeds from 10 s/cm to 2500 s/cm are available, making this mode ideal for recording transient events.

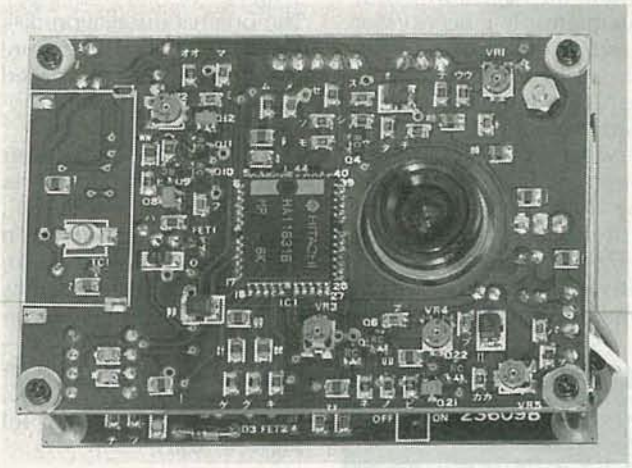
Since the interface is RS-232-compatible, you can, as you might expect, transfer data and waveforms to your PC. Waveform-transfer software, *Grabber II*, is included with the scope.

A flexible assortment of differential measurement capabilities add to the value of the scope. Signals can be inverted and added together to cancel unwanted common-mode noise and offsets.

The 2214 isn't a mass-market oscilloscope. If you're looking for a digital oscilloscope that offers the analog operation with which you're familiar, you'd be better served by one of the other, less expensive, scopes in Tektronix's 2200 series. However, if you have special applications that require dual differential measurement capability, or if full four-channel capability is important to you, then the 2214 becomes the obvious choice. The scope is priced at $3995, including the RS-232 interface, waveform-grabbing software, and two 10 × probes. **R-E**

NEW PRODUCTS

INDUSTRIAL SECURITY CAMERA. Small enough to be hidden in a standard electrical receptacle box, *Chinon's CX-101* camera is also versatile enough to meet a wide variety of security needs. Combining ultra-compactness, wide-angle viewing, and the ability to view even under near-dark conditions, the CCTV camera can be positioned in many locations, including doors. Suitable for industrial or home security systems, it features a 4.5mm lens with a fixed iris and electronic shutter that allows viewing in such diverse locations as loading docks, stores, and hotel or apartment lobbies. Measuring just $1\frac{13}{16} \times 2\frac{3}{4} \times 1$ inches, and weighing only 6.3 ounces, the camera is easy to place for robotic vision and inspection applications in quality control, manufacturing, and production. Its f/1.8 lens and $\frac{1}{3}$-inch MOS-type imaging chip provide light sensitivity as low as 2 lux—candle-light conditions—and sharp resolution of 230×240 TV lines, or 80,000 pixels. In addition, the *CX-101* runs composite video leads, allowing direct cable connection to a television monitor. The camera requires only 0.8 watts from a standard 12-volt DC power supply, and has an operating temperature range of 0–40°C. A metal housing with $\frac{1}{4}$-inch-20 mounting is also available.



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The *CX-101* costs $550.—**Chinon America, Inc.**, Industrial Products Division, 1065 Bristol Road, P.O. Box 1248, Mountainside, NJ 07092-1248; Tel. 201-654-0404.

FREQUENCY COUNTER. Designed to provide an unusual number of convenience features and to operate over a broad frequency range, *Beckman Industrial's FC130A* microprocessor-controlled frequency counter measures frequency, period, and RPM from 0.01 Hz to 1.3 GHz. Its standard features include very high resolution (as low as 10 nHz for a 1-Hz input); a bright, 8-digit LED frequency readout with floating point and overflow; 10-mV input sensitivity (typical); continuously variable gate time selection; switchable AC or DC coupling; a built-in self-diagnosis routine; and a switchable $\times 20$ input attenuator and low-pass filter. Two separate channels are used to achieve high measurement ranges: Channel A covers frequency measurements from 0.01 Hz to 120 MHz, and Channel B covers 50 MHz to 1.3 GHz. Its wide range, combined with its heavy-duty design, makes the *FC130A* suitable for both bench and field use in a variety of applications ranging from amateur and business radio, cordless-phone repairs, and computer service. The instrument can be used in R&D, for troubleshooting and repair, and to check equipment calibration.

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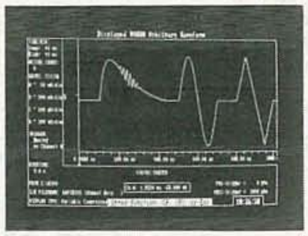
The *FC130A* frequency counter—complete with power cord, operator's manual, two BNC-to-alligator-clip test cables, and a spare fuse—has a suggested list price of $595.00.—**Beckman Industrial Corporation**, 3883 Ruffin Road, San Diego, CA 92123-1898; Tel. 619-495-3200.

WAVEFORM GENERATOR. *Rapid Systems' R4010* waveform-creation and -generation instrument lets you use a mouse to visually create any waveform and then output the electrical waveform with a 10-MHz, 12-bit, arbitrary waveform generator. The advanced PC-based product easily accomplishes waveform creation and realization functions where stand-alone function generators, synthesizers, and signal sources cannot graphically create electrical waveforms. The *R4010* also makes it easy to edit any digitized real-world signal on a PC screen and output the same signal. Special features include color waveform-creation software (with free demo disk); 16,000-point waveform memory; continuous, sweep, and burst output modes; programmable output voltage to 10 volts p-p; and a built-in library of waveforms that includes sine, square, triangle, ramp, pulse, noise, and telephone waves.



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The *R4010* waveform creator/generator costs $2995.00.—**Rapid Systems, Inc.**, 433 North 34th Street, Seattle, WA 98103; Tel. 206-547-8311.

SOLDERING STATION. Designed to meet hand-soldering needs of the 1990's, The *SA-570 Series* soldering station from *OK Industries* provides cost-effective flexibility and consistent performance. Offering both durability and quick recovery, it features a powerful 70-watt heating element with precise RTD temperature control that allows excellent stability and repeatability, as well as quick recovery on "heavy joints." The *SA-570 Series'* operating range of 600–800°F offers high power for a variety of applications, including on

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boards with exceptional thermal demands. Its directly grounded tip meets MIL-STD-2000 resistance and voltage requirements. The soldering station's low-profile, small-footprint housing takes up little bench space, and the iron's light-weight handpiece provides maximum operator comfort and safety. The station uses high-mass soldering tips that are available in a wide range of profiles.

The *SA-570 Series* soldering station has a list price of $86.90.—**OK Industries, Inc.**, 4 Executive Plaza, Yonkers, NY 10701; Tel. 1-800-523-0667.

RAM-RESIDENT ELECTRONIC MAIL. Offering the distinct advantage of not requiring the user to leave his application program, *Notework* is a RAM-resident electronic-mail program that uses only 5K of RAM on each PC. It allows users to pop up a note, file-transfer, or phone-message form without interrupting his work on a word-processing or spreadsheet program. Even non-technical users can learn to send, receive, and forward notes and phone messages right away, learning as they go from the *Notework's* menu. *Notework* also allows screen samples to be attached to a message, and files to be transferred between directories and from disk to disk without leaving the original application program. Other capabilities include printing hard copies of any message, importing messages to text files in word-processing and desktop-publishing programs to keep a mail log, and sending "Urgent" messages. The original installation disk authorizes eight users; more users can be easily installed with additional user-authorization disks.

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The *Notework* eight-user installation disk costs $495.00; additional 2-, 10-, and 50-user authorization disks cost $99.00, $399.00, and $1499.00, respectively. Additional discounts are offered on larger networks.—**Professional Productivity Corporation**, 72 Kent Street, Brookline, MA 02146; Tel 1-800-767-6683.

RADIO-FREQUENCY FINDER. A handheld frequency counter from *Optoelectronics* detects and displays two overlapping frequency ranges, from 10 Hz to 12 MHz and from 10 MHz to 2.4 GHz, with 1-Hz and 100-Hz resolution, respectively. The model *2210-A* personal frequency finder/counter's exceptional range is accomplished by using a unique input-prescaling technique similar to television-receiver design. Rather than dividing the incoming signal by a decade number, the instrument divides it by 256, which extends the upper range—and, in the process, uses low-cost TV parts. Because of the bin-

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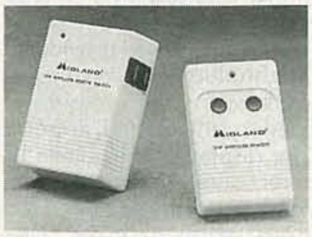
ary scheme, the internal time base is referenced to a popular 3.90625-MHz crystal, which is the correct frequency to divide by 256. That approach reduces the prescaler time base to just four parts, and affords it a 10-mV input sensitivity. At the low-frequency range, the *2210-A* uses a 10-MHz crystal and a divide-by-decade technique to get down to as low as sub-audio 10 Hz.

Front-panel features include an eight-place LED display, range-select switch, power-select switch (external 9–12 VDC or four rechargeable Ni-Cd batteries), and a gate-control switch and LED indicator for long or short sampling times. Available options include five different antennas, a probe for PC-board work, and a high-accuracy time base for better than ±1-PPM accuracy. Housed in a high-impact aluminum housing for years of durability and maximum EMI/RFI shielding, the frequency finder measures an easily portable 4×3½×1 inches and weighs only 9 ounces.

The model *2210-A* hand-held frequency finder/counter costs $219.00.—**Optoelectronics Inc.**, 5821 NE 14th Avenue, Fort Lauderdale, FL 33334; Tel. 800-327-5912 (in FL, 305-771-2050).



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REMOTE AC-POWER CONTROL SYSTEM. A compact remote-control switch that can be used to turn on and off any AC-powered device, *Midland International's* model *72-300*, consists of a compact transmitter and a small module that plugs an AC outlet. Electrical items that are plugged into the module can be controlled by the transmitter from as far as 50 feet away. The *72-300* can handle up to 1000-watt loads and can be used to control such things as televisions, lamps, stereos, appliances, fans, and most other electrical appliances. It operates on the UHF radio band and is powered by an ordinary 9-volt battery.

The *72-300* remote AC power switch system has a suggested list price of $39.95.—**Midland International Corporation**, Consumer Communications Division, 1690 North Topping, Kansas City, MO 64120; Tel. 816-241-8500.

PORTABLE WAVEFORM MONITOR. An upgraded EFP/ENG waveform monitor from *Leader Instruments*, model *5864A*, offers studio-quality monitoring for on-location shooting, and the convenience of dual-input capability for signal comparison and timing adjustments. The battery-powered unit, which weighs less than three pounds, provides 2H/2V MAG and 2H/2V sweep rates. It offers flat and IRE filters as well as a 4× vertical magnifier that simplifies set-up level and black-balance checks. Designed for use with Leader's compact vectorscope (model *5854*) and SID signal generator (model *LCG-413*), the *5864-A* is portable, rugged, and easy to use.

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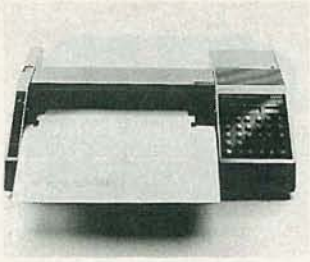
The *5864-A* portable waveform monitor costs $1,395.00.—**Leader Instruments Corporation**, 380 Oser Avenue, Hauppauge, NY 11788; Tel. 1-800-645-5104.



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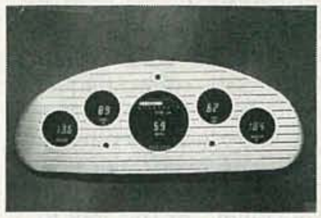
ANALOG CHART RECORDER. Combining both XY and strip-chart modes, *Fluke's PM 8278* dual-pen analog chart recorder also adds digital enhancements, such as built-in facilities for automatic chart annotation and pen-offset compensation. Optional IEEE-488 or RS-232 interfaces are available for complete remote control and data transfer in instrument systems or for use as a hard-copy output device for a digital storage scope.

The *PM 8278* is easy to use. At the push of one button, time, date, and instrument settings—including channel number, span, zero-suppression, and chart speed—are printed on the chart output. User-defined text can also be added through the optional interfaces. The chart recorder accepts 8-1/2 × 11 and 11 × 17-inch paper, as well as Z-fold paper for continuous charts. It features automatic paper-edge detection and sheet positioning and an optical pen-positioning system for reliable operation.

As an XY recorder, the *PM 8278* has 25 calibrated input ranges on both X and Y channels, with a sensitivity range of 40 μV/cm to 2 V/cm. Fast dynamic response of 100 cm/s and 10-G acceleration ensure that even fast-changing signals are accurately traced. In strip-chart mode, the recorder has 24 timebase settings, including 10 user-programmable lines, varying from 10 mm/h to 120 mm/min. Step response is 0.25 seconds full scale.

The *PM 2878* dual-pen analog chart recorder has a U.S. list price of $3360.00. (A single-pen chart recorder, model *PM 2877*, has a list price of $2340.00)—**John Fluke Mfg. Co., Inc.**, P.O. Box 9090, Everett, WA 98026; Tel. 800-443-5853, ext. 77.

VACUUM FLUORESCENT DIGITAL DASHBOARD. Breaking away from traditional LED displays, *Dakota Digital's vacuum-fluorescent digital dashboard* provides a bright-blue fluorescent readouts with superior performance and visual appeal. The displays are readable in direct sunlight, and the system automatically dims for night-time driving. The dashboard uses a microprocessor system to measure, calculate, and display speed, RPM, mileage, voltage, oil pressure, water temperature, and fuel level. If a reading should vary from normal limits, an "idiot light" system causes the gauge display to flash. A resettable "trip meter" is included. Vehicle mileage is stored in a nonvolatile memory that does not loose its information even when the battery is disconnected. Intended to hobbyists, car buffs, and street-rod enthusiasts, the dashboard systems can be custom-built to virtually any user-specified arrangement, and can be easily installed in any truck, car, or boat.



CIRCLE 20 ON FREE INFORMATION CARD

The *vacuum-fluorescent digital dashboard* is available as a complete set with aluminum insert (as pictured) for $499.95. Alternately, if you send in your dashboard, the display can be mounted in it (without the aluminum insert) for approximately $420.00.—**Dakota Digital**, 11301 Kuhle Drive, Sioux Falls, SD 57107; Tel. 1-800-852-3228. **R-E**

NEW LIT

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THE ELECTRONIC PROJECT BUILDER'S BOOK: DESIGNING AND MODIFYING CIRCUITS; by Josef Bernard. TAB Books, Inc., Blue Ridge Summit, PA 17294-0850; 1-800-822-8158 (in PA and AK, 717-794-2191); softcover; $14.95.

If, like many electronics hobbyists, you've ever found yourself stumped—stuck at a dead-end while building a project, or unable to answer a deceptively simple question—and had no place to turn for help, you'll appreciate this book. In it, former **Radio-Electronics** technical editor Joe Bernard has compiled a treasury of practical advice and information that will go a long way toward eliminating that kind of frustration. Along the way, he gives you tips and pointers and shows you how to design, build, and troubleshoot your own, customized electronics projects.

What sets this book apart from the crowd is that it focuses not only on what to do, but on *why* and *how* to do it. A practical understanding of basic concepts is emphasized throughout the book. When combined with the answers to dozens of commonly asked electronics questions—Why are there so many different kinds of transistors? How do I choose the value of a current-limiting resistor?—that knowledge becomes a powerful skill that can be applied to designing and building your own circuits. In his usual easy-going, easy-to-understand style, the author takes the mystery out of electronics by clearly explaining how all those laws and formulas relate to the real world, and how you can put them to work for you.

1990 FLUKE DISTRIBUTOR PRODUCTS CATALOG. John Fluke Mfg. Co., Inc., P.O. Box 9090, Everett, WA 98206; 1-800-443-5853; free.

Featuring analog and digital multimeters, digital thermometers, and multifunction counters, this 20-page catalog also includes an expanded section of new leads, probes, and clips for a variety of applications. The versatile *Fluke 80 Series* of handheld multimeters, which offer a combination of measurement functions and special features for automotive, electrical, and electronic test applications, is highlighted. Also highlighted is the *Fluke 45* dual-display multimeter, which allows the user to make two different measurements of signal parameters simultaneously.

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SOLDERING IRONS CATALOG. M.M. Newman Corporation, 24 Tioga Way, P.O. Box 615, Marblehead, MA 01945; 617-631-7100; free.

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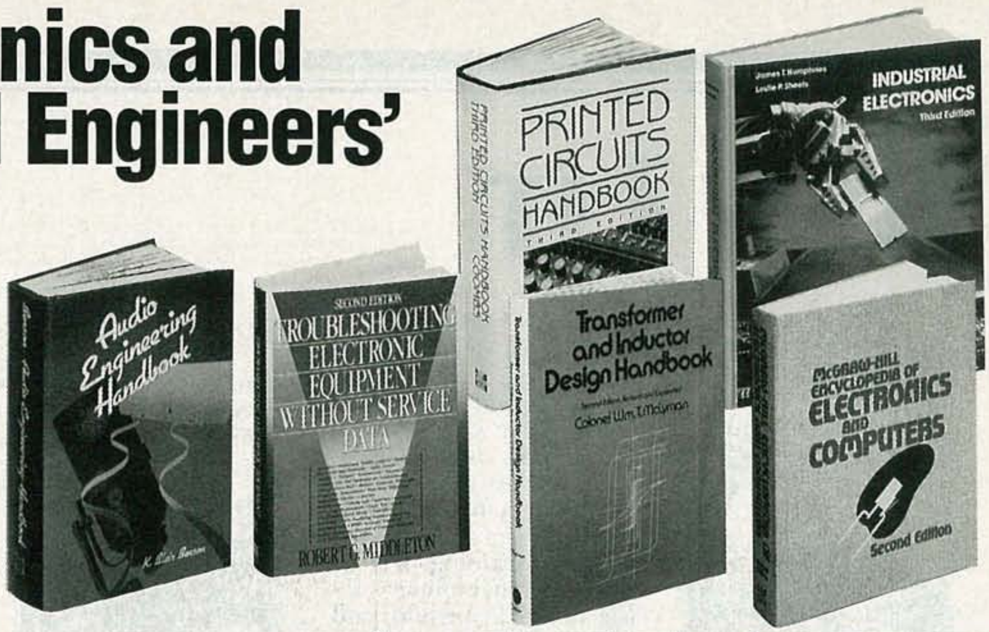

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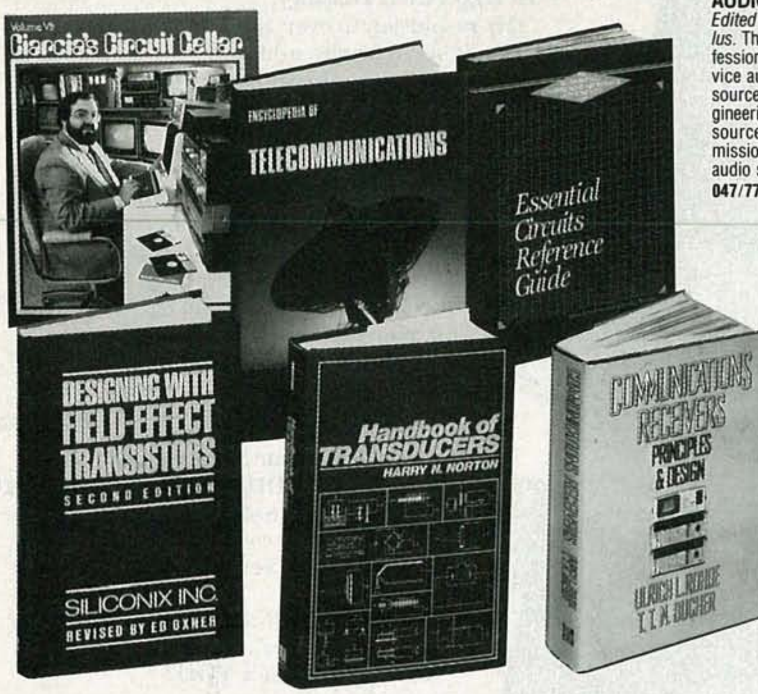

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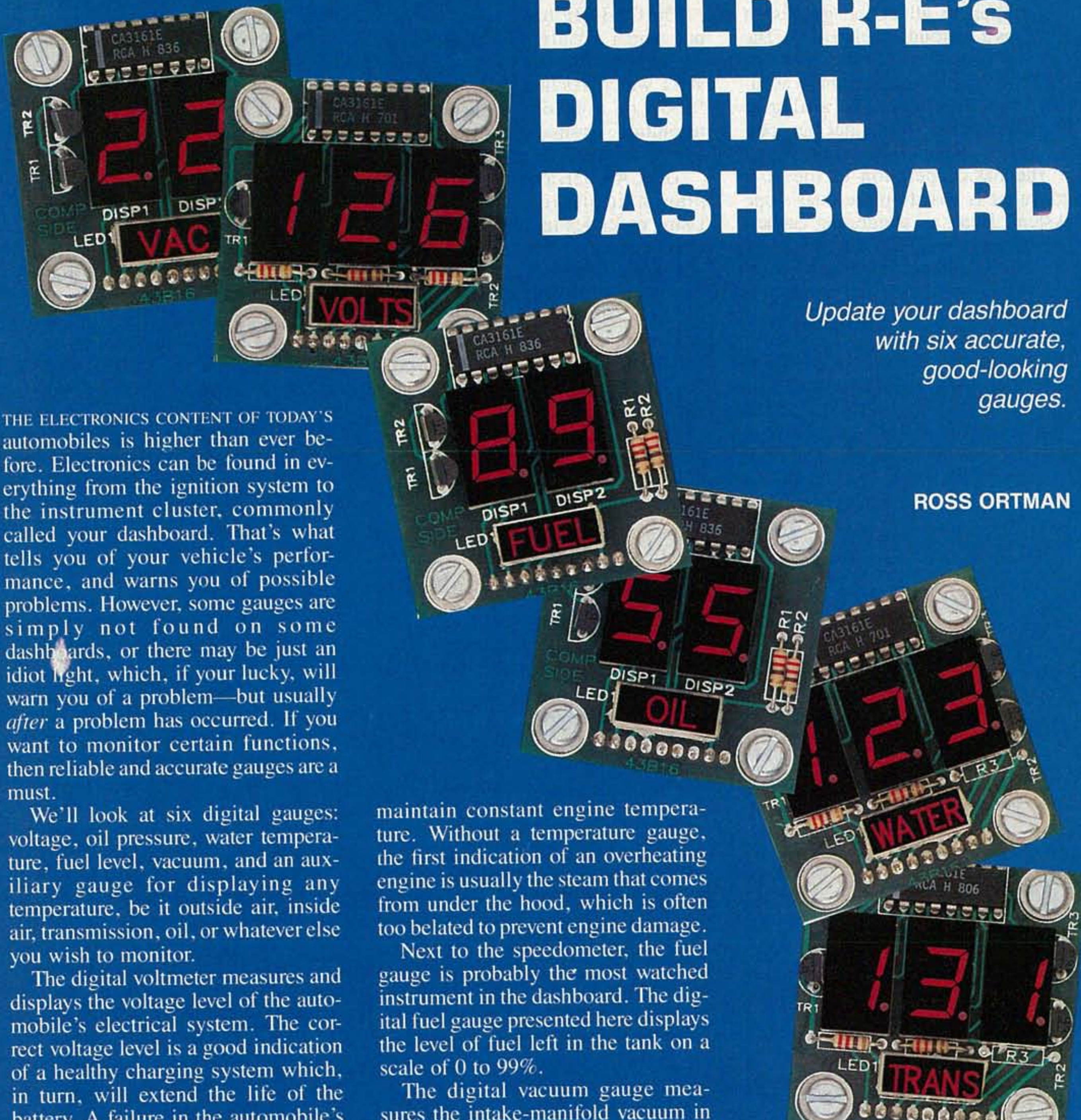

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THE ELECTRONICS CONTENT OF TODAY'S automobiles is higher than ever before. Electronics can be found in everything from the ignition system to the instrument cluster, commonly called your dashboard. That's what tells you of your vehicle's performance, and warns you of possible problems. However, some gauges are simply not found on some dashboards, or there may be just an idiot light, which, if your lucky, will warn you of a problem—but usually *after* a problem has occurred. If you want to monitor certain functions, then reliable and accurate gauges are a must.

We'll look at six digital gauges: voltage, oil pressure, water temperature, fuel level, vacuum, and an auxiliary gauge for displaying any temperature, be it outside air, inside air, transmission, oil, or whatever else you wish to monitor.

The digital voltmeter measures and displays the voltage level of the automobile's electrical system. The correct voltage level is a good indication of a healthy charging system which, in turn, will extend the life of the battery. A failure in the automobile's charging system can, of course, leave you stranded.

Proper oil pressure is very important to the operation of your automobile's engine. Without it, the oil would not be pumped into bearings, journals, and over moving metal parts. The end result would be a seized or badly damaged engine. The digital oil-pressure gauge keeps you informed as to how well your engine is being lubricated.

The digital water-temperature gauge is used to monitor the engine's cooling system, which is designed to maintain constant engine temperature. Without a temperature gauge, the first indication of an overheating engine is usually the steam that comes from under the hood, which is often too belated to prevent engine damage.

Next to the speedometer, the fuel gauge is probably the most watched instrument in the dashboard. The digital fuel gauge presented here displays the level of fuel left in the tank on a scale of 0 to 99%.

The digital vacuum gauge measures the intake-manifold vacuum in inches of mercury (in. Hg). Normal driving usually produces a vacuum reading between 16 and 22 in. Hg. The general rule of thumb is, the higher the vacuum level, the lower the gauge reading, and the better the gas mileage.

As you probably already know, an automobile uses many other fluids besides the water and antifreeze in the radiator. And, just like the coolant in the radiator, many of those fluids get hot under use. Since excessive heating indicates a potentially serious problem, it is advantageous to monitor such things as the oil, transmission fluid, differential fluid, etc. In addition to automotive operating parameters, convenience items such as outside air temperature and inside air temperature can also be monitored.

Circuitry

A block diagram, which describes the circuitry that's common to all of the gauges, is shown in Fig. 1. The central component of each digital gauge is the A/D converter. Because it is common to all of the gauges, it deserves a thorough explanation. The CA3162E A/D converter and the CA3161E display driver form an accurate, low-cost, three-digit analog to digital converter system that can operate from a single 5-volt supply.

The basic operation of the A/D converter is based on the dual slope system. Here, an integrating capacitor is charged to a level determined by the input voltage. That is accomplished by converting the input voltage to a relative current and using that current to charge the integrating capacitor for a predetermined time. After that charge time, the voltage-to-current converter is removed and a current source of opposite polarity is connected to the capacitor. The time required to discharge the capacitor to its original value is measured to determine the original input voltage level.

The CA3161E has a differential input which greatly simplifies circuit design. The full-scale input is 0.999 volts which results in a reading of "999" on a three-digit display. The resolution, or smallest change the A/D converter can show, is 1 mV.

The CA3162E also controls the display multiplexing and updating. Using multiplexing, the parts count is greatly reduced, and, although only one digit is lighted at a time, it appears that all the digits are on all the time.

The *B*inary *C*oded *D*ecimal (BCD) output of the CA3162E is sent to the CA3161E display decoder/driver, which supplies segment current to each of the displays. Because the display driver contains internal current limiting, external current-limiting resistors are not needed.

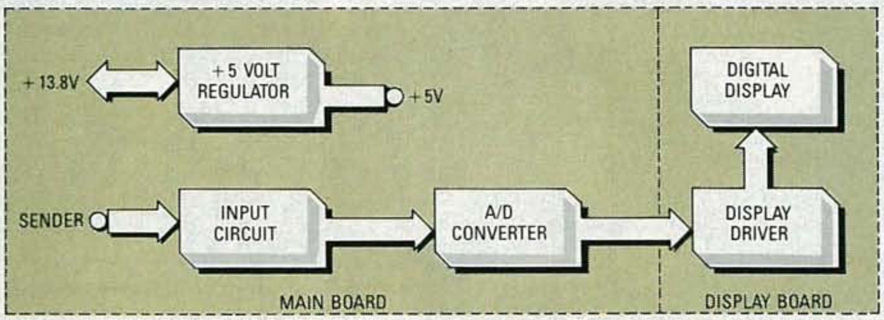

FIG. 1—BLOCK DIAGRAM COMMON to all of the gauges. The central component of each digital gauge is the A/D converter.

Let's take a closer look at each individual gauge. The gauges are very similar to each other, so we will not repeat descriptions for similar sections. The same goes for the display boards.

Voltage gauge

The voltage gauge displays the voltage of the automobile's electrical system on a three-digit readout with 0.1-volt resolution. The gauge will display voltages from 8 to 19.9 volts. Because the input of the A/D converter has a maximum input of 0.999 volts, the input voltage to the meter must be divided by 100. That way, the A/D's actual input voltage ranges from 0.080 to 0.199. That results in a reading of "080" to "199," and by fixing the decimal point to the second digit, a resulting display of "08.0" to "19.9" is obtained.

The voltage gauge schematic is shown in Fig. 2. Power is supplied to the voltmeter through P1. The unit is protected from excessive current by fuse F1. Diode D2 assists in protecting from reverse battery connection, and also clamps any momentary negative spikes on the automobile's electrical system. Diode D2 allows only positive voltage to reach the 5-volt regulator, IC1, that reduces the vehicle's 12 to 13.8 volts to the 5-volt level needed by the gauge's circuitry.

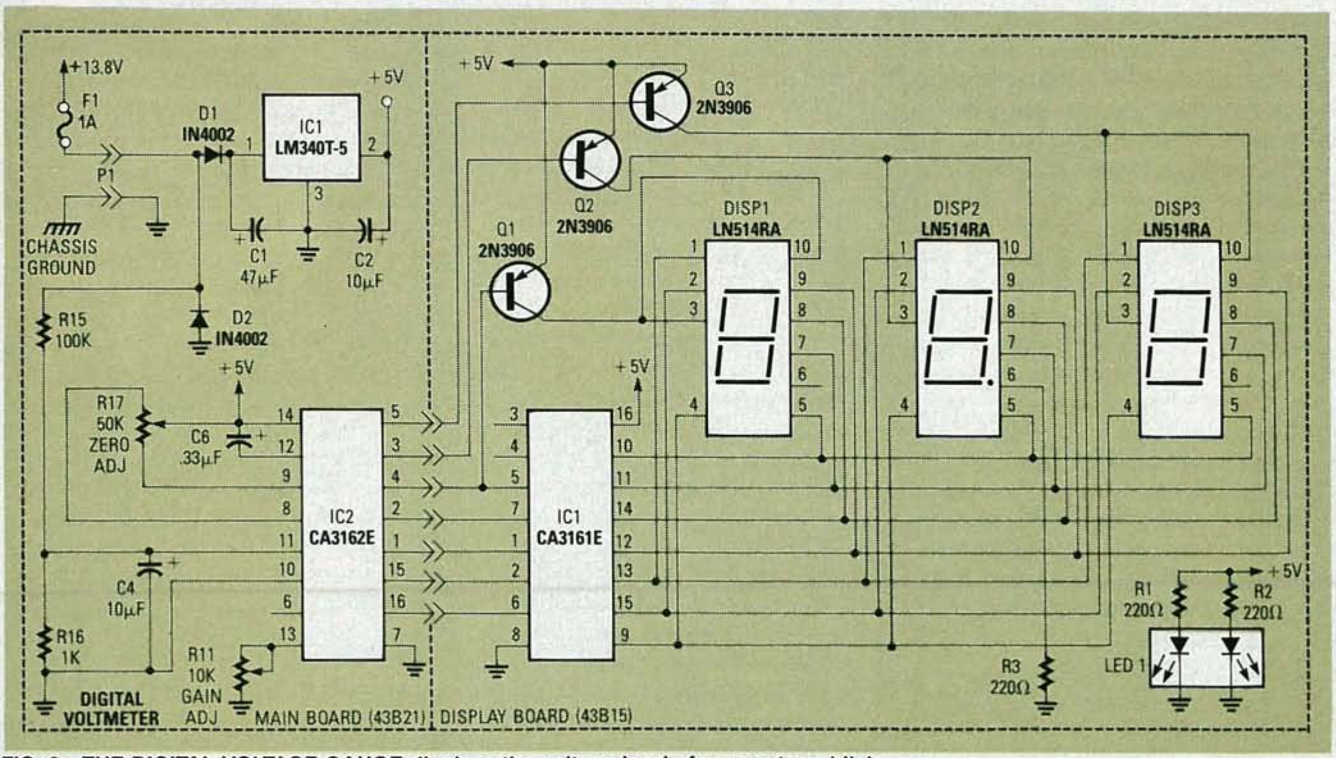

FIG. 2—THE DIGITAL VOLTAGE GAUGE displays the voltage level of your automobile's electrical system.

VOLTAGE GAUGE
All resistors are ¼-watt, 5%, unless otherwise indicated.
R1–R10, R12–R14—not used
R11—10,000 ohms, PC-mounted trimmer potentiometer
R15—100,000 ohms
R16—1000 ohms
R17—50,000 ohms, PC-mounted trimmer potentiometer
Capacitors
C1—47 µF, 25 volts, electrolytic
C2, C5—10 µF, 35 volts, electrolytic
C3, C4—not used
C6—0.33 µF, 50 volts, stacked film
Semiconductors
IC1—LM340T-5, 5-volt regulator
IC2—CA3132E, A/D converter
D1, D2—1N4002 diode
Miscellaneous: 43B21 main PC board, 3-digit display board, in-line fuse holder, 1-amp fuse, four 6-32 × 0.625" standoffs, eight 5/16-inch #6 screws, bronze or red plexiglass, mounting hardware, hookup wire

Capacitors C1 and C2 help reduce voltage transients and fluctuations.

The A/D converter (IC2) converts the input voltage to a relative digital value, and C6 is the integrating capacitor that was discussed earlier. A divide-by-100 network, that provides the proper input voltage for the A/D converter, is formed by R15 and R16. Capacitor C4 filters the A/D input voltage to ensure stable readings. A zero-adjust is provided by R17 and a gain-adjust by R11.

Once the input voltage has been converted, its digital value is sent to the display section. There, IC1 of the display board receives multiplexed BCD information and outputs that information to the three seven-segment displays, one at a time. The multiplexing is controlled by IC2. Current to each display is switched by Q1, Q2, and Q3. For example, when Q1 is on, current is delivered to DISP1, the most significant digit of the display. To display a "138," the CA3162E would send a binary 0001 to the CA3161E, which would then turn on the necessary segments to display a "1" on the first digit. After a predetermined time, the system moves on to the second and third digits and finally repeats itself. Because the voltmeter is designed to display 0.1-volt increments, the decimal point on DISP2 is kept on all of the time by R3. A "VOLTS" annunciator is formed by LED1, which is a pre-formed module containing two LED's, and limiting resistors R1 and R2. The module has a plastic "lens" over it that is all black except for the clear letters V-O-L-T-S.

OIL-PRESSURE GAUGE
All resistors are ¼-watt, 5%, unless otherwise indicated.
R1—470 ohms
R2–R8, R10, R12–R16—not used
R9—100,000 ohms
R11—10,000 ohms, PC-mounted trimmer potentiometer
R17—50,000 ohms, PC-mounted trimmer potentiometer
Capacitors
C1—47 µF, 25 volts, electrolytic
C2, C3, C4—10 µF, 35 volts, electrolytic
C5—not used
C6—0.33 µF, 50 volts, stacked film
Semiconductors
IC1—LM340T-5, 5-volt regulator
IC2—CA3132E, A/D converter
D1, D2—1N4002 diode
Miscellaneous: 43B21 main PC board, 15G5 oil-pressure sender, 2-digit display board, in-line fuse holder, 1-amp fuse, four 6-32 × 0.625" standoffs, eight 5/16-inch #6 screws, bronze or red plexiglass, mounting hardware, hookup wire

Oil pressure

The oil-pressure gauge, shown in Fig. 3, displays engine oil pressure from 0 to 80 psi (*p*ounds per *s*quare *i*nch) with 1-psi resolution. The inpu voltage to the A/D converter mus therefore range from 0 to 0.80 volts The oil pressure is sensed by the oil pressure sending unit which convert pressure to electrical resistance. I the case of the sending unit used here pressure is converted to resistanc

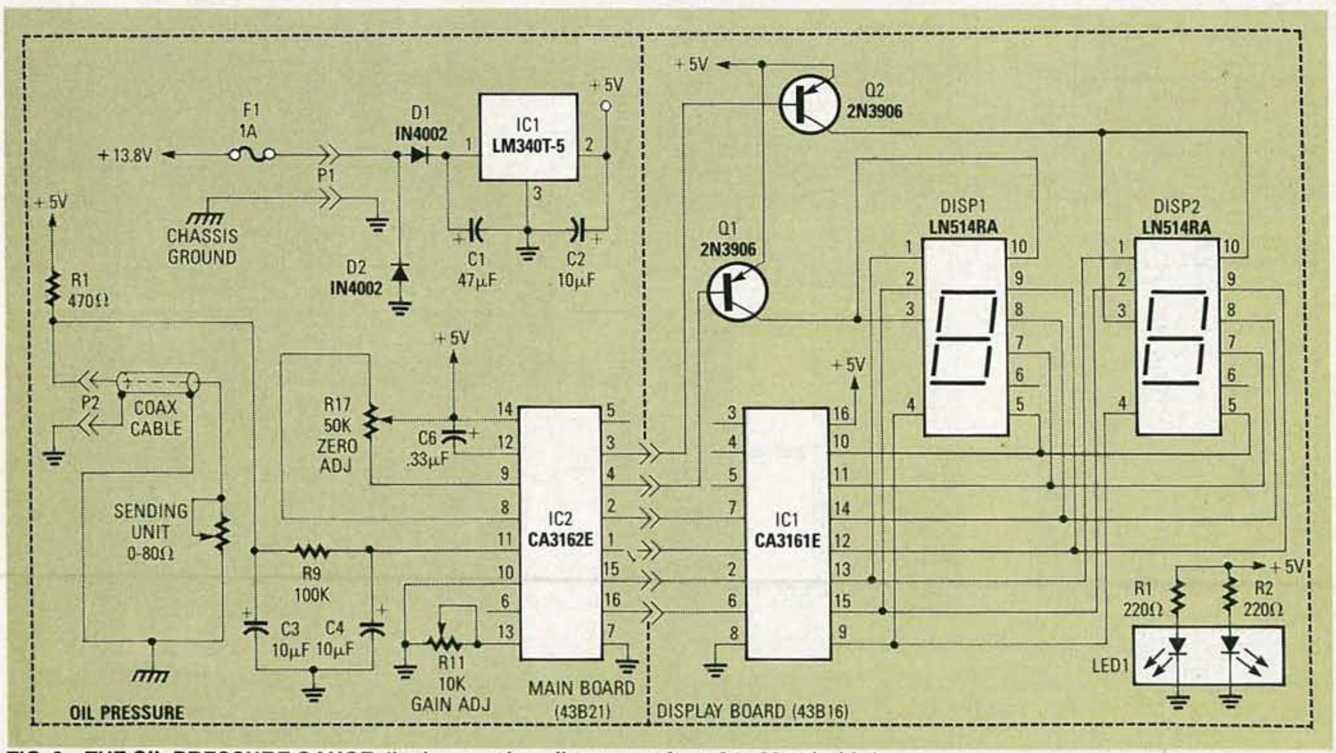

FIG. 3—THE OIL-PRESSURE GAUGE displays engine oil pressure from 0 to 80 psi with 1-psi resolution.

with an approximate 1:1 ratio. That is, with 60 pounds of oil pressure, the sender's resistance is approximately 60 ohms, with a 0.6-volt drop across it. With no oil pressure, the sender's resistance is zero ohms. The voltage drop across the sending unit is then filtered and read directly by the A/D converter. The regulator and A/D converter sections are similar to the voltmeter, and the display section is identical except for one less digit.

The sending unit and R1 on the main board form a resistive divider. The voltage drop across the sending unit equates to 0.01 volt/psi. That is, for every psi of oil pressure, the voltage across the sender increases by approximately 10 millivolts. The relative voltage across the sender is then filtered by C3, R9, and C4 to maintain a more stable reading. An "OIL" annunciator (LED1) specifies the reading of the gauge.

Water

The water-temperature gauge, shown in Fig. 4, displays the automobile's coolant-system temperature on a three-digit readout with 1-degree resolution. The actual temperature is obtained by measuring the resistance across a standard automotive temperature sending unit, which is essentiality a thermistor contained in a brass enclosure. Because the sending unit's resistance is inversely proportional to temperature (the greater the temperature, the lower the resistance), the differential input of the A/D converter is used. That means that the A/D converter CA3161E measures the difference between its positive and negative inputs (pins 11 and 10, respectively).

A reference voltage, set by R6, R7, and R8 is applied to the positive input at pin 11. The negative input (pin 10) is connected to the temperature-sending unit via a resistor network. As the temperature of the sending unit increases, its resistance will decrease, lowering the voltage across it. When the lower voltage is seen at the negative input of the A/D converter, and compared to the level set at the positive input, the temperature reading will rise. The opposite happens as the sending unit cools; its resistance becomes greater and more voltage is applied to the negative input. The temperature reading then decreases as the negative input gets closer in potential to the positive input. A reading of 0 will result when the positive and negative inputs are equal. Note that the negative input is limited to a maximum of 1.2 volts.

The regulator and display sections

WATER-TEMPERATURE GAUGE
All resistors are ¼-watt, 5%, unless otherwise indicated.
R1—100 ohms, ½-watt
R2—430,000 ohms
R3, R7—10,000 ohms, PC-mounted trimmer potentiometer
R4, R8—22,000 ohms
R5, R9, R11–R16—not used
R6—470,000 ohms
R10—2200 ohms
R17—50,000 ohms, PC-mounted trimmer potentiometer
Capacitors
C1—47 µF, 25 volts, electrolytic
C2, C5—10 µF, 35 volts, electrolytic
C3, C4—not used
C6—0.33 µF, 50 volts, stacked film
Semiconductors
D1, D2—1N4002 diode
IC1—LM340T-5, 5-volt regulator
IC2—CA3132E, A/D converter
Miscellaneous: 43B21 main PC board, 14G11 water-temperature sender, 3-digit display board, in-line fuse holder, 1-amp fuse, four 6-32 × 0.625" standoffs, eight 5/16-inch #6 screws, bronze or red plexiglass, mounting hardware, hookup wire.

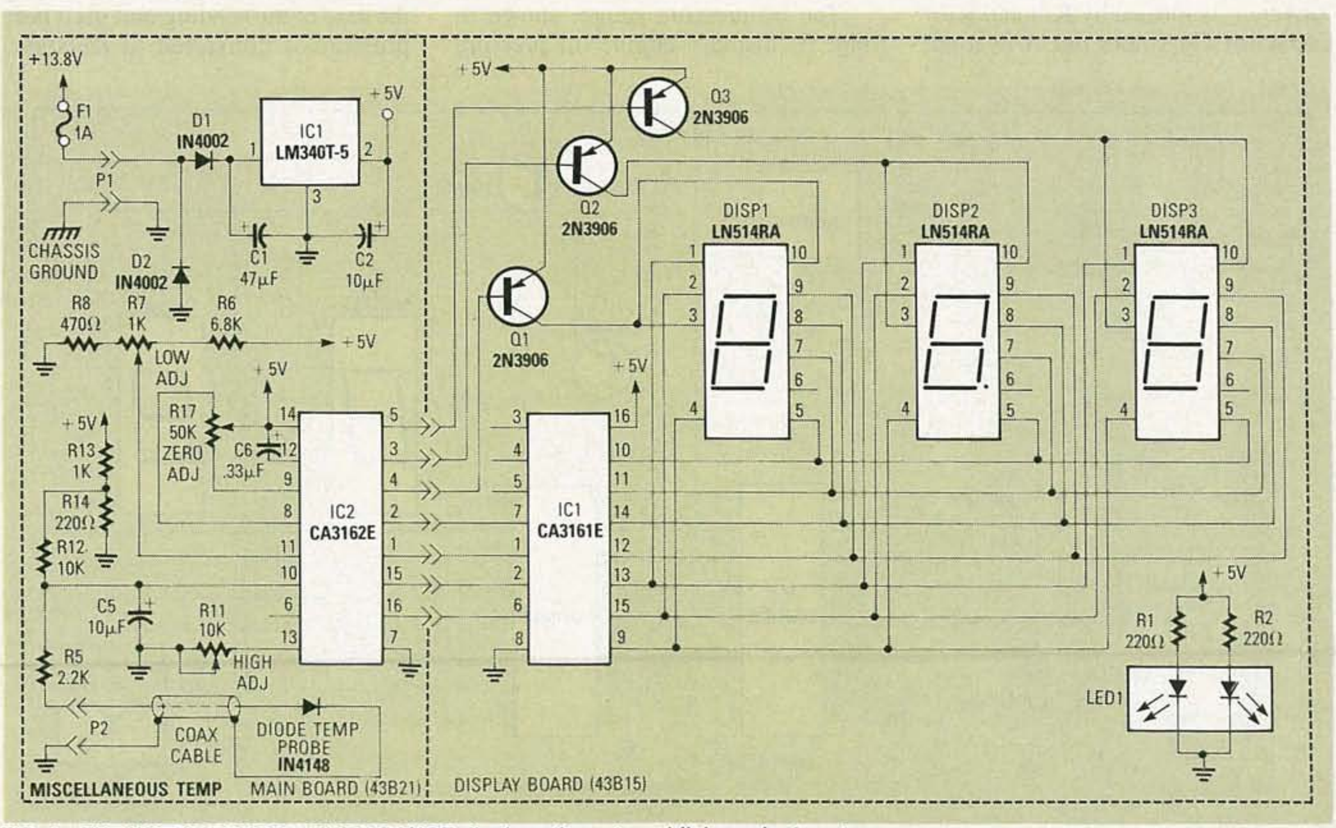

FIG. 4—THE WATER-TEMPERATURE GAUGE displays the automobile's coolant-system temperature on a three-digit readout with 1-degree resolution.

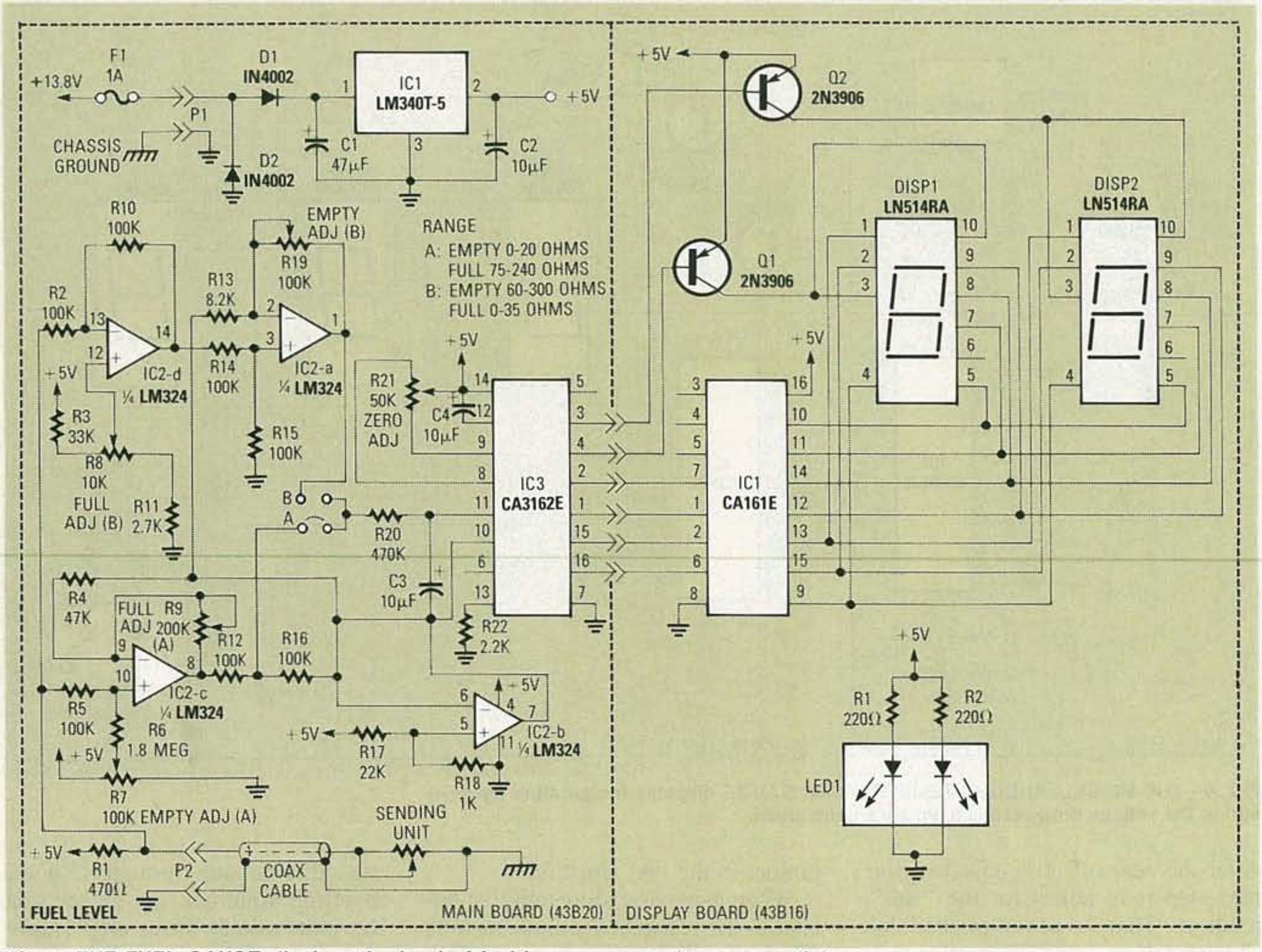

FIG. 5—THE FUEL GAUGE displays the level of fuel in your gas tank on a two-digit readout, which is interpreted as percentage of the fuel remaining.

are again similar to that of the voltmeter's. Looking at the A/D converter's input circuitry, note that R1 and the temperature sending unit form a resistive divider network with the sending unit connected through P2. The relative voltage at that point is then divided down by R2, R3, and R4. Potentiometer R3 provides the low-temperature calibration adjustment, and C5 filters the input voltage for stable readings. That voltage is then sent to the negative input of the A/D converter, IC2. Resistors R6, R7, and R8 form a resistive divider that sets the upper reference voltage, the high-temperature calibration is set by R7, and the A/D converter zero adjust is set by R17. A "WATER" annunciator is formed using LED1, R1, and R2.

Fuel

The fuel gauge displays the level of fuel in your gas tank on a two-digit readout (see Fig. 5). The readout's range is from 0 to 99, and is interpreted as percentage of the fuel remaining. The fuel gauge senses the resistance of the fuel sending unit located in the gas tank. Typical sending units consist of a potentiometer with its wiper connected to a float. As the fuel level rises and falls, the resistance of the potentiometer changes. Although sending units are not completely linear, due in part to the irregular shape of most gas tanks, their output resistance does go consistently from low to high. Some sending units have a high resistance when empty and a low resistance when full, as with most Ford, AMC, marine, and aftermarket senders, and some go from a low resistance when empty to a high resistance when full, as is the case with most GM sending units. By having two range settings, the fuel gauge can handle both kinds of sending units. The range settings (A and B) are shown in Fig. 5.

Current for the sending unit is derived from R1, which forms a voltage divider with the sending unit. The voltage developed across the sending unit proportional to the fuel level. For sending units that increase in resistance as the tank is filled, the R5 path is taken. Because the voltage increases as the fuel level rises, we offset the empty reading and adjust the top scale for a "full" reading.

Because the gauge works from a single supply, and the A/D compares its positive input to its negative, we need to be able to reach zero volts in order to display a zero (0% fuel left). Most op-amps will work very close to their negative supply, which in this case is ground, but not completely. By biasing the negative input of the A/D converter to 0.21 volts, the ground reference for the op-amp "zero" level becomes 0.21 volts. The op-amp output can then easily reach the "ground" reference level to obtain a "00" on the display. All other voltage values are then referenced to the 0.21 volt "ground." Potentiometer R7, along with R6, is used to offset the output of IC2 (pin 8) to 0.21 volts.

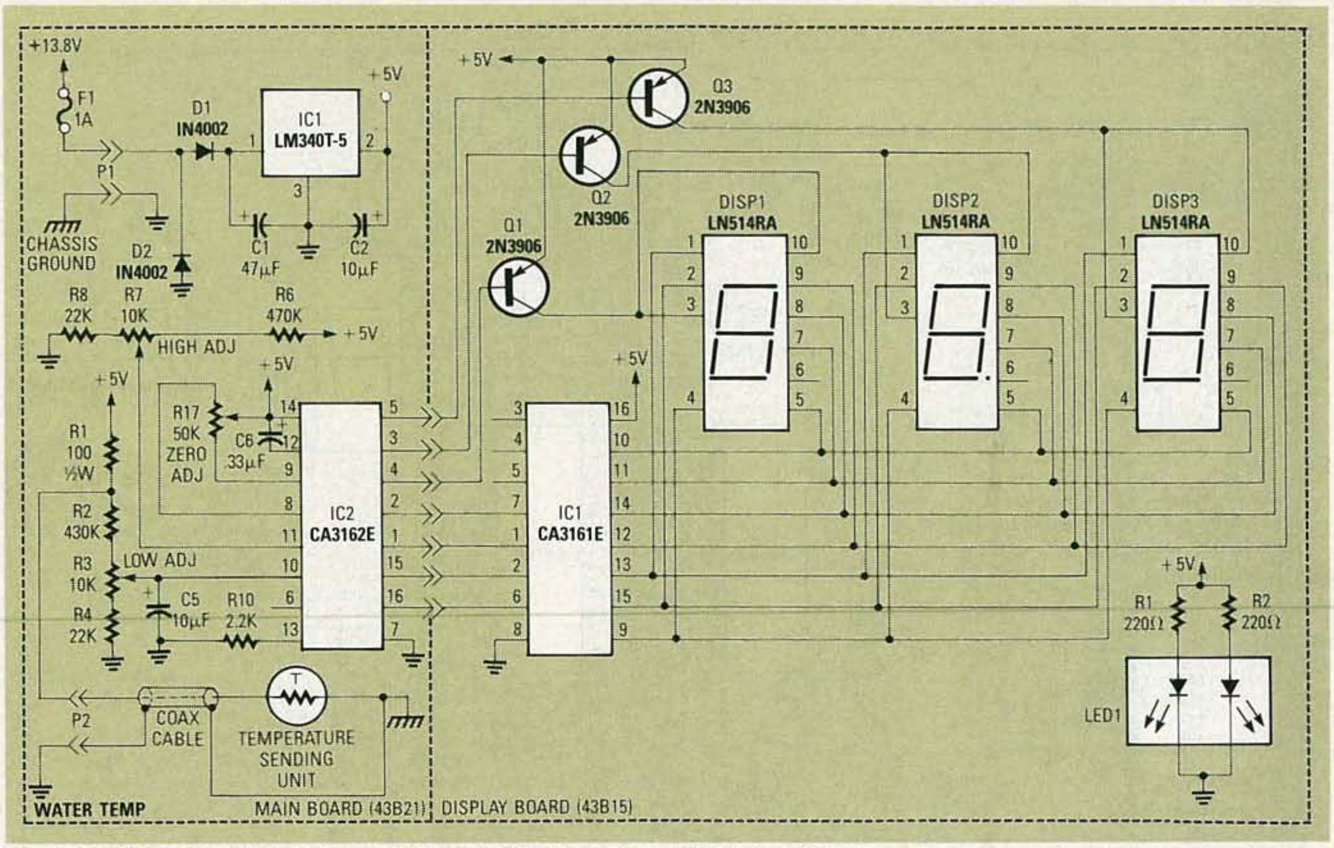

FIG. 6—THE MISCELLANEOUS TEMPERATURE GAUGE displays temperature by measuring the voltage drop across a typical silicon diode.

After the zero offset is adjusted, the next step is to adjust for the "full" reading. That is accomplished by changing the gain of IC2, by placing a jumper in the "A" position.

When using a sending unit that decreases in resistance as the tank is filled, the "B" jumper is used. That way, after passing through R2 and an inverting amplifier, the higher sending-unit voltage from an "empty"

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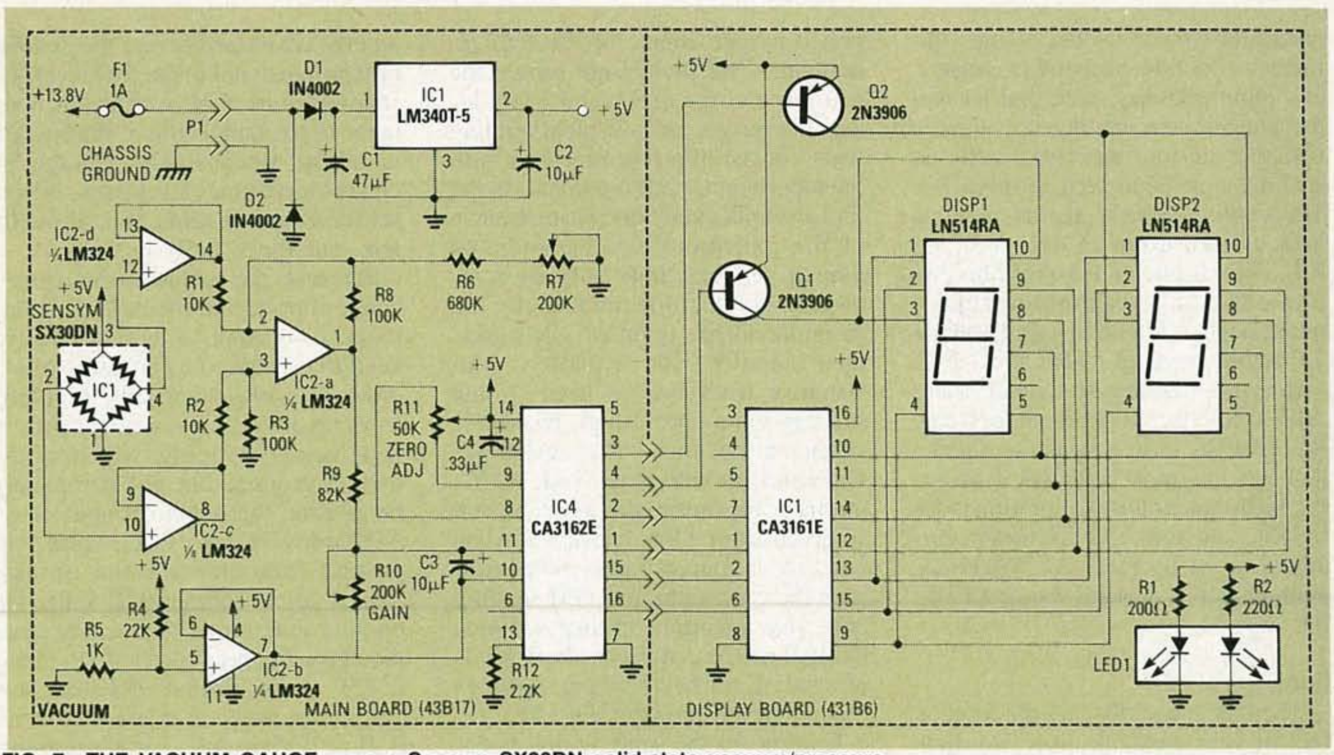


FIG. 7—THE VACUUM GAUGE uses a Sensym SX30DN solid-state vacuum/pressure sensor to monitor the intake-manifold vacuum during engine operation. Between 0 and 30 inches of mercury can be displayed.

Note: The following items are available from Dakota Digital, 11301 Kuhle Drive, Sioux Falls, SD 57107 (605) 332-6513: a PC-board set for each gauge (includes main PC board and display board) is $6.95. A parts kit for each gauge (includes PC boards, components, and manual) is $29.95. Each gauge assembled and tested is $39.95. Stock numbers are as follows: voltage-gauge kit #2005-KIT, assembled and tested #3005-UNIT; oil-pressure gauge kit #2006-KIT, assembled and tested #3006-UNIT (order oil-pressure sender separately); water-temperature gauge kit #2007-KIT, assembled and tested #3007-UNIT (order water-temperature sender separately); miscellaneous temperature gauge kit #2008-KIT, assembled and tested #3008-UNIT; fuel-gauge kit #2009-KIT, assembled and tested #3009-UNIT; vacuum-gauge kit #2010-KIT, assembled and tested #3010-UNIT (order vacuum sensor separately). Oil-pressure sender (#15G5), $15.50; water-temperature sender (#14G11), $5.50; vacuum sensor (#69G18), $19.95; RCA CA3161E driver (#69G16), $1.95; RCA CA3162 A/D converter (#69G15), $7.95. All orders add 4% shipping and handling ($1.50 minimum), Visa and Mastercard accepted.

reading is offset by R8 to produce an output at pin 14 of IC2 that is near 0.41 volts. Divided down to 0.21 volts by R14 and R15, the output at pin 1 of IC2 is at the proper 0.21-volt zero reference. The "empty" voltage is adjusted by R19. Components R20 and C3 are used to average the input voltage to avoid erratic readings caused by the sloshing of gasoline in the fuel tank. The zero adjustment of the A/D converter is set by R17, and LED1, with an appropriate lens, is used as a "FUEL" annunciator.

Temperature

The miscellaneous temperature gauge, shown in Fig. 6, displays temperature by measuring the voltage drop across a typical silicon diode, which is determined by the formula $V_D = 2mV$ per degree Celsius, where V_D is the voltage drop. Because the temperature gauge is calibrated to read out in degrees Fahrenheit, the voltage across the diode is scaled accordingly. The temperature is then displayed on a three-digit readout with 1-degree resolution.

Because the voltage across the diode is inversely proportional to temperature, the differential input of the A/D converter is used in the same manner as the water-temperature gauge. Note that the positive input at pin 11 is connected only to a reference voltage set by R6, R7, and R8. The negative input (pin 10) is connected to the 1N4148 diode temperature probe via a resistor network. As the temperature of the diode increases, the voltage across it will decrease resulting in a lower voltage at the negative input of the A/D converter and, when compared to the level set at the positive input, the reading will rise. Just the opposite happens as the diode cools.

Resistors R13 and R14 form a voltage-divider network that provides a reference of 0.9 volts for the second divider network consisting of R12 and R5. That second divider scales the relative voltage developed across the temperature probe to coincide with the range of the A/D converter. It is also used to bias the temperature-probe diode. For example, suppose the voltage across the diode at 32 degrees Fahrenheit is 0.6 volts. Then, 0.654 volts would be delivered to the negative input of the A/D converter. With the positive input of the A/D converter calibrated to 0.686 volts, "032" would be displayed on the digital readout. As the temperature-probe diode heats to 212 degrees Fahrenheit, the drop is reduced to 0.4 volts. We would now have 0.49 volts at the negative A/D converter input. The display will now read "212."

Although the negative input is not a full 180 millivolts lower than at 32 degrees, the gain control of the A/D converter compensates for that. The compensation also allows the converter to have an adjustment window so tolerance effects can be calibrated out. Looking at the remaining circuitry, C5 is used to filter the input voltage for stable readings. Resistors R6, R7,

continued on page 61

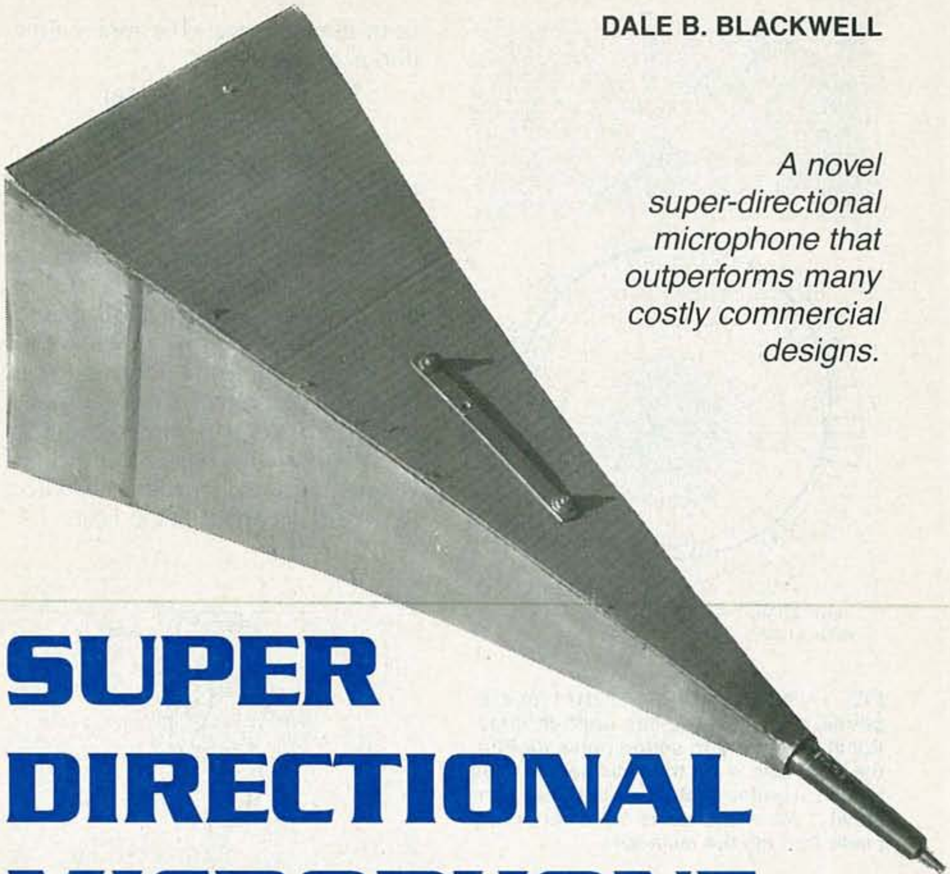
FUEL GAUGE
All resistors are ¼-watt, 5%, unless otherwise indicated.
R1—470 ohms
R2, R5, R10, R12, R14, R15, R16—100,000 ohms
R3—33,000 ohms
R4—47,000 ohms
R6—1.8 megohms
R7, R19—100,000 ohms, PC-mounted trimmer potentiometer
R8—10,000 ohms, PC-mounted trimmer potentiometer
R9—200,000 ohms, PC-mounted trimmer potentiometer
R11—2700 ohms
R13—8200 ohms
R17—22,000 ohms
R18—1000 ohms
R20—470,000 ohms
R21—50,000 ohms, PC-mounted trimmer potentiometer
R22—2200 ohms
Capacitors
C1—47 µF, 25 volts, electrolytic
C2, C3—10 µF, 35 volts, electrolytic
C4—0.33 µF, 50 volts, stacked film
Semiconductors
IC1—LM340T-5, 5-volt regulator
IC2—LM324, quad op-amp
IC3—CA3132E, A/D converter
D1, D2—1N4002 diode
Miscellaneous: 43B20 main PC board, 2-digit display board, 0.1" 3-conductor header, 2-conductor jumper, in-line fuse holder, 1-amp fuse, four 6-32 × 0.625" standoffs, eight 5⁄16-inch #6 screws, bronze or red plexiglass, mounting hardware, hookup wire.

MISCELLANEOUS TEMPERATURE GAUGE
All resistors are ¼-watt, 5%, unless otherwise indicated.
R1–R4, R9, R10, R15, R16—not used
R5—2200 ohms
R6—6800 ohms
R7—1000 ohms, PC-mounted trimmer potentiometer
R8—470 ohms
R11—10,000 ohms, PC-mounted trimmer potentiometer
R12—10,000 ohms
R13—1000 ohms
R14—220 ohms
R17—50,000 ohms, PC-mounted trimmer potentiometer
Capacitors
C1—47 µF, 25 volts, electrolytic
C2, C5—10 µF, 35 volts, electrolytic
C3, C4—not used
C6—0.33 µF, 50 volts, stacked film
Semiconductors
IC1—LM340T-5, 5-volt regulator
IC2—CA3132E, A/D converter
D1, D2—1N4002 diode
Miscellaneous: 43B21 main PC board, 1N4148 diode for temperature probe, 3-digit display board, coax cable, in-line fuse holder, 1-amp fuse, four 6-32 × 0.625" standoffs, eight 5⁄16-inch #6 screws, bronze or red plexiglass, mounting hardware, hookup wire.

DALE B. BLACKWELL

SUPER DIRECTIONAL MICROPHONE

A novel super-directional microphone that outperforms many costly commercial designs.



THERE ARE SEVERAL WAYS TO CAPTURE and listen to sounds at a distance. Obviously, you could always set microphones at a location of interest, and transmit the sounds by wire or radio to your position. However, that's not always convenient or practical in certain cases of surveillance, or when dealing with bird calls or animal sounds.

Another option is to use a sensitive, directional microphone similar to those used in network TV broadcasts of football or other sporting events. Such microphones typically have parabolic reflectors for focusing sound onto them. The microphone we'll describe here uses a different approach, yet is perfect for long-distance monitoring or surveillance.

Theory

The major criteria that determine microphone performance are directional sensitivity and frequency response (bandwidth). Just as frequency response and directional sensitivity in antennas are changed by varying the lengths, diameters, and relative angles of metal radiators or reflectors, the analogous characteristics of microphones can be adjusted by similar geometric variations. One lesser known antenna type, normally used in microwave applications, is the horn antenna. The horn microphone presented in this article is designed using analogous principles which could, incidentally, also be applied with equal validity to the design of a loudspeaker, for reasons discussed below.

A very helpful concept in either acoustic or electromagnetic design is to think of a microphone, loudspeaker, or antenna, as just a transducer. This concept can be extended still further, if you consider a transducer of wave-propagated energy that focuses such energy onto a receptor to be a lens. Consider the similarities, taking the antenna first, since it's the more obvious. Both antennas and lenses focus and collect electromagnetic energy, the only difference being that light is at a much higher frequency range, and obeys the laws of optics. (Actually, microwave antennas also exhibit quasi-optical physical phenomena.)

Consider for a moment; don't both electromagnetic radiation and light exhibit the same phenomena of reflection, refraction, absorption or attenuation, and polarization? And in like fashion, acoustic energy also exhibits the same phenomena. Just as antennas are *electromagnetic* lenses, so too are microphones and loudspeakers *acoustic* lenses.

Not only are microphones and loudspeakers acoustic transducers or lenses, but also acoustic filters. Just as all filters have frequency and phase response, so too do microphones and loudspeakers. However, here, as with antennas, two types of filtering occur: directional and frequency.

Another term for directional sensitivity is directivity, often a desirable trait, since it prevents spurious sound from entering from undesired directions. A microphone with uniform directivity is termed omnidirectional; however, flat directional response doesn't imply flat frequency response. A microphone can either have a flat response over the audio spectrum (20 Hz–20 kHz), or be tailored for greater sensitivity over specific audio bands. The acoustic horn presented here has very high directivity over the entire audio spectrum.

The last property microphones and speakers have in common is reciprocity, which lets a microphone work equally well as a loudspeaker of identical design, both directionally and in frequency response; this property also holds true for antennas.

Different microphone types

Most microphones are omnidirectional, as shown in Fig. 1. Figure 1-*a* shows the basic shape of an omnidirectional microphone with the main axis, while Fig. 1-*b* shows a linear polar plot of relative sensitivity $P(\theta)$ (dynes/cm^2) as a function of angle θ about the main axis; all curves are normalized to 1 at the peak of the main beam. The main beam can be at any angle, although it's normally depicted at 0°. If several people sit around a table, an omnidirectional microphone at the center will pick them all up equally well. Any plane that passes through the main axis will exhibit this sensitivity response.

The second most common microphone type is the *cardioid*, shown in Fig. 2-*a*, which has greater directivity toward the front over most of the audio range. The sensitivity pattern shown in Fig. 2-*b* looks like the mathemati-

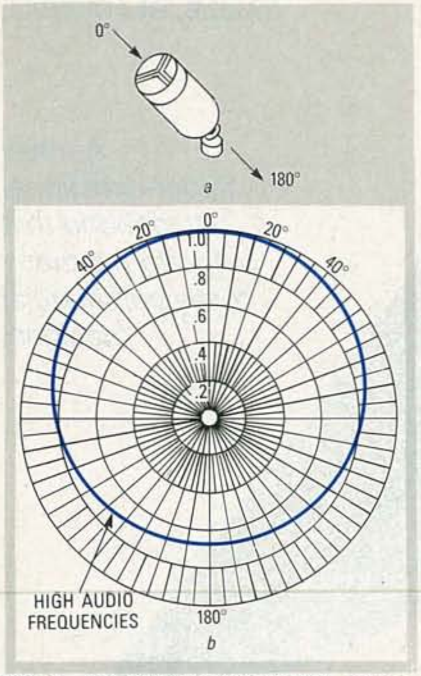


FIG. 1—AN OMNIDIRECTIONAL microphone, shown in (*a*), has uniform directional sensitivity to sound pressure P(θ); the main axis is out the indicated. In (*b*) is shown a polar plot of directional sensitivity; the response is identical in any plane through the main axis.

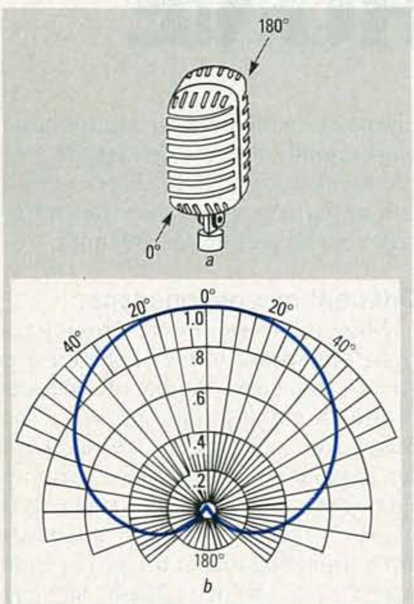


FIG. 2—A CARDIOID MICROPHONE, shown in (*a*), has greater sensitivity from the front than the rear. The 0° and 180° directions are along its main axis, pointing through the main face. The sound pressure sensitivity P(θ) shown in (*b*) was taken through a plane normal to the main axis.

cal curve called a cardioid (heart-shaped), hence the name. An orchestra in a night club might use a cardioid microphone so that only their music is picked up, not sounds from the audience. The power function is of the form:

$$P(\theta) = P_{ref}[1 + \cos(\theta)],$$
$$= 2 \times P_{ref}\cos^2(\theta/2).$$

At $\theta = 0°$, the sensitivity is maximized. The sensitivity goes to zero (a null) at $\theta = 180°$.

The ribbon element microphone shown in Fig. 3-*a* is the industry standard, well-known from all the photos of radio stars in front of them. It's sensitive from both front and rear, producing the figure-8 pattern shown in Fig. 3-*b*. A microphone that picks up equally well in opposite directions is advantageous in a talk show where the guest sits opposite the host.

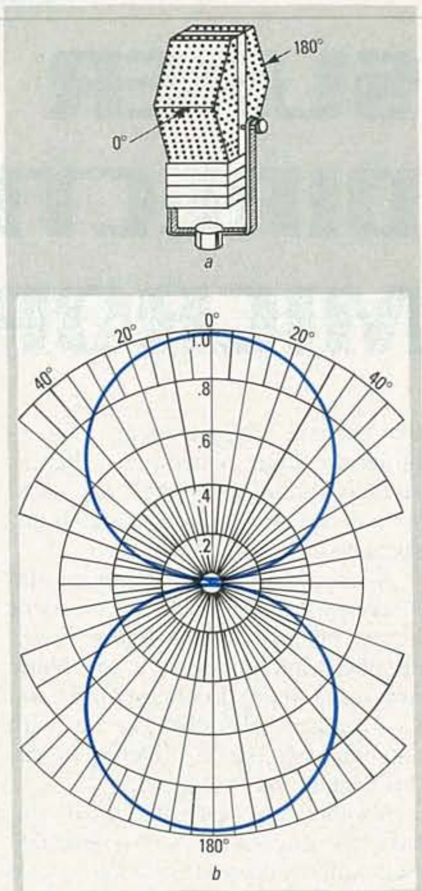


FIG. 3—A BIDIRECTIONAL microphone, shown in (*a*), is uniformly sensitive to sound from front and rear, but less sensitive from the side; the main axis is the same as that for a cardioid microphone. Note, however, that P(θ) in (*b*) has two lobes, not one, with two maxima and two minima (zeros, or nulls).

Increasing directivity

Experimenting with basic microphone directivity patterns yield more specialized designs that are much more sensitive from the front. Figure 4-*a* shows a parabolic reflector micro-

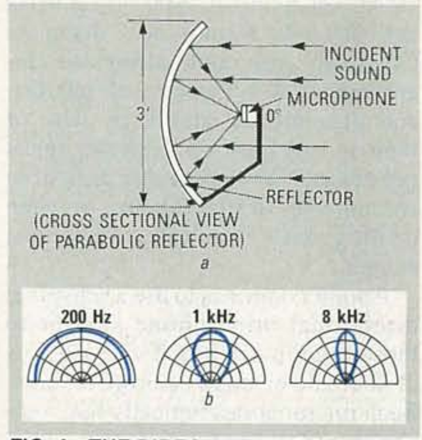


FIG. 4—THE DIRECTIVITY OF A parabolic reflector microphone increases with frequency. In (*a*), the incident parallel rays converge to the microphone at the focal point. In (*b*) are shown linear polar plots of acoustic power at four frequencies.

phone; all parallel rays, wherever they strike the curve, are reflected to the focal point, where the microphone is located. Parabolic microphones are also especially directive at higher audio frequencies, as shown in the sensitivity patterns of Fig. 4-*b*.

As shown in Fig. 5-*a*, the line (shotgun) microphone is another commercial directive version, albeit not quite as focused as a parabolic reflector. The line microphone has either a single long tube with spaced openings, or several tubes of increasing length, in front of the microphone element. The sensitivity patterns in Fig. 5-*b* *aren't* for differing frequencies, but for different tube lengths, being integral multiples of λ/2, or half a wavelength.

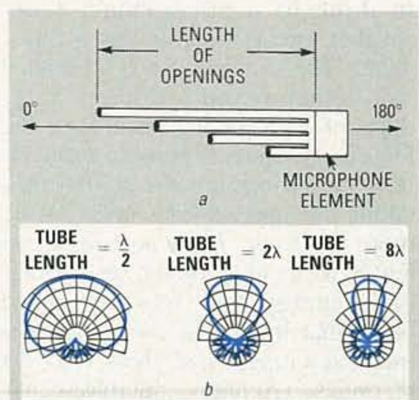


FIG. 5—A LINE (SHOTGUN) microphone becomes more directive as the length of its tubes increase. It's not as directive as a parabolic reflector, and either has one long tube with spaced openings, or several tubes of increasing length each with one opening, right in front of the diaphragm.

Both the reflector and line microphones are directive, but neither compares with the narrow beam of the horn shown in Fig. 6. Figure 6-*a* shows the geometry of the basic horn shell for the horn microphone prototype, without the screw-on extension piece, while Fig 6-*b* shows the directivity patterns for different frequencies.

All microphones, of whatever type, work equally well when the same basic shape is used in a loudspeaker due to reciprocity. The narrow beam of a horn stems from the ability to match the impedance between a small microphone diaphragm and free air, making the small microphone diaphragm (or receptor) seem as large as the mouth of the horn.

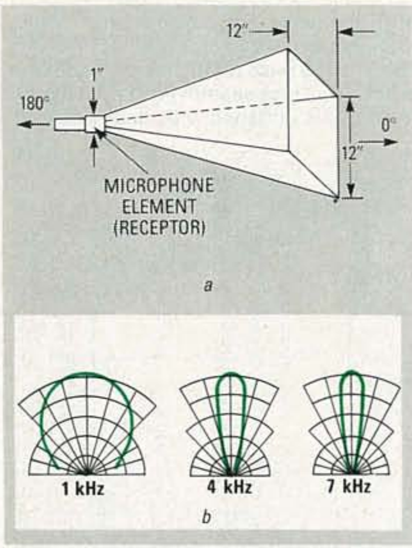


FIG. 6—HORN MICROPHONES ARE VERY directive; they match acoustic impedance from diaphragm to open air. In (*a*) are the prototype dimensions; the narrow beamwidth makes the receptor act as large as the mouth, due to phasing and pressure effects, so the incident volume is greater from the front, than sides or rear. In (*b*) are directivity plots for 1, 4, and 7 kHz.

Horn microphone

The high directivity of all horn microphones stems from phasing and pressure effects, making the volume at the receptor greater from the front, than from the sides or rear. The mouth, length, shape, and frequency range to be received, all determine the directivity. One reason for the high directivity is that audio wavelengths are made comparable to the mouth size. The relation is $\lambda = C/f$, where λ is wavelength (cm), C is speed of sound (340 m/s), and f is frequency in Hz.

Since 1 ft = 30.48 cm, then from 20 Hz to a few hundred Hz, the wavelengths are over a foot. At $f = 1.115483$ kHz, then $\lambda = 1$ ft, so the 1-foot diameter horn presented here should be quite directive at that frequency. Figure 7 shows additional directivity patterns, but not for explicit frequencies. Note that those patterns are for various mouth sizes relative to wavelength. As the ratio of mouth size to wavelength increases, so does directivity. Another way to achieve higher directivity is to increase horn length for a given mouth size. As shown in Fig. 8, to achieve this, the horn angle α must be reduced.

FIG. 7—AS HORN MOUTH SIZE increases relative to wavelength, directivity increases, since audio wavelength is comparable to mouth size. Shown are directional patterns of decreasing beamwidth, for four horn diameters relative to λ.

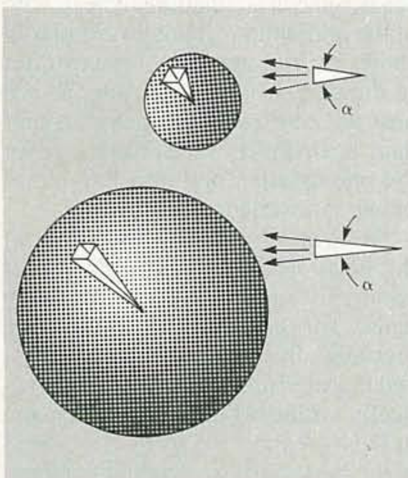


FIG. 8—ANOTHER WAY TO ACHIEVE directivity in a horn microphone is to increase length versus mouth size, requiring that horn angle α be reduced.

Horns of different shapes are commonly used as loudspeakers, with the exponential, hyperbolic, and conical versions the most common, in that order. Horns are uniquely able to transform and match acoustic impedances. The horn loudspeaker is an acoustic transformer, changing large pressures and small volume currents in the throat to small pressures and large volume currents in its mouth; horn microphones do the reverse.

As shown in Fig. 9, the conical horn has a gradual impedance-transformation curve as cutoff frequency is approached, with a smooth transition from a high-directivity pattern to one of lower directivity. Such smooth transitions are more desirable than the abrupt low-frequency cutoff of both exponential and hyperbolic horns.

In the horn of Fig. 6-*a*, the transition from square horn to receptor is smoothed into a cone using modeling clay. At the higher audio frequencies, the conical walls reflect the short wavelengths (a few inches or less) down to the microphone diaphragm, helping to optimize high-end audio directivity for a narrower beamwidth.

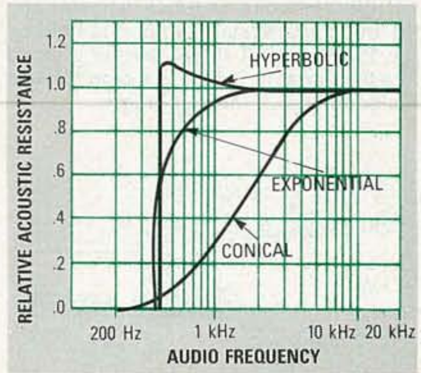


FIG. 9—RELATIVE ACOUSTIC resistance for several horn microphones of size and bandwidth similar to Fig. 6. Each works just as well as a loudspeaker by reciprocity, with the exponential, hyperbolic, and conical the most common.

Construction

The horn presented here can be made using low-cost materials and a little time. Because sound pressure waves exert low force, light-weight materials can be used. Figure 10 shows the prototype, made from cor-

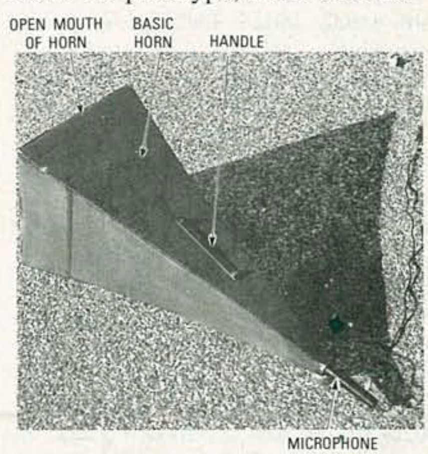


FIG. 10—THE PROTOTYPE HORN WAS made from corrugated cardboard; a removable extension with larger mouth and a carrying handle was added. At high audio frequencies, the walls reflect short wavelengths of a few inches or less to the diaphragm, to optimize directivity.

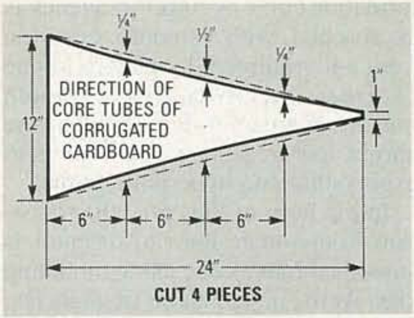


FIG. 11—HERE'S THE CUTOUT FOR ONE side of the basic horn; note the direction of the corrugated ribs. The edges have slight curvature so the sides have added strength, and don't resonate easily. The edges were taped, and paper glue was used on the inner and outer corners. The small end was cut to a 1-inch diameter, and the microphone slides in and is held by the four sides. A metal washer slipped into the throat face acts as a stop, yet lets the sound reach the diaphragm.

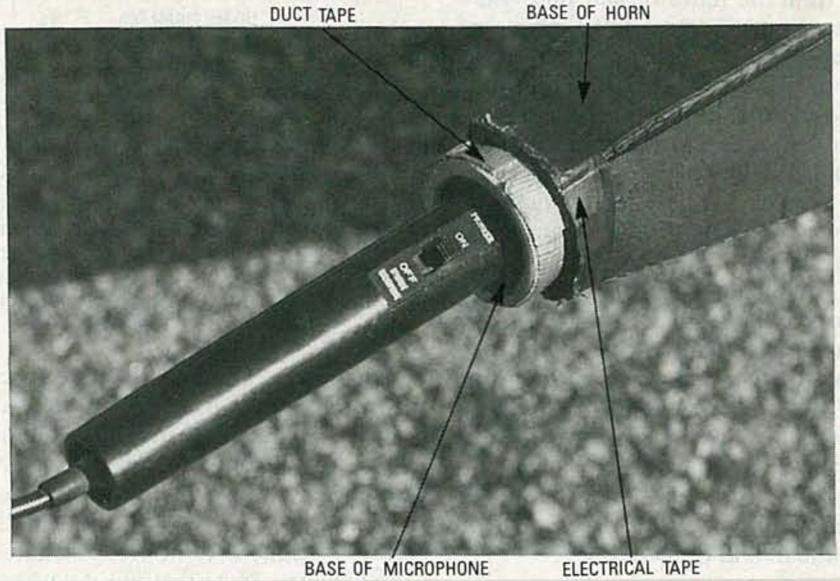


FIG. 13—A CLOSE-UP VIEW OF THE EXTERIOR of the neck. The carboard is tapered, producing an opening of proper size for the microphone, and the microphone is inserted. Note the silvery ring at the base of the horn, just behind the base of the horn. The bottom of the microphone protrudes from the base of the horn, and was sealed mechanically and acoustically with duct tape, while the base of the horn was stiffened with electrical tape.

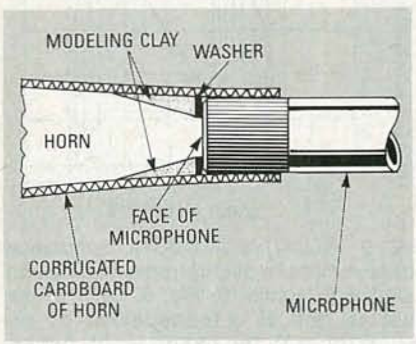


FIG. 12—WHEN MOUNTING THE microphone in the horn, the washer aperture should be at least 75% of the diaphragm diameter. The modeling clay smoothed the transition from the square horn to the washer opening, so that the sound wasn't restricted from reaching the diaphragm.

rugated cardboard, cut to the correct size and glued together, with a carrying handle added. The horn was constructed, assembled, and tested; then, a removable extension was added to gauge the benefits of a larger mouth.

The basic horn was built with four sides from the pattern in Fig. 11. The edges have slight curvature for additional strength, so they won't resonate easily. The edges were taped enough to hold them in place, and simple white paper glue was applied to both the outside and inside corners. The small end was cut to a 1-inch diameter, letting the microphone slide in and be held by the four cardboard sides. A metal washer slipped into the throat against the microphone face acts as a position stop, while letting the sound reach the diaphragm.

As Fig. 12 shows, modeling clay smoothed the transition from the square horn to the round washer opening, so the sound wasn't prevented from reaching the diaphragm. The washer needs an opening at least 75% of the microphone diameter. Figure 13 shows a close-up view of the exterior of the neck of the horn. You can see how the cardboard is tapered to produce an opening of the proper size for the microphone, and how the microphone is inserted.

Note the silvery ring at the base of the horn in Fig. 13, just in front of where the microphone apparently ends. The base of the microphone protrudes from the base of the horn, and is sealed mechanically and acoustically with duct tape. The extension in Figs. 14 and 15 slips over the front of the basic horn, to extend the length and expand the mouth, and two 1/4-20 screws with washers hold both sections together.

By adding the extension, the mouth was increased in size from 1 × 1 ft to 2 × 2 ft, quadrupling the area. Also, the new size is one wavelength across at $f = 557.742$ Hz, matching wavelengths down to lower audio frequencies and increasing directivity beyond that of the basic horn alone. The larger diameter and greater total area improves pick-up, raising the theoretical pressure level by 3 dB. In practice, the horn picks up more at lower frequencies because the impedance matching at those frequencies is improved.

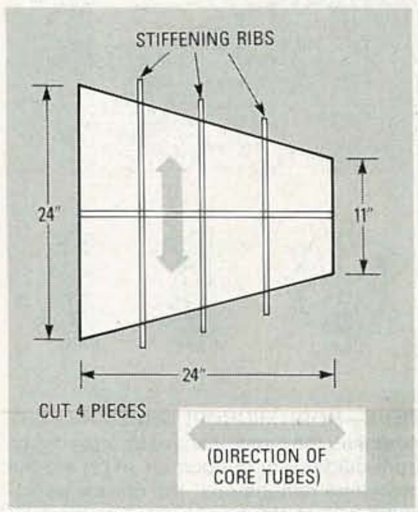


FIG. 14—HORN EXTENSION CUTOUT; the ribs stiffen the cardboard. The extension slips over the horn, extending its length and expanding its mouth, and two 1/4-20 screws with washers hold both together. The mouth is now 2 × 2 ft, one wavelength across at $f = 557.742$ Hz, matching wavelengths down to lower audio frequencies, improving directivity, raising the pressure level by 3 dB, and providing better low-frequency pick-up, since impedance matching is improved.

Testing

The preliminary tests were conducted at a large parking lot at a local beach. In actual use, aim the horn in the direction of the desired sound, and plug the microphone into a tape recorder, allowing playback later on. In evaluating the prototype, all tests were recorded to allow detailed sound pressure evaluation of an individual

(Continued on page 52)

Build the Lawn Ranger

This month we discuss the motor-controller board.

Raymond Rafaels

LAST MONTH WE INTRODUCED YOU TO THE LAWN RANGER, THE world's first personal robotic lawn mower. For those of you who missed last month's issue, the Lawn Ranger is a computerized robot that can cut grass by itself. All you have to do is cut a boundary around the perimeter of your yard and around any obstacles using the manual controller, switch the mower to automatic, and watch in amazement as it completes the job.

Control system

Let's quickly review the block diagram of the electronic control system shown in Fig. 1. The grass-sensor assembly is used to detect the position of cut and uncut grass that lies beneath the Lawn Ranger. That information is amplified on the motor-controller board and then forwarded to the *C*entral *P*rocessing *U*nit (CPU). The CPU will calculate the steering direction and send it to the motor-controller board. The motor-controller and power-switching circuitry will steer the robot in the direction defined by the CPU by varying the speed of the rear drive wheels. If the right wheel is made to spin faster than the left wheel, the robot will steer to the left—just as a tank works.

Motor-controller board

Figure 2 shows a block diagram of the motor-controller board, which is used to control the speed of each drive wheel and to amplify the grass-sensor signals. The motor-speed control circuitry contained on the board is designed to increase or decrease power to the drive motors based upon the drive motor's actual speed. The circuitry has three major sections: the D/A converter, velocity-feedback loops, and *P*ulse-*W*idth *M*odulators (PWM).

The D/A converter converts the Z80 microprocessor's digital steering command into an analog voltage. The D/A converter, hand-held manual controller, and speed-set adjustment provide steering reference signals to the velocity-feedback loops.

There are two feedback loops: one for the right wheel, and one for the left. The loops are designed to "lock on" to the reference-signal input and provide a constant motor speed. The D/A and the manual-controller outputs are designed to slow down the left or right wheel for steering purposes. When the robot is steering straight, the D/A and manual-control outputs will be zero and both drive wheels will spin at the same speed. If the actual wheel speed (from the velocity-feedback signal) is equal to the desired wheel speed, the error voltage will be zero. When the wheel speed is too slow, the velocity-feedback signal will cause the error voltage (reference input minus the feedback) to increase and additional power will be delivered to the drive motors. If the wheel speed is too

Lawn Ranger is a registered trademark of Technical Solutions, Inc.

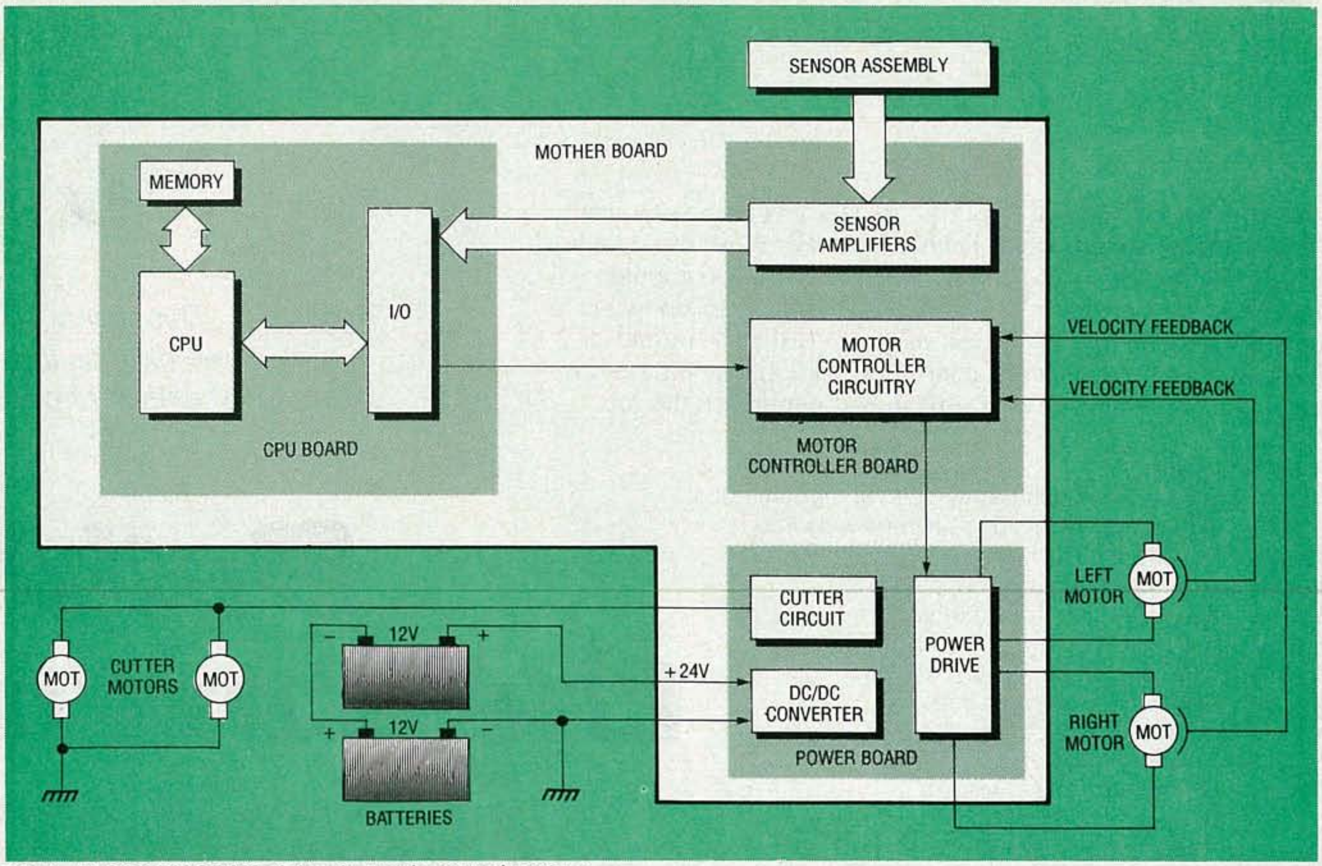


FIG. 1—BLOCK DIAGRAM of the electronic control system.

fast, the velocity-feedback signal will cause the error voltage to decrease and less power will be delivered to the drive motors.

The PWM circuitry is used to achieve high-efficiency power amplification. The technique allows the +24-volt supply to be switched (applied and then removed) from the drive motors for the sake of increased efficiency. The "on" and "off" times are precisely controlled and the effect on the motors is the same as if a lower voltage were continuously applied to them.

PARTS LIST

MOTOR-CONTROLLER

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

R1, R93—two 16-ohm, 1-watt resistors in parallel
R2, R16, R28, R41—22,000 ohms
R3, R17, R21, R25, R43, R55, R56, R59, R60, R73, R83, R86, R90—100,000 ohms
R4, R5, R18, R19—2200 ohms
R6, R30, R38, R39, R44, R45, R47, R50, R108, R110, R112, R115—1 megohm
R7—806,000 ohms, 1%
R8—402,000 ohms, 1%
R9, R26, R27, R52—200,000 ohms, 1%
R10—150,000 ohms
R11, R23, R46, R53, R54, R62, R65, R69, R72, R75, R78, R79, R84, R89—10,000 ohms
R12—499,000 ohms, 1%
R13—180,000 ohms
R14—604,000 ohms, 1%
R15—4500 ohms, 1%
R20—2.7 megohms
R22, R36, R48—220,000 ohms
R24—82,000 ohms
R29—680,000 ohms
R31–R35, R37, R104–R106, R117–R200—not used
R40, R42—68,000 ohms
R49—820,000 ohms
R51, R57, R109, R111, R113, R114, R116—8200 ohms
R58, R61—39,000 ohms
R63, R64, R81, R82, R94—1000 ohms, 1%
R66, R68, R74, R87—270 ohms
R67, R70, R77, R80—3300 ohms
R71, R76, R85, R88—2700 ohms (with 0.1 μF capacitor in parallel, see text)
R91, R92, R107—jumper
R95, R98, R102—3900 ohms, 8-pin SIP resistor network
R96, R97, R99–R101, R103—2200 ohms, 8-pin SIP resistor network
R201, R202—2000 ohms, potentiometer
R203—10,000 ohms, potentiometer

Capacitors

C1, C5, C7, C10, C11, C16, C18–C21, C26, C42, C47–C51—0.1 μF, 50 volts
C2, C4, C8, C15, C43–C45—0.01 μF, 25 volts, disc
C3, C9, C27–C41—1 μF, 35 volts, electrolytic
C6, C17, C46—100 μF, 35 volts, electrolytic
C12–C14, C22—0.002 μF, 25 volts
C23–C25—10 μF, 16 volts, electrolytic

Semiconductors

IC1, IC12–IC14—74LS14N hex inverter
IC2—74LS74N D-type latch
IC3, IC11—not used
IC4, IC7—LM324 op amp
IC5, IC6—LM2907N-8 frequency-to-voltage converter
IC8—LF13202 analog switch
IC9, IC10—UC3637N pulse-width modulator
IC15, IC18—LM339 comparator

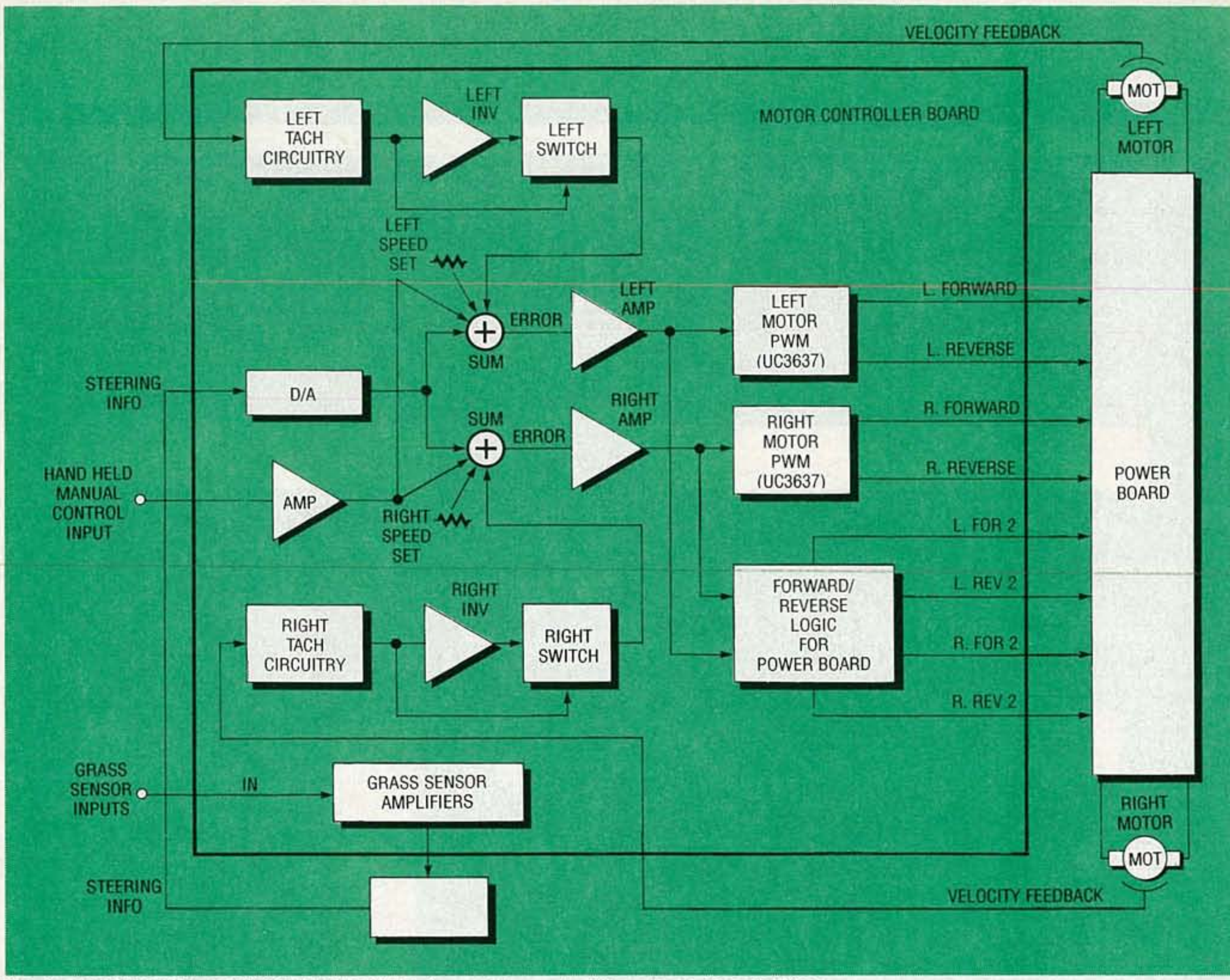


FIG. 2—THE MOTOR-CONTROLLER BOARD is used to control the speed of each drive wheel and to amplify the grass-sensor signals.

IC16, IC17—ULN2081A transistor array
IC19, IC20—OPB822S dual opto module
D1–D3, D6–D11, D13, D15, D17, D20–D22—1N4148 diode
D4, D5, D12, D14, D16, D18, D19—not used
Q2, Q3, Q5, Q6, Q8, Q9, Q11–Q16—2N3904 transistor
Q1, Q4, Q7, Q10—2N3906 transistor

Other components

J1—20-pin IDC connector
J2—not used
J3—10-pin IDC connector
J4—16-pin IDC connector

Miscellaneous: PC board, IC sockets (two 8-pin, nine 14-pin, three 16-pin, and two 18-pin), jumper wire, solder, etc.

MOTHERBOARD

PC board; P21, P23—44-pin edge connector; P22—50-pin edge connector

Note: The following items can be purchased from Technical Solutions, Inc., P.O. Box 284, Damascus, MD 20872 (301) 253-4933: PC boards for the CPU, motor-controller, power board, and motherboard, $39 each; programmed EPROM, $39 (contains computer program and firmware license); grass sensors, $8.99 each; hand-held manual controller kit, $39; full CPU-board kit, $129 (includes EPROM, PC board, and all parts); full kit for motherboard, $69 (contains PC board and all parts); kit for power board, $149 (contains PC board and all parts except DC/DC converters); full kit for motor-controller board, $169 (contains PC board and all parts); Lawn Ranger demo VHS tape, $19 (refundable for orders of $100 or more). Please add $8 for S/H (U.S. orders). Maryland residents add sales tax.

D/A converter

Figure 3 shows a detailed schematic diagram of the motor-controller board. The D/A circuit uses op-amp IC4-b, which is basically an inverting summing amplifier that adds the voltages from data bits DA0–DA5. The lower the amplifier input resistance, the higher the gain for that particular data bit line. The resistance (and gain) used to couple the six data lines to the input of the summing amplifier will vary by a factor of two. For instance, the resistance at DA0 (R12 and R20) will be twice as large as the resistance at DA1 (R6 and R14), which will be twice as large as DA2 (R7), etc. That allows the magnitudes of each binary number to be properly weighted with respect to each other. A small bias voltage is applied through R13 and R203 into the summing junction to force the D/A output to swing both positive and negative. Potentiometer R203 will adjust the level of the D/A

Text continued on page 71

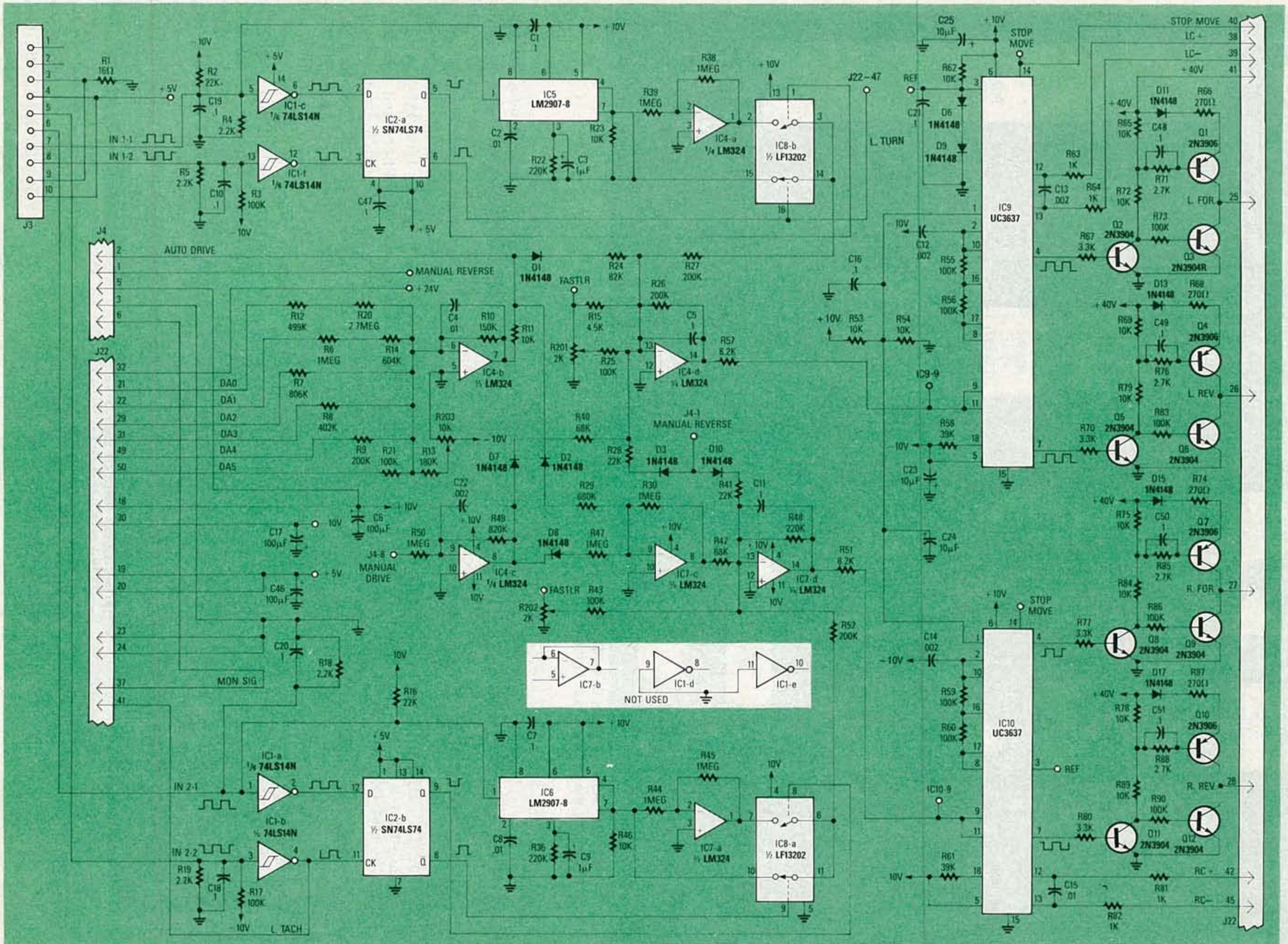


FIG. 3—PARTIAL SCHEMATIC DIAGRAM of the motor-controller board.

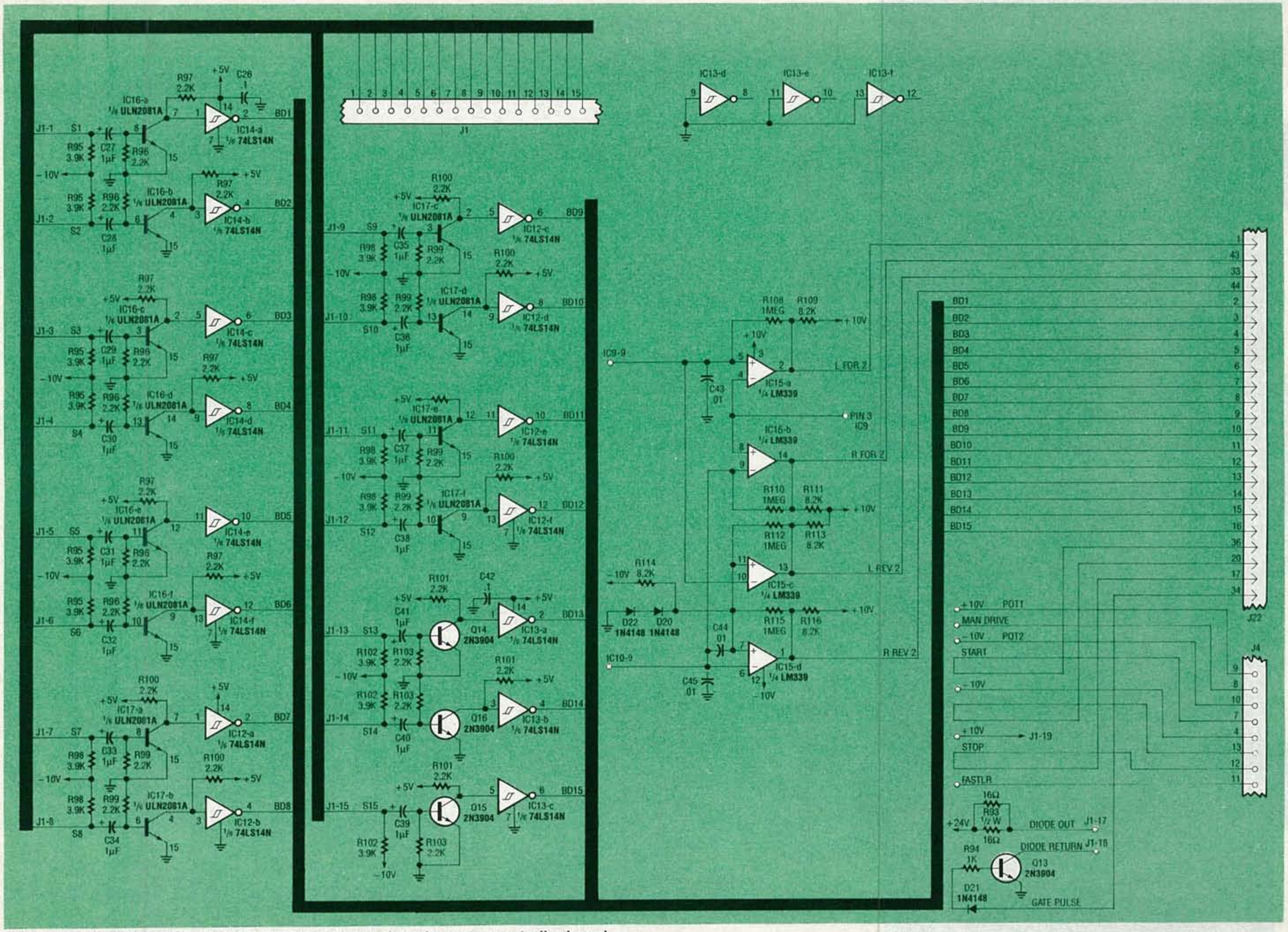
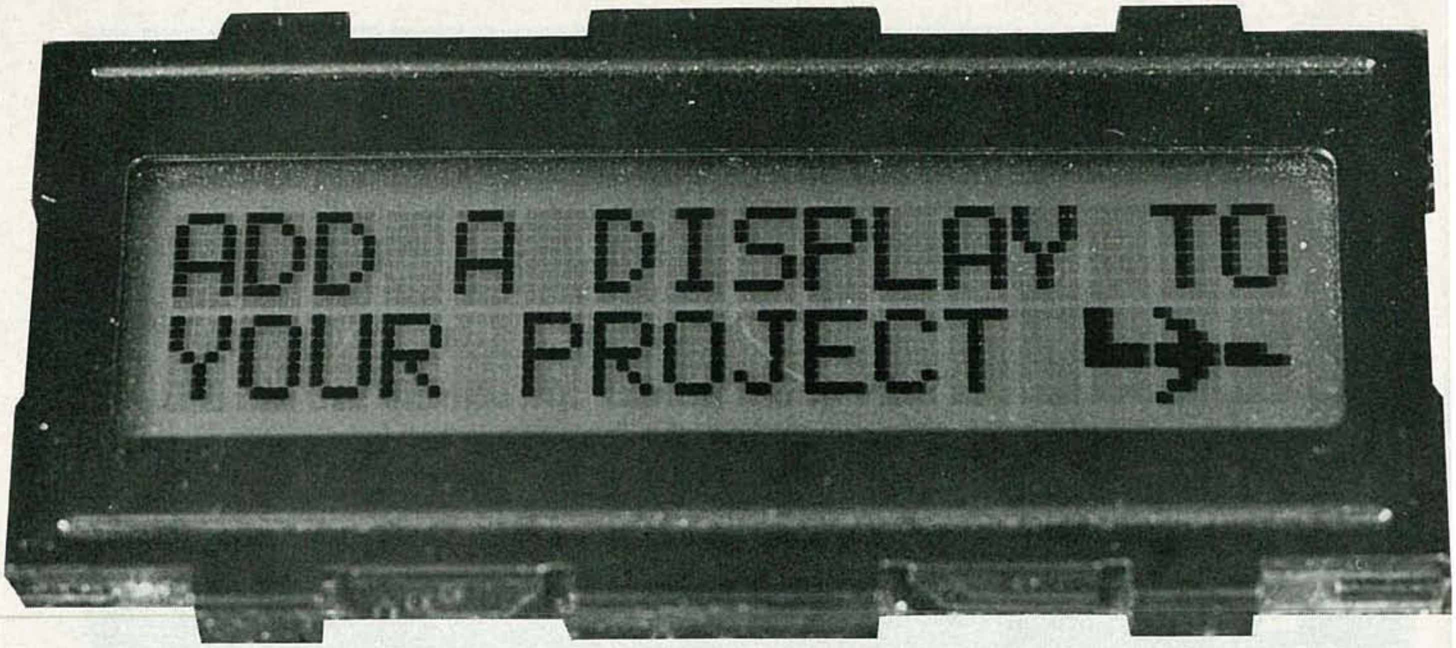


FIG. 4—THE GRASS-SENSOR AMPLIFIERS are located on the motor controller board.



Add a Display to Your Project

The days of LED indicators and segmented displays are numbered. Now you can add an alpha-numeric LCD to your home project easily and inexpensively.

STEVEN AVRITCH

LAST MONTH WE BEGAN OUR DISCUSSION on alpha-numeric LCD's, and showed you how to use them in your own designs. We showed you how they can eliminate components and interconnections when used instead of 7-segment displays. Let's finish up now, so that you can actually use one in your next project.

Last month

Before we begin, though, there is something from the first half of this article (**Radio-Electronics**, June 1990), that should be pointed out. At the end of the story, we had said that once the display has been properly initialized, the ASCII codes must be written to the display with a series of Data Write operations. We told you that the "SET DD RAM ADDRESS" command must precede the data operations to ensure that the data goes to DD RAM and not CG RAM, and that data writes to CG RAM must be preceded by a "SET CG RAM ADDRESS" command. As an example, we said that the routine in Listing 6 would display the message "PLANE," assuming that the user-defined Character Generator RAM was set up as defined in Listing 5. Well, Listing 5 did appear in that article, but Listing 6 never made it to print. We have therefore put Listing 6 in this second half of the article, shown below.

Hardware interface

There are a variety of ways to interface an LCD module to a host processor or microcontroller. A microcontroller such as a Motorola MC68705 (see **Radio-Electronics**, September 1989, for information on the MC68705) is easy to interface with because it has port pins that can be dedicated to the LCD module. A processor that does not have dedicated port pins requires a small amount of additional decode logic in order to establish the LCD module as an I/O device.

LCD modules with an on-board HD44780 LCD controller chip have two hardware interface modes: a 4-bit mode and an 8-bit mode. In the 4-bit mode, each data byte is transferred to the LCD module with two write operations. The 4-bit mode utilizes only

LISTING 6

```
JSR   INIT      INITIALIZE DISPLAY
LDA   #$80      SET UP FOR DD RAM WRITES
JSR   CONTROL
LDA   #$02      RETURN DIPLAY TO HOME POSITION
JSR   CONTROL
LDA   'P'     \
JSR   DISLET   \
LDA   'L'       \
JSR   DISLET     \
LDA   'A'         \
JSR   DISLET       \   LOAD AND DISPLAY EACH LETTER
LDA   'N'          /   OF THE WORD  'PLANE '
JSR   DISLET      /
LDA   'E'        /
JSR   DISLET    /
LDA   ' '      /
JSR   DISLET  /
LDA   #$02         ASCII CODE FOR AIRPLANE TAIL SECTION
JSR   DISLET
LDA   #$01         ASCII CODE FOR AIRPLANE BODY SECTION
JSR   DISLET
LDA   #$00         ASCII CODE FOR AIRPLANE NOSE SECTION
JSR   DISLET
```

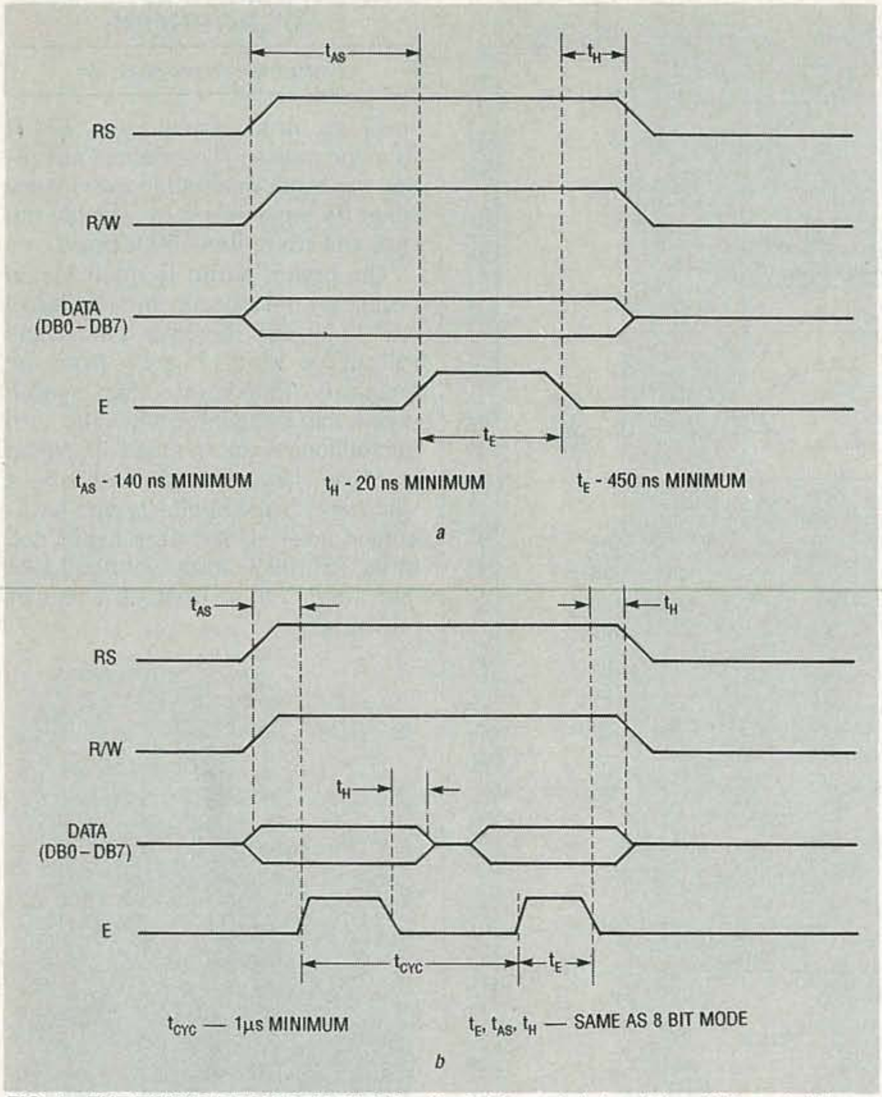


FIG. 4—THE TIMING REQUIREMENTS for the 8-bit mode (*a*) and the 4-bit mode (*b*).

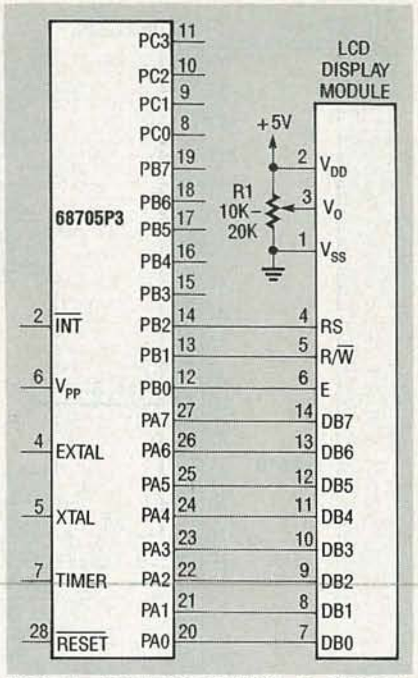


FIG. 5—TO INTERFACE A MICROCONTROLLER to a HD44780-based LCD module, simply connect the control and data lines of the module directly to the port pins of the microcontroller.

the upper four data-bus lines (DB4–DB7). In the 8-bit mode, data bytes are transferred with a single write operation which saves time by using all eight data-bus lines (DB0–DB7). The only advantage to using the 4-bit interface mode is a saving of four data-bus lines. The 8-bit mode is slightly easier to interface with (with respect to software), so you should therefore use the 8-bit mode unless the project that you've designed uses a microcontroller that has a limited number of available port pins. Figure 4 shows the timing requirements for both the 8- and 4-bit mode.

ORDERING INFORMATION

The following items are available from Simple Design Implementations (SDI), P.O. Box 9303, Forestville, CT 06010 (203) 582-8526: Experimenter's kit (contains 16 × 1 OPTREX LCD module, programmed MC68705P3, contrast-control potentiometer, PC board, IC socket, software listings, schematic, and instructions), $29.95 + $3 S/H; Same experimenter's kit with 40 × 1 display, $39.95 + $3 S/H; Programmed MC68705P3 and instructions, $15.95 + $2.50 S/H.

Microcontroller interface

Interfacing a microcontroller to a HD44780-based LCD module is as simple as connecting the control and data lines of the module directly to the port pins of the microcontroller as shown in Fig. 5. Note that R1 is the contrast-control potentiometer for the display.

Microprocessor interface

Interfacing the HD44780-based LCD module to a processor (such as the Zilog Z80 8-bit CPU) requires some additional logic as shown in Fig. 6. That logic establishes the LCD module as being an I/O device in addition to providing the required setup time on the RS line (The RS line must be stable for 140 nanoseconds before the ENABLE line is strobed). In that configuration, the LCD module is accessed using "IN" and "OUT" instructions for reads and writes respectively. Data operations are distinguished from control operations by the address of the I/O operation with address 00 (hex) being a control operation and address 01 (hex) being a data operation. The I/O address of the LCD module can be changed very easily by changing the chip-select decode logic.

Sample project

The prototype display module has been incorporated into an automated check list for airplane pilots. The check-list project uses an MC68HC701 (similar to the MC68705) for the host microcontroller, a series of pushbutton switches for scrolling up and down the check lists, and a small beeper that sounds every time a button is pressed. The LCD is 16 characters wide by 2 lines for a total of 32 characters. Since the current draw of the LCD was less than the load ca-

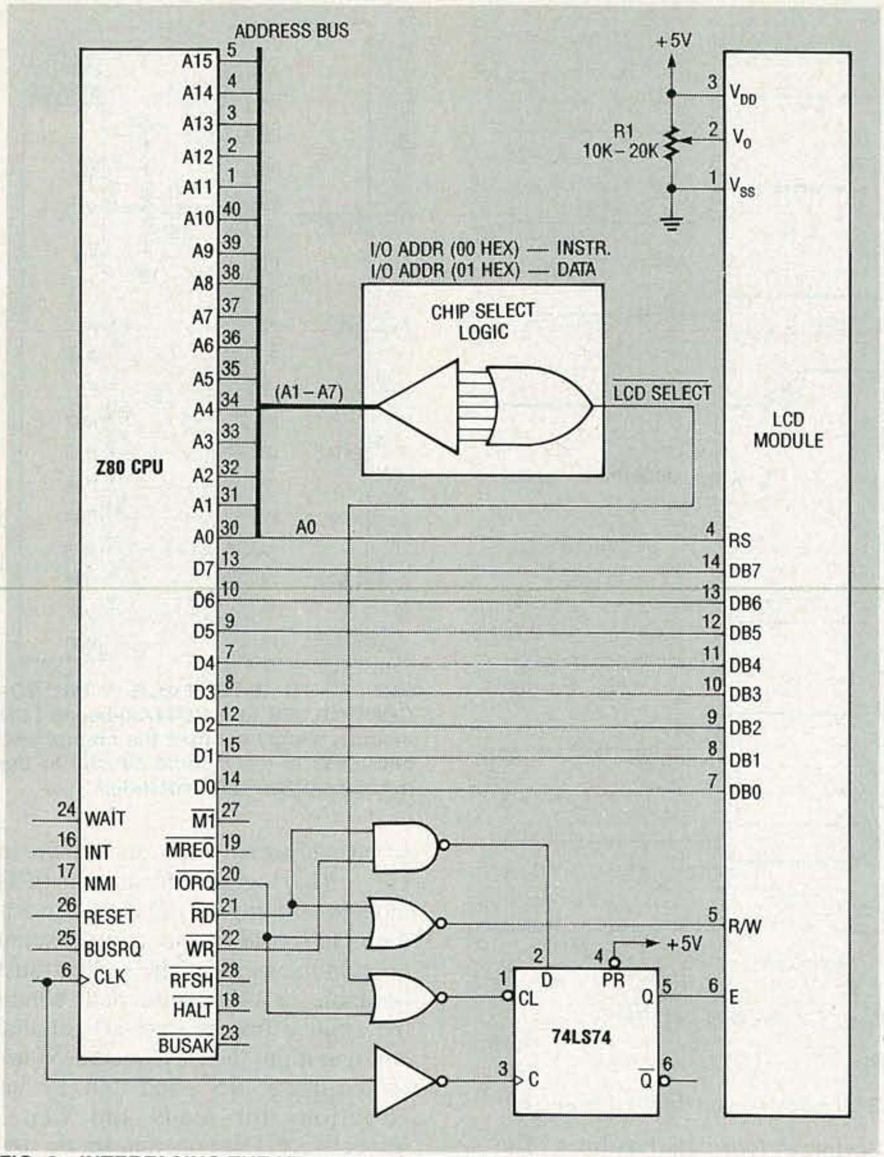


FIG. 6—INTERFACING THE HD44780-BASED LCD module to a microprocessor requires some additional logic.

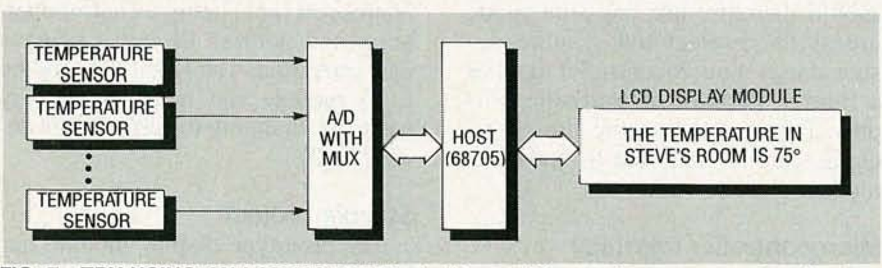


FIG. 7—TRY USING AN LCD MODULE to build a multi-zone thermometer that displays temperatures throughout your house with your own custom messages.

pability of the port pins of the microcontroller, the LCD is powered directly from a port pin of the microcontroller. That allows the convenient feature of letting the microcontroller power down the display when it's not needed in order to conserve battery power. It should be noted that the entire design uses fewer than thirty interconnecting wires.

As a suggestion for your own project using an LCD module, why don't you try to build a multi-zone thermometer that displays temperatures throughout your house with simple, non-cryptic messages. For example, you could display "THE TEMPERATURE IN STEVE'S ROOM IS 72°." A block diagram of such a project is shown in Fig. 7. **R-E**

MICROPHONE

continued from page 44

speaking, in a normal voice, 100 ft from the mouth. The resultant recording was quite intelligible even above seagulls squawking overhead, the surf, and car noises 500 ft away.

The higher audio frequencies so necessary for speech intelligibility tend to be very directive. Noticeable roll-off occurred 5° away from the main axis of the horn; in fact, speech wasn't understandable when the horn microphone wasn't pointed directly at someone. Beyond 10–15° off-axis, a voice vanished completely into background noise. However, seagulls and birds 75–100 ft away sounded like they were 2 ft in front of a regular microphone.

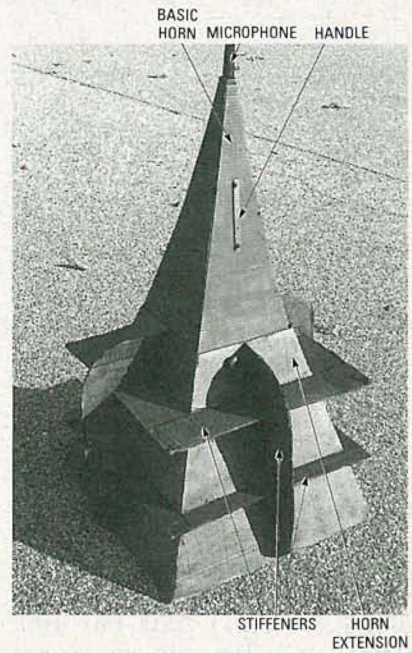
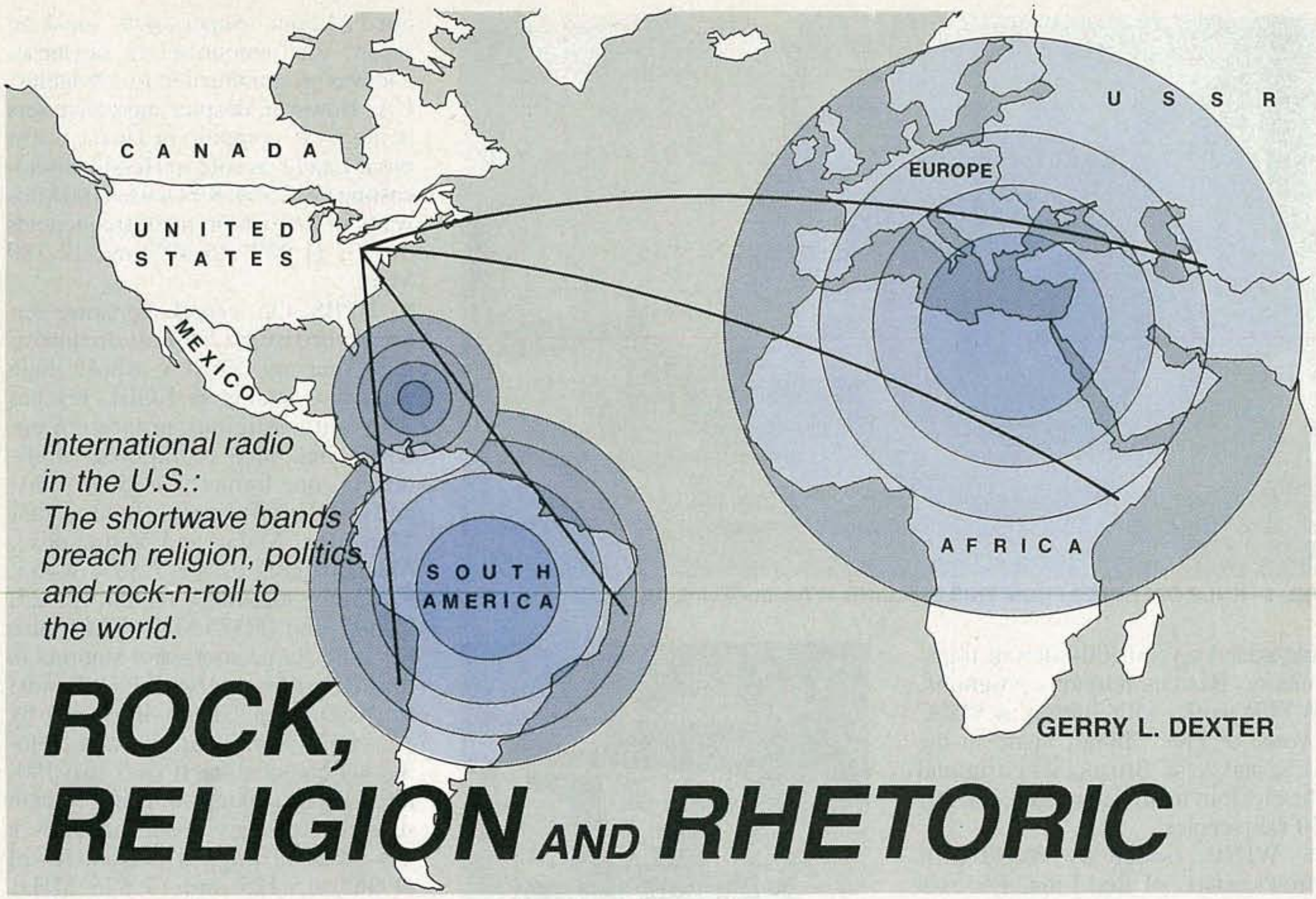


FIG. 15—HERE'S THE COMPLETED HORN MICROPHONE. At the top is the receptor microphone, then comes the basic horn, and lastly, the horn extension is shown with its support ribs.

Surprisingly, the extension didn't really improve directivity, and apparently wasn't worth the effort, given the time and effort needed, as well as its size. Frequency response tests with polar pattern measurements would be needed for verification of this, and to optimize the extension performance. However, recording bird calls and animal sounds is a perfect application for this horn, since both the horn and extension are small enough for field use, and give excellent performance over the full audio range. **R-E**



International radio in the U.S.: The shortwave bands preach religion, politics, and rock-n-roll to the world.

ROCK, RELIGION AND RHETORIC

GERRY L. DEXTER

PRIVATE U.S. SHORTWAVE BROADCASTERS are a pretty select group. Out of a total of over 10,000 private broadcasters under FCC control, only about 15 of them use shortwave, or the *H*igh *F*requency (HF) range from 2 MHz–30 MHz. However, while this overall number may seem small, the 1980's witnessed a 500% increase in U.S. shortwave stations, which is an outstanding growth rate.

In the 1930's, when radio had the potential and excitement that cable and satellite TV offer today, many U.S. broadcasters like GE, Westinghouse, and the major radio networks tried shortwave HF, in addition to AM. The potential U.S. audience was sizable because many old floor-standing living-room radios included shortwave bands. As shortwave radio developed, so did the potential audience for it.

Then, however, came World War II. The government soon recognized the obvious need for an international voice to combat Axis propaganda. There was no time to wait for facilities to be built, so the government nationalized private shortwave stations for the first *V*oice *O*f *A*merica (VOA) broadcasts.

In 1948, a new law governing U.S. shortwave broadcasting made the VOA a permanent government entity, but encouraged private broadcasting by forbidding a government monopoly on radio, and particularly shortwave. The law let the VOA lease private shortwave stations from NBC and Crosley Broadcasting; this practice continued until about 1960, when the VOA shortwave station in Greenville, NC was finished. As private leases expired, however, nearly all private firms opted to get out of the shortwave broadcasting business.

The postwar U.S. shortwave audience dropped drastically, mainly due to the popularity of television, and the elimination of shortwave bands on postwar home receivers. By 1960, the only two remaining private broadcasters were WRUL and KGEI, although WINB was added in 1963. That year, the FCC froze further applications for shortwave station licenses, until new rules could be written to account for changes in international shortwave broadcasting regulations.

That took 10 years, but afterward, four years elapsed before KTWR began broadcasting from Guam, which went unnoticed. The first major change came in 1982, when WRNO Worldwide, of New Orleans, LA, began broadcasting, after which the FCC found itself granting licenses at an increasing rate fast. Here's a capsule look at the current private U.S. shortwave broadcasters:

- KGEI, of Redwood City, San Francisco, CA, was owned by GE for several years, then sold to Far East Broadcasting Company, a worldwide religious group. KGEI, "The Voice of Friendship," transmits mainly in Spanish to Latin America. It runs 50 and 250 kilowatts on 6.010, 6.075, 6.095, 6.150, 7.365, 9.615 and 15.280 Megahertz.
- WYFR, owned by Family Stations, Inc., of Oakland, CA, a large religious group, can trace its history back to WRUL of Massachusetts in the 1930's. The "Voice of Freedom" for the VOA in World War II, it moved to NY City and worked with the anti-Castro movement in the early 1960's. It was owned by CBS, the Mormon Church, and was WNYW (Radio NY Worldwide) for years. Family Stations bought it in 1972, changed to WYFR (Your Family Radio), closed WRUL, moved to Okeechobee, FL,

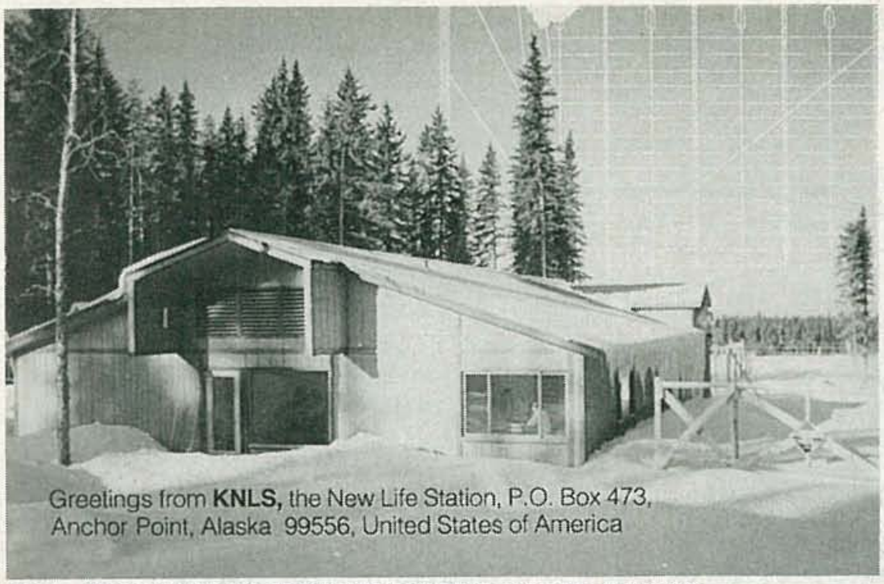


FIG. 1—KNLS OPERATES FROM THIS BUILDING at Anchor Point, AK.

and added several 100-kilowatt transmitters. Besides religious programs, WYFR works with Taiwan as VOFC (Voice of Free China), heard in the U.S. and Asia. Broadcasts go around the clock in many languages, on over 50 frequencies.

• WINB, owned by World Intl. Broadcasters, of Red Lion, PA, is a religious shortwave station. It uses 50 kilowatts, covering North Africa, Latin America, Western Europe, and the Mediterranean, in several languages, and broadcasts run 11 hours a day on 15.145, 15.150 and 15.185 MHz, and other frequencies.

• KTWR, on Guam, is run by Trans World Radio, a worldwide religious organization started in the 1950's. It has four 100-kilowatt transmitters covering China, Indonesia, India, Japan, SE Asia, and parts of the USSR. Trans World also has shortwave stations in Monaco, Swaziland, and Bonaire in the Dutch Antilles. KTWR airs in English and 10 other languages; English frequencies include 9.590 and 11.805 MHz.

• WRNO (Rock of New Orleans) is owned by Joseph Costello III, of New Orleans, LA, who also owns affiliated AM/FM stations there. Its early programs had FM simulcasts, but it's separate now and has some 40 religious programs, including rock, pop, New Orleans Saints football, and other sports. WRNO showed up in audience surveys halfway across the U.S., too far away to have been the AM station. It uses two 100-kilowatt transmitters, programs are nearly all English, and the main frequencies are

FIG. 2—PART OF THE TRANSMITTING FACILITY at WHRI in Nobelsville, IN.

FIG. 3—A CONTROL ROOM OPERATOR INSPECTING broadcast equipment at KUSW, in Salt Lake City, UT.

6.185, 9.495, 11.965, 13.760 and 15.420 MHz.

• KYOI, owned by Marcom, Inc., on Saipan in the U.S. Northern Marianas Islands, wasn't as successful. It aired 24-hour "Super Rock" music to Japan, was announced in Japanese, and was programmed in Los Angeles, CA. However, despite shortwave sets being fairly common in Japan, it lost money and was sold to Herald Broadcasting (WCSN). KYOI uses 100 kilowatts in English on main frequencies 9.670, 11.900, 15.405 and 17.780 MHz.

• KFBS, the second shortwave station owned by the *F*ar *E*ast *B*roadcasting *C*ompany (FEBC), whose main shortwave station is KGEI, reaches Asia with religious programming. KFBS has three 100-kilowatt transmitters, one formerly used by VOA, and airs in Burmese, Indonesian, Mandarin, Malay and Vietnamese. Main frequencies are 7.365, 9.465, 9.575, 9.830, 9.840, 11.980, 12.025, 15.305, and 15.375 MHz. FEBC also has other large shortwave stations in the Philippines and Seychelle Islands.

• KSDA, on Guam, is owned by Adventist World Radio, another religious broadcaster. It uses two 100-kilowatt transmitters, aimed at Asia in several languages about 20 hours a day on main English frequencies of 11.965, 15.125 and 17.685 MHz. There are smaller shortwave stations in Italy, Guatemala, and Costa Rica.

• KNLS (New Life Station), owned by World Christian Broadcasting, of Texas, started in 1983 from Anchor Point, AK, after two staff members were killed in a plane crash, and an arsonist burned down the 100-kilowatt transmitter. Main frequencies are 6.095, 7.355, 9.535, 9.750, 9.870, 11.700, 11,820, 11.960, 11.930 and 11.980 MHz. KNLS airs to Asia in Chinese, Japanese, English and Russian, but hasn't reached Europe due to severe HF absorption and refraction at the North Pole. This occurs during solar events like aurora, sunspots, proton events, or geomagnetic substorms, which expands the ionosphere. The bottom moves closer to the Earth, the top elevates, and the charged particle density increases, degrading HF propagation. A picture of the station from a listener-confirmation card is shown in Fig. 1.

• WMLK is run by the Assemblies of Yaweh, Bethel, PA, a religious group that took two years to convert an old 50-kilowatt AM transmitter to shortwave. They transmit a few hours a day on 9.455 MHz from a converted gas station. Programming focuses on the premise that salvation awaits only those who worship God by the Old Testament name, Yaweh. The station call sign is a contraction of "Malek," or "Messenger."

- WHRI (World Harvest Radio), of South Bend, IN, is owned by LeSea Broadcasting, part of Lester Sumrall ministries. They also have AM/FM and TV operations, and were badly damaged by fire last year. However, WHRI missed minimal air time, as broadcasts were switched to a standby transmitter in Nobelsville, IN. There are two 100-kilowatt transmitters aimed at Latin America, the Middle East, and North Africa, on 6.100, 6.155, 7.355, 7.400, 9.455, 9.745, 9.765, 9.770, 11.770, 11.790, 11.980, 15.105 and 17.830 MHz. LeSea has several TV stations and a satellite uplink transmitter. Figure 2 shows an operator working on part of the transmitting facility at the station.
- KVOH (Voice of Hope), in Christian Southern Lebanon, is owned by High Adventure Ministries in California, and got started literally under the gun. Broadcasting has continued for several years, despite a rocket attack that destroyed the studios. They recently started KVOH from Rancho Simi, CA, in English and Spanish for the Americas using 50 kilowatts on 9.495 or 17.775 MHz. Their next project is to transmit from the Phillipines to China.
- KUSW, of Salt Lake City, UT, is one of only two commercial U.S. shortwave broadcasters. It's part of Carlson Communications, which owns an AM/FM outlet there, and several others in the western U.S. KUSW runs a pop format, and runs several commercials, though really big accounts like Coca-Cola haven't yet been obtained. KUSW airs 18 hours a day on 5.980, 6.010, 6.185, 9.852, 11.980, 15.225, 15.580 and 17.715 MHz. Figure 3 shows a control room operator inspecting broadcast equipment at the station, and Fig. 4 shows the transmitting towers there.
- WCSN (Christian Science Network), of Scotts Corner, ME, is owned by Herald Broadcasting, part of Christian Science Monitor. It airs a two-hour English news/features segment several times a day around the world. On weekends, the program is the "Herald of Christian Science" in English, French and German. WCSN runs 500 kilowatts on 7.365, 9.465, 9.852, 15.280, 17.640 and 21.515 MHz. As noted earlier, WCSN bought KYOI, which now carries WCSN via satellite. Next year, WCSN will add WSHB in South Carolina, with a pair of 500-kilowatt transmitters aimed at Latin America.
- WWCR (Worldwide Christian Radio), of Nashville, TN, is a new religious broadcaster that may be starting up any time, perhaps by the time you read this. WWCR will be part of a multi-station group of AM/FM outlets in the south, and will have a 100-kilowatt transmitter, and sell program time to churches, other religious groups, and maybe even political groups or other stations that can't reach North America.

In contrast with AM/FM stations, shortwave stations are much more complex and expensive. The FCC won't grant international shortwave broadcast station licenses unless applicants can prove there's a real need, that they have the technical, programming, and financial capability, and will serve the "public interest, convenience and necessity."

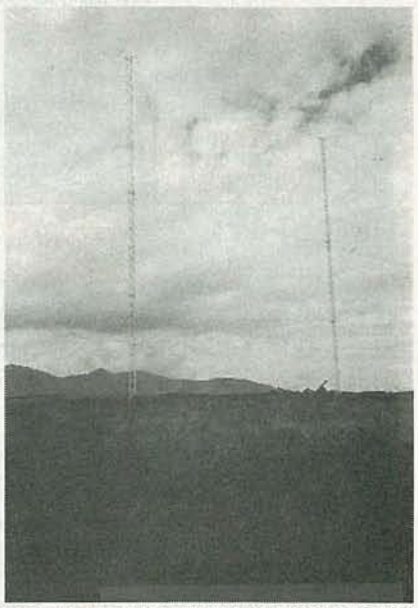


FIG. 4—TRANSMITTING TOWERS AT KUSW, IN Salt Lake City, UT.

A key item in the FCC rules says that "any program solely intended for and directed to the U.S. doesn't meet the requirements for this service." Thus, these shortwave stations aren't supposed to broadcast to the U.S., but many obviously do. The key appears to lie in the use of the word "solely," which apparently allows a U.S. audience to listen in, so long as the programming is officially aimed elsewhere. Also, the physics of shortwave propagation make preventing U.S. listeners from listening to the broadcasts impossible.

The FCC sets a minimum power level of 50 kilowatts as its requirements for international shortwave, whereas on AM, 50 kilowatts is the maximum; however, that's still small potatoes. WCSN is just one of many worldwide shortwave stations that now uses 500 kilowatts, and even 2.5 megawatt shortwave stations are common. The shortwave broadcaster needs complex directional HF antennas aimed at the desired area, along with requirements like minimum antenna gain, HF signal launch angle, bandwidth, and site selection. Once running, the right frequency has to be adjusted to reach a specific area, at a specific season and time of day. It's not just a case of needing only one transmitter, antenna pattern, and frequency, all the time.

An ordinary AM/FM station is expensive, but not when compared with a shortwave station. George Jacobs is a former official of VOA and Radio Free Europe (RFE), who now heads his own highly regarded broadcast-engineering firm, which acts as technical consultant to several U.S. shortwave broadcasters. According to him, a 50-kilowatt site with suitable antennas goes for about $400,000, while a 500-kilowatt version can easily run $2.5 million. And that's excluding the land, studio, and buildings, which can easily double the overall cost. He estimates the power cost for a 500-kilowatt site 18 hours a day for a year at over $53,000.

So far, programming formats have been mostly of two types, and one has to wonder how much more audience potential exists for religious programming. Pop and rock formats, already filling AM/FM bands, are also heard on many foreign stations, both AM/FM and shortwave. The curtain hasn't fallen on this play yet, though. There are still a few more actors yet to arrive.

The oldest and largest religious shortwave broadcaster of all, HCJB of Quito, Ecuador, is planning a facility on Hawaii to better reach Asia and the Pacific. Other companies are reportedly considering shortwave stations California, Kentucky, and Florida. Beyond that, whether that strange world above AM, still alien to most in North America, will prove a good place for broadcasters in the 1990's, is yet to be seen. **R-E**

SECURITY-CIRCUIT COOKBOOK

We continue our survey of home-security system principles by looking at sirens, and various types of "fault-indicator" alarms.

RAY MARSTON

IN OUR MAY ISSUE WE REVIEWED THE basic operating theory and installation principles of home-security systems, and examined several practical security-alarm circuits that give a high degree of protection against fire, burglary, or intruders. All of them had a relay output that can activate an external siren via a pair of relay contacts.

In practice, the siren can also be a bell or buzzer, either electro-mechanical or electronic. The first half of this article describes ways of connecting sensor systems and sirens, and describes some practical circuits, while the second half describes various types of "fault-indicator" alarms.

Siren configurations

A siren can use the same supply as the actual sensor system it's used with, or each may need separate power. All home-security systems should have battery backup for power outages. If the sensor system and siren use similar voltages, and the sensor system self-latches via relay, both can run off of the same supply, as shown in Fig. 1.

If, however, the sensor system and siren need different supplies or the sensor system doesn't self-latch, they absolutely must have separate supplies, as shown in Fig. 2. A siren induces considerable noise on its supply, which can cause a non-latching alarm to malfunction with one supply.

Auto-turn-off alarm system

Once a self-latching sensor system is activated, it automatically sounds

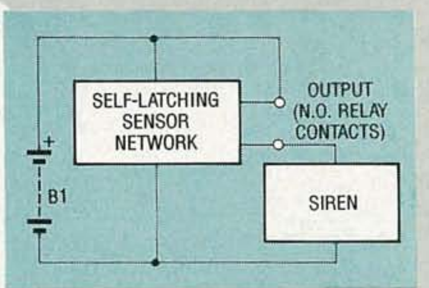


FIG. 1—HOW TO CONNECT A SIREN to a relay-output burglar alarm, with a single supply.

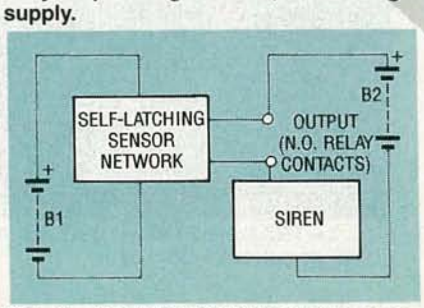


FIG. 2.—HOW TO CONNECT A SIREN to a burglar alarm, with double supplies.

the siren until it's reset manually, or the supply is cut off. The main purpose of a siren is to scare off intruders, while alerting the owner and/or neighbors. If that isn't achieved in a few minutes after activation, there's clearly no point in letting the siren to continue to operate. Thus, simple self-latching action tends to be rather inefficient.

A far more efficient type of siren can be obtained by interposing an automatic turn-off timer between the sensor system and siren, as shown in Figs. 3 and 4. Both versions incorporate a relay that closes as soon as an alarm occurs, but then automatically turns off and disables the siren after some preset period if manual reset hasn't occurred, typically 5–15 minutes maximum. The circuit of Fig. 3 shows how to interconnect the three units when a single supply battery is used, and the circuit of Fig. 4 shows how to accomplish the same for dual supplies.

The circuit of Fig. 5 shows a practical auto-turn-off circuit with a basic timing period of about 8 minutes. The period is proportional to C1, and can be doubled, for example, by using: C1 = 0.2 µF. Here, IC1 is a 17-Hz 555 astable multivibrator that feeds clock pulses to IC2, a 14-stage binary counter that changes state on the 8192nd clock pulse.

When power is first applied, the output of IC2 is set low via C2. As the output goes low, RY1 is driven on via Q1, closing the contact. That turns on IC1, which starts operating and feeding pulses to the input of IC2. When the 8192nd clock pulse arrives after about 8 minutes, the output of IC2 flips high and turns relay RY1 off via Q1, shutting off IC1 and the siren, completing operation.

The 8-minute period of the circuit shown in Fig. 5 is fairly long, but is accomplished without resorting to large electrolytic capacitors or resistors. The period is determined by time constant R2 × C1, and has excellent repeatability and thermal stability. Note that LED1 is a visual intrusion indicator that lights as long as voltage is present, and it continues to glow even after the siren shuts off. It alerts the owner to the presence of an intruder after the fact, even if no overt disturbance occurred to cause one to take notice during the incident.

Electronic siren circuits

A siren can be a bell, siren, buzzer, or other sound siren, whether electro-mechanical or electronic. In some cases, two sirens, connected either in parallel or via dual-contact relay may be a good idea. For example, an electronic siren could be used inside a house, while a bell sounds outside. Electronic sirens can take a number of different forms, and can generate very

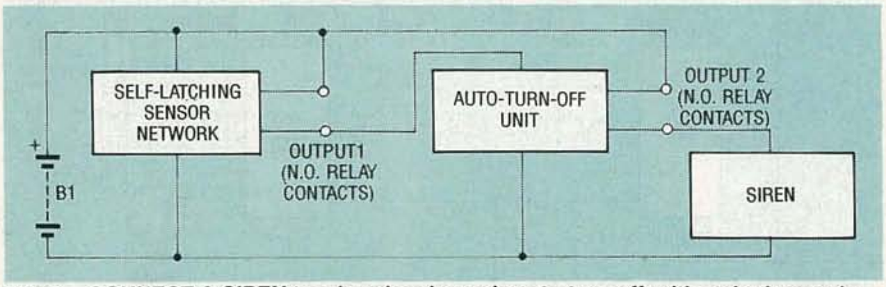


FIG. 3.—CONNECT A SIREN to a burglar alarm via auto-turn-off, with a single supply.

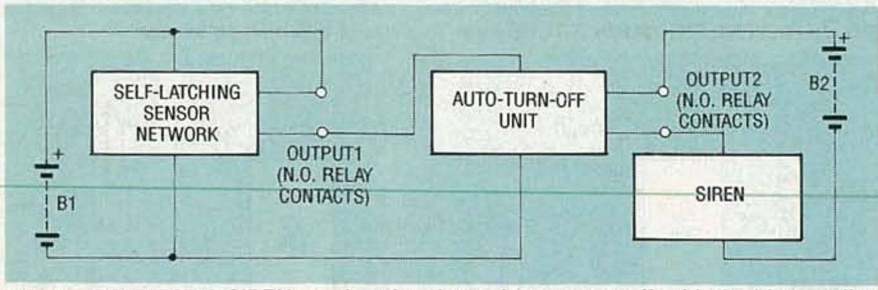


FIG. 4.—CONNECT A SIREN to a burglar alarm via auto-turn-off, with double supplies.

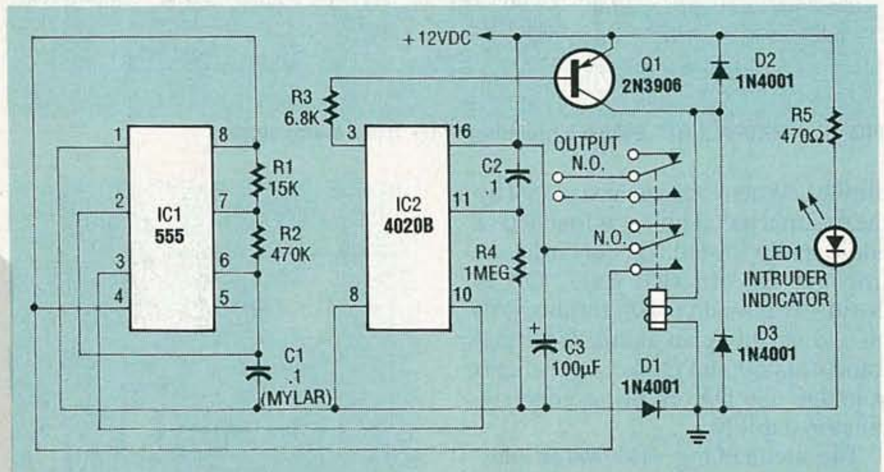


FIG. 5.—AN AUTO-TURN-OFF UNIT with 8-minute delay.

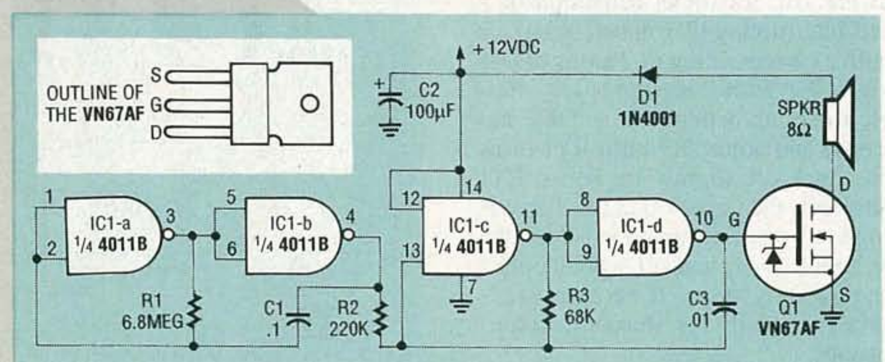


FIG. 6.—WARBLE-TONE 6-WATT SIREN with VMOS output.

distinctive and easily recognizable sounds. The circuits of Figs. 6–8 show three useful versions.

The circuit shown in Fig. 6 generates a warble tone siren. Here, IC1 is a quad CMOS NAND gate, and IC1-a and IC1-b are used to make a simple 1-Hz astable multivibrator, that alternately gates the 1-kHz astable multivibrator made from IC1-c and IC1-d on and off via pin 8. The resulting warble-tone is amplified by a VN67AFVMOS output stage to generate 6 watts in an 8-ohm speaker.

You can greatly increase the maximum supply voltage and available output power by modifying the design to limit the supply to IC1 to 12 volts DC with a 12-volt zener diode while increasing the speaker supply to 30 volts DC. The version shown in Fig. 6 generates a "dee-dah" warble tone, similar to that of a British police car siren. It generates a maximum of 18 watts into an 8-ohm speaker using 24 volts DC.

The frequency-shift "symmetry" of the circuit shown in Fig. 7 depends somewhat on the individual performance characteristics of IC1. The circuit of Fig. 7 shows an alternate warble-tone generator that doesn't suffer from this defect. The modulation frequency is varied via R2, and the tone frequency via R5. It uses a pair of 555's, rather than a single CMOS IC.

Here, IC1 is a 1-kHz astable multivibrator, and IC2 is a somewhat higher-frequency astable multivibrator, around a few kHz. Note that this design is based on the use of a pair of 555 timers, rather than on a single CMOS IC. Here, IC1 is used as a 1-kHz astable multivibrator, while IC2 is used as a higher-frequency astable multivibrator, around a couple of kHz. Astable multivibrator IC1 frequency-shifts IC2 by feeding a square-wave to the pin-5 modulation terminal.

You can generate a variation on that theme, creating a "wailing" tone, alternately rising and falling like that of an American police siren, by using an emitter follower to buffer the 1-Hz "sawtooth" signal of IC1. The sawtooth signal is then fed to pin 5 of IC2, the modulation terminal of the higher-frequency astable multivibrator.

The circuit shown in Fig. 8 generates a "zeep-zeep" tone similar to the "Red Alert" signal on "Star Trek." The period is varied via R2, and the tone via R6; this is an ideal hobby project. Here, D1 and C2 are used to ensure that the astable multivibrator isn't adversely affected by voltage transients resulting from the inductive characteristics of the SPKR.

Touch- and proximity-alarms

A commonly-used home-security technique is that of arranging baited "traps," like door handles, clocks, metal trays, etc., in such a way that they sound an alarm whenever they're touched. If the bait is a small metal object, one way of achieving this effect is to use a "hum-detecting" touch sensor system, of the type shown in the circuit shown in Fig. 9.

The circuit shown in Fig. 9 detects the AC hum that's picked up by an electrical contact when it's touched by a human finger, when the individual in proximity to an AC power line. Here, one of the gates of a CD4001B is used as a simple pulse-inverting amplifier, and has its input terminal connected to the external metal object via R1. This gate is powered by 5 volts DC, derived from 12 volts DC via R2 and R3, and biased via R5 so that its output is normally low.

When a pick-up signal with a peak amplitude greater than a couple of volts appears at the input, the gate output is a 5-volt, 60-Hz square wave, that activates RY1 via Q1-Q2 and D1-C1-R4. Sensitivity-control R5 is adjusted so that RY1 turns on and sounds an alarm when the object is touched, and shuts off when the object is released. Note that the low side of the 12-volt DC supply must be properly grounded. The circuit draws a quiescent current of 1 milliamp. If the object is placed more than 10 cm from the input, the connections to it must use shielded leads, to prevent stray signal pickup.

The circuit of Fig. 10 shows another version; in that case, the object is part of the antenna of an RF oscillator. The circuit uses capacitive-loading, where the gain of the RF oscillator is adjusted so that oscillation is barely sustained, and the antenna is part of the tank circuit; as before, the low end of the supply must be properly grounded. Consequently, any increase in the antenna-to-ground capacitance, like that caused by touching or approaching the antenna, causes enough damping of the tank circuit to reduce the oscillator gain below critical level, cutting off the oscillator, and turning on the siren.

In this case, Q1 is a Colpitts oscillator running at about 300 kHz, with the gain adjusted by R9, and the antenna coupled to the tank circuit via C5. The output of the oscillator is buffered via Q2 and rectified via D1-D2, to produce a positive bias that's fed to the base of Q3. When Q1 is operating normally, Q3 is driven to saturation and Q4 is cut off, turning

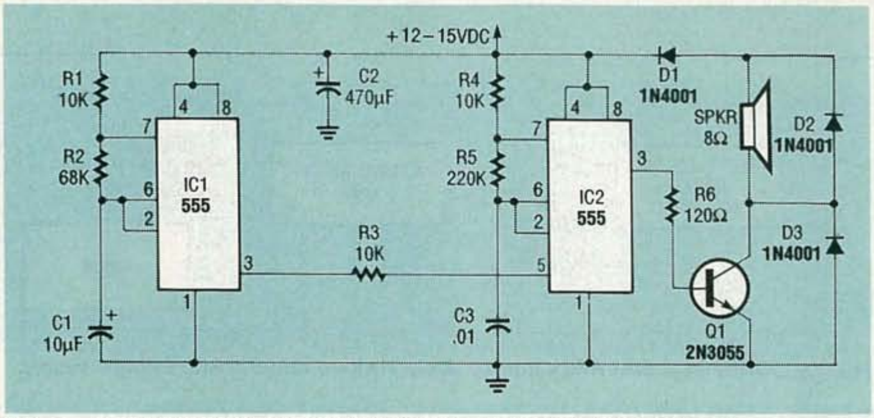


FIG. 7.—ALTERNATE WARBLE-TONE siren like that of a British police car.

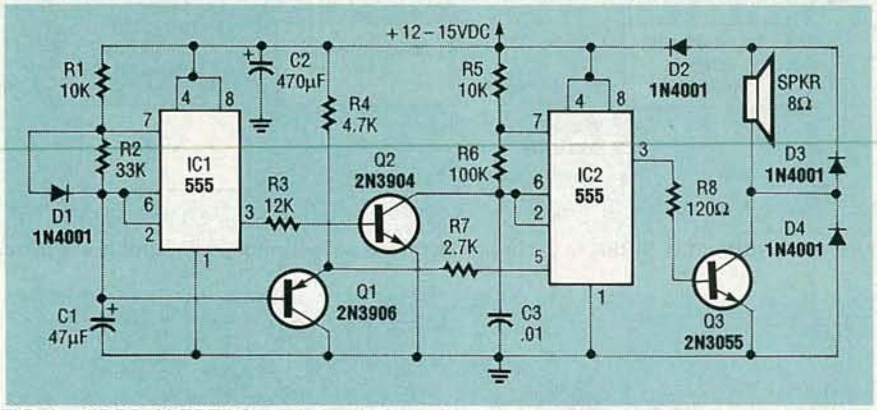


FIG. 8.—"RED-ALERT" SIREN simulating "Star Trek" alarm signal.

off RY1. When the antenna created by the external metal object is touched or additionally loaded, Q1 cuts off, cutting off Q3. In that case, Q4 is positively biased via R8, turning RY1 on and sounding an alarm. Note that transistors Q1 and Q2 are fed using 6 volts DC via D3, ensuring good oscillator stability.

The circuit of Fig. 11 shows an alternate output stage for the circuit shown in Fig. 10, for direct activation of a self-interrupting 12-volt bell or buzzer with a current rating or 2 amps or less via SCR1. Either version is very simple to set up. Connect a suitable antenna, and adjust R9 until RY1 turns on. Back off slightly on R9 so RY1 turns off, then check that the alarm is sounded when the antenna is touched or approached, and off when contact or proximity stops. If necessary, adjust R9 again for maximum sensitivity.

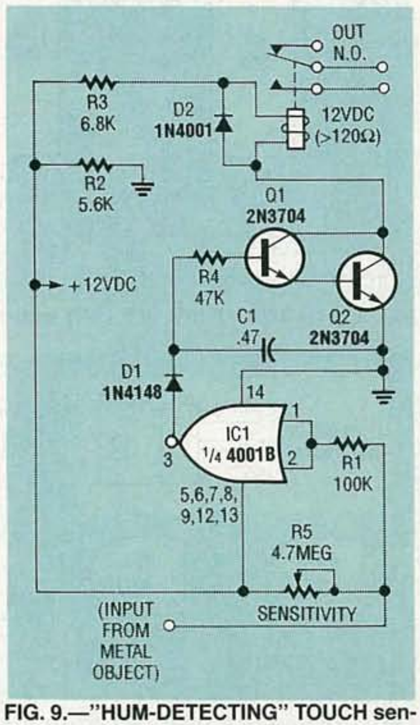


FIG. 9.—"HUM-DETECTING" TOUCH sensor system.

Sound- and vibration-alarms

Sound-activated alarms can be made to activate when an intruder enters a protected area and creates noise. Vibration-activated alarms can be made to activate when a drawer or cabinet is opened, inducing a small vibration in a protected object. Both types use the same principle, as shown in the block diagram shown in Fig. 12. In this case, a microphone or other kind of similar transducer picks up the basic noise or vibration, which is then amplified and rectified, and the resulting DC is used to sound an

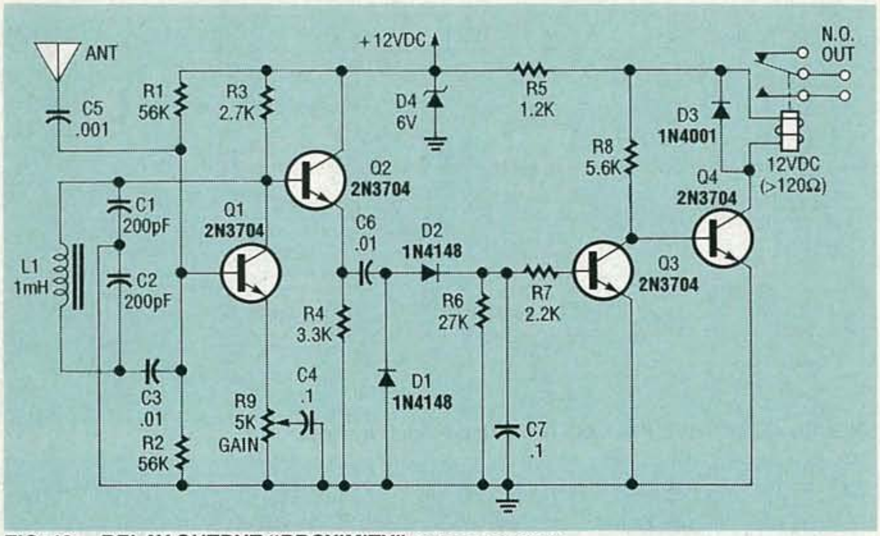


FIG. 10.—RELAY-OUTPUT "PROXIMITY" sensor system.

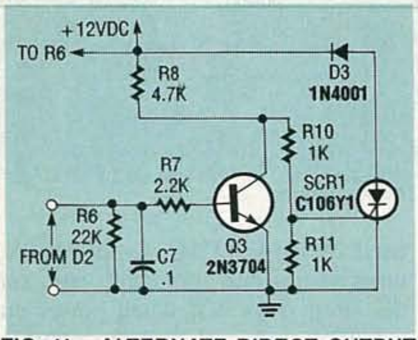


FIG. 11.—ALTERNATE DIRECT OUTPUT stage for the circuit shown in Fig. 13.

alarm.

The circuit of Fig. 13 shows a simple sensor system, that needs about 1-volt RMS to turn on RY1. The circuit action is such that RY1 turns on rapidly when a suitable input signal appears, but turns off slowly when the signal is removed. The turn-off time is determined by time constant R1 × C2, which is most easily changed by varying C2.

That version can be made self-latching by using additional contacts for RY1, placed across Q2 as shown. It can be used as a sound- or vibration-activated sensor system by feeding AC from a pickup transducer, via a suitable amplifier. In vibration-alarms, the amplifier should have a low-pass response, while sound-alarms must operate with a band-pass response.

The circuit of Fig. 14 shows a practical speech-amplifier circuit to be used in conjunction with the circuit shown in Fig. 13 to make a sensitive sound-activated alarm. The RCA CA3035 IC is an ultra-high-gain wide-band amplifier array, with a voltage gain of 120 dB between pins 1 and 7. In that circuit, R1 and C1 perform biasing, R5 controls gain, and the other components determine bandwidth.

Flood-alarm systems

One of the many dangers facing the house owner is flooding, like occurs when a water cistern overflows, a water pipe breaks, or rain leaks into a cellar. Fortunately, those dangers can be greatly reduced with the aid of a simple water-activated sensor system, of which the circuits shown in Figs. 15 and 16 are practical versions. Each of the two circuits uses the same basic operating principle, which involves using a pair of metal probes to resistively detect the presence or absence of liquid.

In the absence of liquid, the probes see near-infinite resistance, but when liquid appears across both probes simultaneously, the probe resistance falls to a low value, sounding an alarm. For rain or tap water, the resistance may be less than a few kilohms, but steam or oil may exhibit a higher

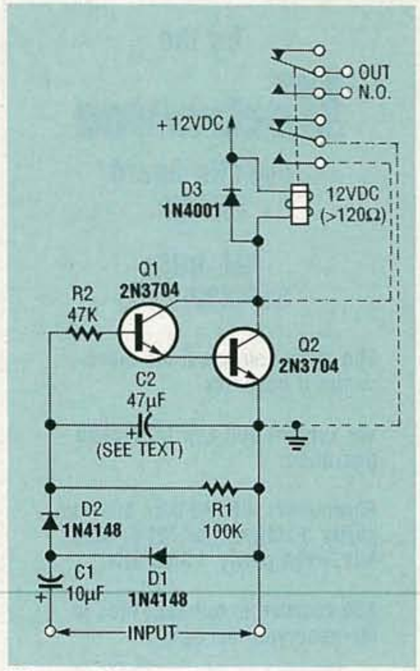


FIG. 13.—SIMPLE RELAY-OUTPUT sound- or vibration-sensor system.

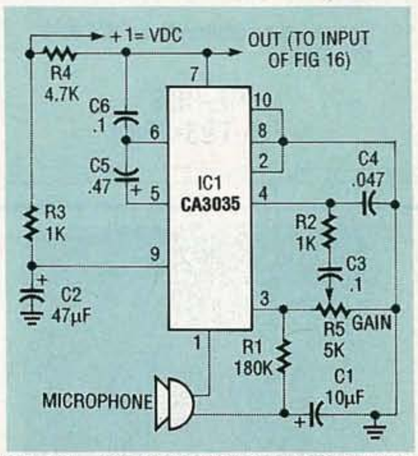


FIG. 14.—SPEECH-FREQUENCY AMPLIFIER used in conjunction with the circuit of Fig. 16 to make a sound-activated sensor system.

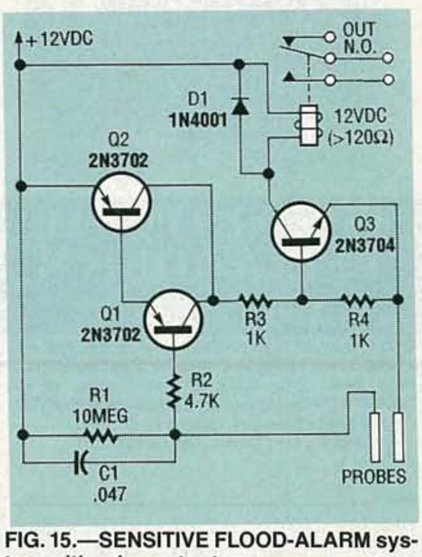


FIG. 15.—SENSITIVE FLOOD-ALARM system with relay output.

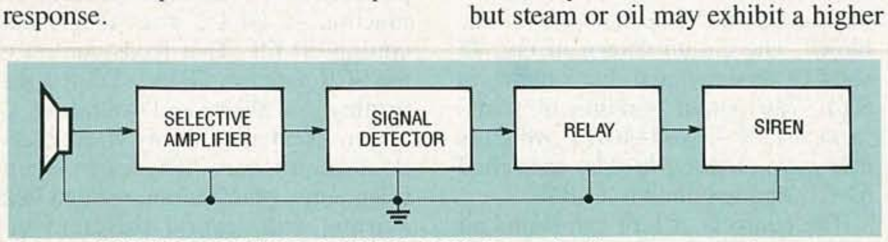


FIG. 12.—BLOCK DIAGRAM OF TYPICAL SOUND- or vibration-sensor system.

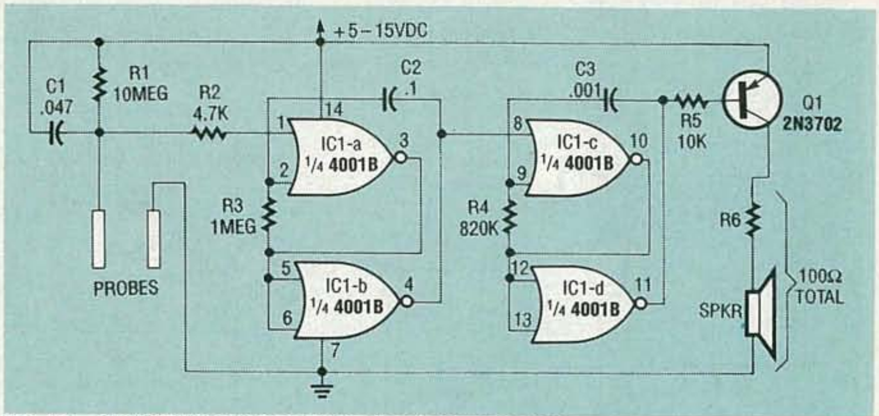


FIG. 16.—SENSITIVE PULSED-TONE flood-alarm system.

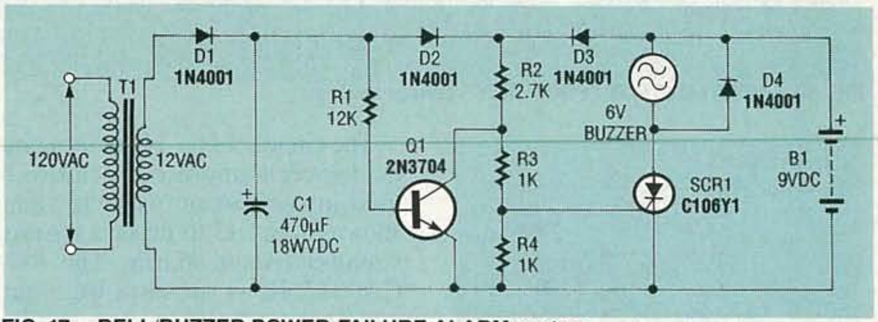


FIG. 17.—BELL/BUZZER POWER-FAILURE ALARM system.

resistance of as much as several megohms.

The operation of the circuit shown in Fig. 15 is very simple. In the absence of liquid, Q1 is held cutoff via R1-R2, so Q2 and RY1 are off also. In the presence of liquid, Q1 turns on, biasing Darlington pair Q1-Q2 on via R3 and turning on RY1, sounding an alarm. It turns on when the resistance between the probes is under about 500K, and has a sensitivity of about 10 megohms, by using a Darlington pair in place of Q1. Finally, the circuit shown in Fig. 16 generates a pulsed-tone alarm when activated, with a sensitivity of about 20 megohms, consumes about 1 µA of quiescent current, and generates an 800-Hz tone that's pulsed on and off at a rate of 6 Hz.

Power-failure alarm systems

Electrical-power failure alarms can be made to activate when power is removed from an electric major appliance like a freezer, either due to a downed power line, or when fuse blows. The circuit shown in Fig. 17 shows a version that trips an alarm via RY1. The output winding of transformer T1 is 12-volts RMS, which is half-wave rectified by D1, smoothed by C1, and fed directly to RY1.

The contacts of RY1 can sound an alarm if *N*ormally-*C*losed (N.C.) are used. When 120 VAC is applied, RY1 turns on, the N.C. contacts open, and the siren stays off; when power cut off, RY1 turns off and the contacts close, sounding an alarm. Here, RY1 can be any 12-volt type with a coil resistance of at least 120 ohms, with one or more N.C. contacts; transformer T1 needs a current rating of at least 100 milliamps.

The secondary winding of transformer T1 is rectified and smoothed by D1-C1 to 12-volts DC at the junctions of D1-D2 and D2-D3. The siren is a self-interrupting bell or buzzer with current rating of 2 amps or less, and is the anode load of SCR1, powered by B1.

Normally, when 12-volts DC appears at the junctions of D1-D2 and D2-D3, Q1 saturates via R1, and the junction of R2-R3 junction goes to ground. In that case, no drive is applied to the gate of SCR1, so the siren is off, D3 is reverse-biased, so no current is drawn from B1. When the power cuts off during a failure, the junction of D1-D2 goes to ground, cutting off Q1. That feeds current to the SCR gate from B1 via D3-R2-R3, turning on SCR1 and sounding an alarm. Next month, we'll conclude this look at security devices, by examining some practical smoke and heat alarms, and several different car alarms. **R-E**

GAUGES

continued from page 40

VACUUM GAUGE
All resistors are ¼-watt, 5%, unless otherwise indicated.
R1, R2—10,000 ohms
R3, R8—100,000 ohms
R4—22,000 ohms
R5—1000 ohms
R6—680,000 ohms
R7, R10—200,000 ohms PC mounted trimmer potentiometer
R9—82,000 ohms
R11—50,000 ohms PC mounted trimmer potentiometer
R12—2200 ohms
Capacitors
C1—47 μF, 25 volts, electrolytic
C2, C3—10 μF, 35 volts, electrolytic
C4—0.33 μF, 50 volts, stacked film
Semiconductors
IC1—Sensym SX30DN vacuum sensor (Dakota Digital #69G18 includes mounting bracket)
IC2—LM324, quad op-amp
IC3—LM340T-5, 5-volt regulator
IC4—CA3132E, A/D converter
D1, D2—1N4002 diode
Miscellaneous: 43B17 main PC board, 2-digit display board, in-line fuse holder, 1-amp fuse, four 6-32 × 0.625" standoffs, eight 5/16-inch #6 screws, bronze or red plexiglass, mounting hardware, hookup wire.

and R8 form a resistive divider that sets the upper reference voltage, with a range of 0.284 to 0.889 volts. The low-temperature calibration is adjusted via R7, while the high-temperature calibration is adjusted via R11. A three-digit display is used, and the annunciator can be anything you "OIL," etc..

The vacuum gauge, shown in Fig. 7, uses a solid-state vacuum/pressure sensor (IC1, Sensym SX30DN) to monitor the intake-manifold vacuum during engine operation. Between 0 and 30 inches (in.) of mercury (Hg.) can be displayed with 1 in. Hg. resolution. The sensor consists of a piezo resistive element housed in a dual ported plastic enclosure. The piezo element changes its resistance as it is flexed or bent. Because a specific amount of flexing is caused by a specific force or pressure, the value of that pressure can be determined by measuring the sensor's resistance. Vacuum has the same effect as it pulls the element instead of pushing it.

The pressure/vacuum sensor (IC1) is essentially a bridge circuit with its outputs at pins 2 and 4. Because it is a bridge, its outputs change proportionally to one another when vacuum or pressure is applied. When both ports have the same pressure, the outputs at pins 2 and 4 are identical. As vacuum is applied to port 2, the output at pin 2 rises while pin 4 is reduced. There is now a difference between the two outputs of the bridge, and that difference represents how much vacuum is present.

3-DIGIT DISPLAY BOARD
All resistors are ¼-watt, 5%, unless otherwise indicated.
R1, R2—220 ohms
R3—220 ohms (voltmeter only)
Semiconductors
IC1—CA3161E, Display driver
DISP1–DISP3—0.43" 7-segment C.A. LED display (Panasonic LN514RA)
Q1–Q3—2N3906 PNP transistor
LED1—5- × 15-mm LED, (Panasonic LN0202RP)

2-DIGIT DISPLAY BOARD
All resistors are ¼-watt, 5%, unless otherwise indicated.
R1, R2—220 ohms
Semiconductors
IC1—CA3161E, display driver
DISP1, DISP2—0.43" 7-segment C.A. LED display (Panasonic LN514RA)
Q1, Q2—2N3906 PNP transistor
LED1—5- × 15-mm LED, (Panasonic LN0202RP)

The first two sections of IC2 are used as buffers to isolate the bridge circuit of IC1. IC2-a is used as a differential amplifier, and R1–R3 and R8 determine the gain. Resistors R6 and R7 are used to offset the differential amplifier so that its normal "zero" output is 0.21 volts above ground. The gain of the differential amplifier is set to give an output approximately 60% higher than that needed by the A/D converter. The voltage level is then reduced by R9 and R10, which is also used to set the full scale of the gauge. The input voltage to the A/D converter is averaged by C3 for stable readings. Resistors R4 and R5 set the 0.21-volt "ground" reference which is buffered at the output of IC2, pin 7. The vacuum value is displayed on a two digit readout. A "VAC" annunciator on the display board indicates the reading of the gauge.

That's all we have room for this month. Next month we'll build and install the gauges. **R-E**

HARDWARE HACKER

Electronic Melody Chips
Unusual Book Resources
Ten Speed Blender Control
Power Control Fundamentals
Hacker Interchange Standard

DON LANCASTER

Power-control fundamentals

AS WE'VE SEEN IN PAST COLUMNS, WITHin a decade we just may reasonably expect electronic hardware having computation abilities that are as complex as those of the human brain. Driven primarily by ultra-cheap and ultra-dense dynamic RAM technology.

Now, admittedly, my timing on this might be off by as much as twenty minutes in either direction. But, things seem to be going even faster now than they were even a few issues ago.

Several Japanese outfits have now actually firmly scheduled their future production of new 256 Meg × 17 SIMM chips. And it appears another level of *threshold effect* just might have been crossed with the concept of *OOPS* or *object oriented programming* which is spreading like wildfire.

So how can you tune yourself into and profit from this near-term inevitability of human brain computer functionality?

As usual, those free industry trade journals are the answer. In this case, the *E.E. Times* is a very good choice. They are very big on dynamic RAM developments, on neuron computing, and on "fuzzy logic" in general.

Cold fusion. This is being written on cold fusion's first birthday. According to today's *Wall Street Journal* (April 3, 1990, page B4), "a small but growing number of scientists believe they are seeing an entirely new phenomenon," and "There is now a growing consensus that you can't explain the excess energy by errors." It appears, in fact, that several distinct and valid cold-fusion mechanisms might be involved. Sixteen laboratories have recently reported fresh and positive new results.

A very interesting report titled as *Electricity by Serendipity* appeared in the *March 2, 1990* issue of *Science*. It describes a new type of fuel cell which permits the *premixing* of the hydrogen and oxygen gases, something previously thought to be utterly impossible. These cells also involve hydrogen being absorbed or adsorbed into palladium, in cells remarkably similar to the cold-fusion setups.

The obvious unanswered question is "how much of cold fusion's excess heat is really this previously unknown type of fuel cell?" And vice versa.

Our usual reminder here that most of the resources mentioned have been gathered together into the *Names and Numbers* or the *Unusual Book Resources* sidebars. You can contact all the listees directly for more info.

Let's start with a lively topic...

Printed circuit standard

The editors at *Popular Electronics*, **Radio-Electronics**, *Probe, Midnight Engineering, Computer Shopper, Nuts and Volts, Byte, Audio Amateur,* and *Circuit Cellar Ink* have all been separately grappling with a common problem: How can clean and accurate printed-circuit layouts get easily and cheaply put in the end user's hands?

Or dialplates, drilling templates, detailed test and debug info, software listings, or most any other tech writing or tech illustrations?

Putting any of those in the magazine does take up valuable space, and the third-generation photocopies or litho negatives you sometimes end up with are often of low accuracy and quality. And it sure gets hard to make a correction three months later on 360,000 already printed pages, some of which are buried in a lesser-known suburb of Moose Jaw, Montana.

On the other hand, the BBS downloading will work only if the sender and sendee do have fully compatible hardware and software. What to do?

I would like to suggest an obvious solution. It is called an EPS file, and is short for *Encapsulated PostScript*.

An EPS file can easily handle any printed-circuit board layout, schematic, isometric or perspective drawing, dialplate, or text or graphics of any sort *to any arbitrarily high resolution*.

The EPS files are extremely device independent. Since an EPS file is an ordinary ASCII text file, it could easily be used with *any* word processor or *any* editor with *any* brand of personal computer of *any* age and CPU.

At the output end, an EPS file can be used directly on a laser printer, by a typesetter, or by a photoplotter. With simple and crude emulators such as *Freedom of the Press, GoScript,* and *UltraScript,* you can also print your results on ordinary dot-matrix or ink-jet printers, albeit to a lower resolution. The latest of fax machines are set up to directly handle *EPS* files, some to device-inde-

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pendent resolutions that can exceed 2650 DPI. There is no high-end limit to print quality.

Better yet, practically all of those CAD/CAM and illustration packages either now use PostScript internally or at the very least are capable of generating EPS output files.

The EPS files can also be extremely compact. For instance, a fancy circuit schematic should need no more than a 10K textfile maximum. So, EPS stores cheap and downloads fast.

But what if you are using an expensive or proprietary CAD/CAM or layout package? Surely you could not provide a free copy of these to every reader in the country, could you? Especially if you are on a Mac and they are on a PC.

There is a simple little trick you can pull that is called *pseudo-compiling*. With pseudo-compiling, you might convert any source of PostScript code into a *Just the facts, Ma'am* form that uses nothing except the simplest of put-and-place PostScript commands. Anyone can run a pseudo-compiled EPS file, and absolutely nothing will remain of the original code or the way it was generated.

Better yet, that pseudo-compiled PostScript often will run ridiculously faster than the original. And pseudo-compiling is easily and quickly done by using Adobe System's brand new and cheap *Distillery* program, by one of my *gonzo justification* routines, or your own custom code.

What about screen images? In any broad based user interchange standard, you certainly would not want to use any screen images if they hurt the device independence in any way.

Fortunately, systems using display PostScript or the display PostScript emulation are now becoming readily available, as is software that returns printer bitmaps for screen display. So are programs and applications that internally capture and display EPS.

How does an EPS file differ from an ordinary PostScript textfile listing? Actually by very little. There are a few required remarks at the start of your file plus a few optional ones. And a very few PostScript commands (such as *initgraphics)* are not allowed if they would somehow corrupt the program or system that the EPS file is being imported into. Several other obscure commands (such as *settransfer*) must be carefully saved and restored if they are altered. EPS files are also limited to a single page each, but you can use as many of them as you like.

To get started on all of this, get yourself copies of the *Encapsulated PostScript Files Specification,* v 2.0, and the *Document Structuring Conventions Specification,* v 2.1. Both of them are available free upon request through Cynthia Johnson at *Adobe Systems,* or else through one of the PostScript BBS systems. You should not create or use any EPS files without having these two on hand.

The fundamentals on PostScript are covered by Adobe's blue *PostScript Tutorial* and red *PostScript Reference Manual,* while ready-to-use printed-circuit layout, schematic, isometric, and perspective routines are found in my *PostScript Show and Tell.*

Let me know your thoughts on a standardized hacker interchange approach based on standard EPS file formats.

AC power control

Most hackers have observed at one time or another, that your typical semiconductor will instantly vaporize if you connect it across the AC power line. Obvious problems here are that the power line is high voltage, high current, and either polarity.

One popular semiconductor that can easily be used as a high-power AC line switch is called a *triac.* A typical on-off circuit is shown in Fig. 1.

A triac has two power terminals called *T1* and *T2,* and a control terminal called the *gate.* A triac remains off until a low-level pulse (usually 5 volts at 50 mA) of either polarity is applied to the gate. The triac then turns on its main terminals *and remains on so long as the main current continues flowing in the same direction.*

Thus, a triac turns *on* very shortly after it receives a gate pulse. It stays on until the next zero crossing of the main AC current through it.

When off, the triac can block the full applied line voltage. When on, the triac can conduct several amperes with a drop of only a volt or two. A modest heatsink is usually needed to handle the current. Figure a square inch or so for each 50 watts of load.

As a long-term solid-state on-off switch, a triac can handle most any AC load within its current rating, and still work equally well with any style lamp, heater, or motor.

You can pick up an 8-amp triac at *Radio Shack* for $1.40, and you'll find several low-cost triac selections among our many **Radio-Electronics** advertisers. Three major suppliers of triacs include *Motorola, SGS,* and *Texas Instruments.* While all three have lots of triac data books and application notes available, none could even think of holding a candle to the original and classic *GE SCR Manual,* which, sadly, is long out of print.

While triacs are fun to experiment with and easy to use, do note that you are dealing directly with the AC power line. You have an extreme, *and possibly lethal,* shock hazard.

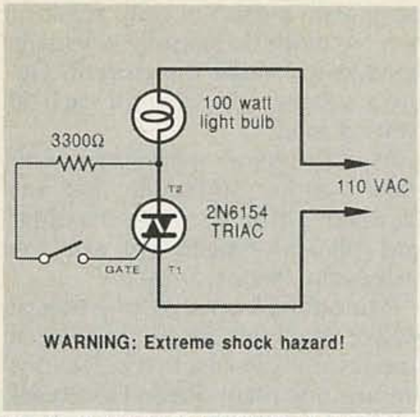

FIG. 1—A TRIAC CAN BE USED as a line-operated AC power switch that can directly control lamps, heaters, or motors. A brief and small current pulse into the gate turns the triac on; it remains on until the main current reverses.

Always keep one hand behind your back. Never leave power applied after a test or experiment. And always use an isolation transformer should you want to view any scope waveforms.

Figure 2 shows you one simple computer-to-AC-power interface. You take a special optocoupler known as a *phototriac isolator* and use it as a safety interface. When your computer port goes low, an LED in the isolator turns on, which fires up an internal baby phototriac, that in turn whomps the main triac. That safety isolates your computer from the power line, yet still allows a small logic signal to directly control a kilowatt or more of AC line power.

Even with the safety isolation, you still have a severe shock hazard on the right side of Fig. 2.

Observe that the interface works backward from what you'd expect. A *low* input powers your load, and vice versa. That makes far better use of the micro's current-sinking ports.

Under certain conditions, a triac can be used to control the brightness or speed of your power load. One way to do that is by using *phase control,* such as is shown in Fig. 3. If you precisely delay the gate pulse to some point in the AC half cycle, only partial AC half cycles will get through to the load. Since full power is applied for only part of the time, you end up with an average lower power sent to the load.

But note that phase control will not work with any old power load. Phase control is fine for heaters, soldering irons and other resistive loads, and is really great for incandescent lamp dimming. While phase control can be used to control the speed of a universal AC-DC motor which uses brushes, a slightly fancier feedback circuit that senses the motor back EMF will often work considerably better.

Note that a simple phase control absolutely, positively must *never* be used with a fluorescent lamp or an AC induction motor. While it is possible to use triacs to dim a fluorescent or to control the speed of an induction motor, they need much fancier and carefully crafted circuits.

Here is how your simple dimmer control works: The *diac* shown consists of two four-layer diodes back to back. It behaves sort of like a neon lamp. It is an open circuit until its terminal voltage gets up to fifty volts or so. Then it will suddenly turn on, dumping the capacitor charge into the triac gate. The diac turns back off when your capacitor is discharged. Varying the brightness control decides how fast the capacitor charges, and thus when in the cycle the triac fires.

The later in the cycle, the less the percentage of the time that power is applied to the load, and the dimmer the lamp. Since this all happens 120 times per second, the repeated off-on actions are well beyond your critical persistence of vision limit, and no flicker will be noticeable. The long thermal inertia of the lamp filament also helps eliminate flicker.

Diac trigger diodes are usually sold by the same sources who supply triacs. These days, though, it is far better to digitally generate all the power line phase delays by either using a micro-processor or a custom power control chip. One example might be...

Touch-controlled blender

Certainly one of the most obscure and low-profile IC chip houses is *LSI Systems*. Yet, those folks do have an outstanding selection of the low-cost hacker integrated circuits. They are particularly strong in AC power controls, counters, timers, delay circuits, electronic locks and melody chips.

Figure 4 shows you their LS3714 chip as it's used for a ten-speed touch-controlled blender. It can also be used for a ten-level dimmer. Cost in singles is a mere $2.75, dropping to seventy cents in production quantities.

There are eleven touch plates used; touching any one sets that selected power level to the load. Their circuit consists of a touch-sensitive one-of-eleven latch which selects and remembers your desired power level. That level is converted into a phase angle which determines when to fire the main power-control triac. A reference input on pin 12 synchronizes an internal phase locked loop to the power line zero crossings. Double resistors are

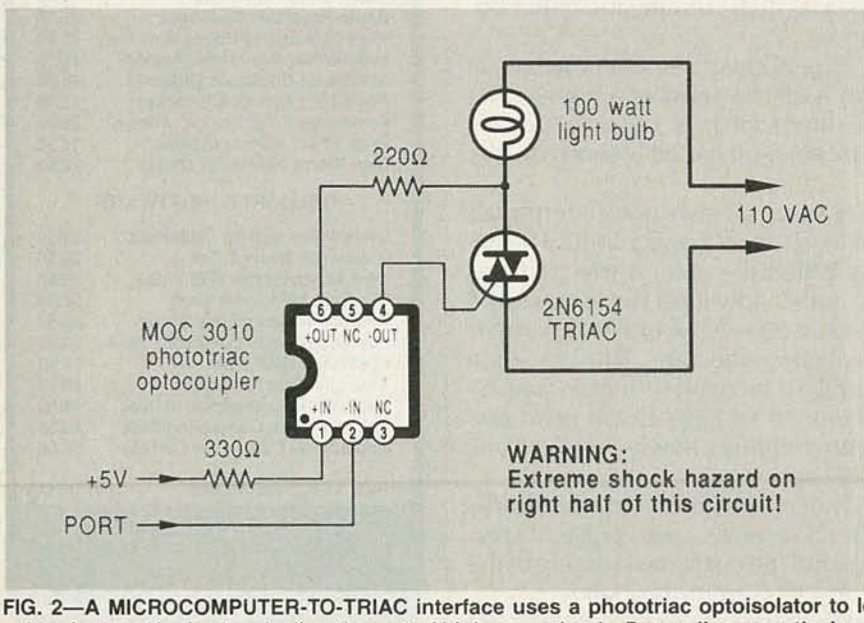

FIG. 2—A MICROCOMPUTER-TO-TRIAC interface uses a phototriac optoisolator to let safety-isolated logic signals directly control high-power loads. Depending upon the input waveforms and the load, this same circuit can be used for either an on-off or a proportional phase control. A low input powers the lamp.

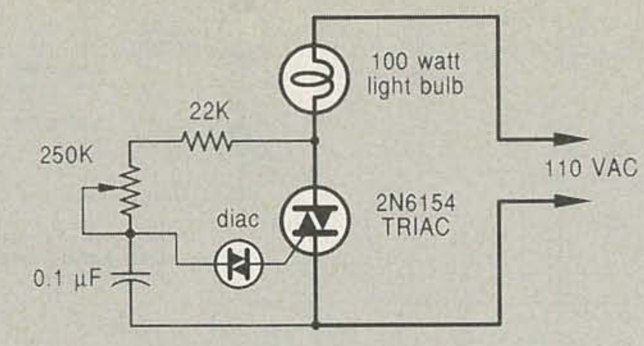

FIG. 3—A PHASE-CONTROLLED DIMMER delays the triac turn-on to a selected point in each successive AC half cycle. Use this circuit ONLY for incandescent lamps, heaters, soldering irons, or "universal" motors that have brushes.

used on the touch plates as a safety feature.

The active touch-plate inputs can also double as LED output drivers, thus lighting one-of-ten selected LED lamps to show your current power or speed level. I have left the RFI noise filter off the output to keep our circuit simple here. You can also customize all of your firing angles to improve linearity for your selected load. Consult the data sheet for full details on these extras.

Play a simple melody

As an entirely different *LSI Systems* circuit, Fig. 5 shows you a LS3404 melody chip. There are 31 melodies in stock, and you can also customize your own (in large quantities) tunes up to 255 notes long.

The envelope of each note gets adjusted to an exponential decay to produce a high-quality, chime-like tone. The circuit shuts off after each tune. The operating current is five mils. Pitch is set by the RC values at pin 5. Decay time is set at pin 3. Pin 4 sets the tempo.

Be sure to get a complete set of LSI data sheets. These folks do have over three dozen low-cost chips that cry out for new hacker uses. What can you come up with here?

UNUSUAL BOOK RESOURCES

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Carlisle, MA 01741
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Ukiah, CA 95482
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CIRCLE 237 ON FREE INFORMATION CARD

SAE
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Warrendale, PA 15096
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CIRCLE 243 ON FREE INFORMATION CARD

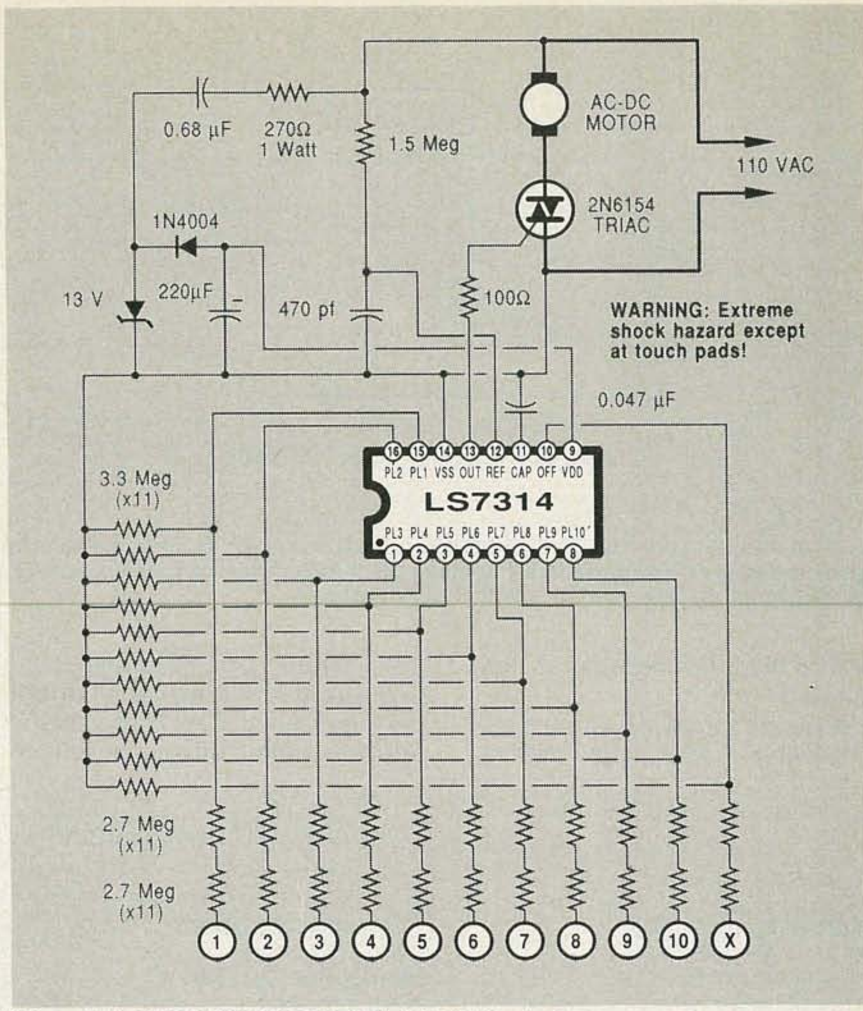

FIG. 4—A 10-SPEED TOUCH-CONTROL BLENDER circuit that uses the low-cost LS7314 chip by LSI Systems. The eleventh touch pad is for power off.

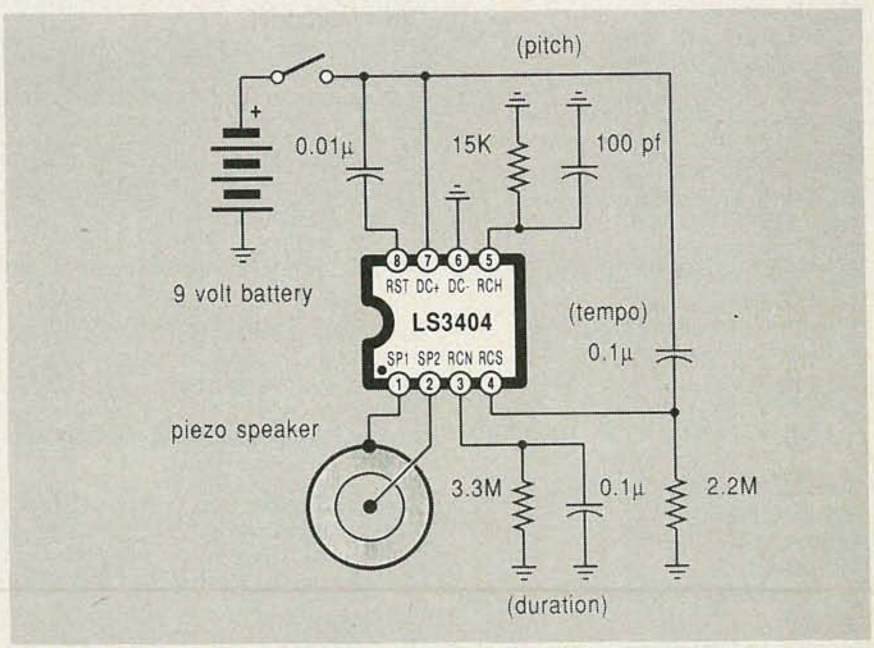

FIG. 5—A HIGH-QUALITY MELODY circuit. The slow decay waveforms produced will create chime-like notes. Pitch, tempo, and duration are all adjustable.

Unusual book resources

I feel that the best possible way for hackers to keep and stay informed is to aggressively expose themselves to the industry trade journals. And the second best is through creative use of on-line access services, most especially the *Dialog Information Service*.

But technical and any other unusual books certainly have their place. As you might have noticed, mall storefronts that have a sign out front that says "book store" are

NAMES AND NUMBERS

Adobe Systems
1585 Charleston Road
Mountain View, CA 94039
(415) 961-4400
CIRCLE 245 ON FREE INFORMATION CARD

Celtec/Vycom
Greenwood Ave & Warner St.
Scranton, PA 18505
(717) 346-8254
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Ron Charles & Associates
PO Box 805
Wilmette, IL 60091
(708) 251-4777
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Compliance Engineering
629 Massachusetts Ave.
Boxborough, MA 01719
(508) 264-4208
CIRCLE 248 ON FREE INFORMATION CARD

EE Times
600 Community Drive
Manhasset, NE 11030
(516) 365-4600
CIRCLE 249 ON FREE INFORMATION CARD

Freedom of the Press
900 Tech Park Drive #8
Billerica, MA 01821
(800) 873-4367
CIRCLE 259 ON FREE INFORMATION CARD

GoScript/LaserGo
9369 Carroll Park Dr. #A
San Diego, CA 92121
(619) 450-4600
CIRCLE 260 ON FREE INFORMATION CARD

Hosfelt Electronics
2700 Sunset Blvd
Steubenville, OH 43952
(800) 524-6464
CIRCLE 261 ON FREE INFORMATION CARD

Intel
3065 Bowers Ave
Santa Clara, CA 95051
(408) 987-8080
CIRCLE 262 ON FREE INFORMATION CARD

JerryCo
601 Linden Place
Evanston, IL 60202
(708) 475-8440
CIRCLE 263 ON FREE INFORMATION CARD

Komacel, Inc
535 N Midland Ave
Saddle Brook, NJ 07662
(201) 791-1511
CIRCLE 264 ON FREE INFORMATION CARD

Lazer Products
12741 East Caley Ave #130
Englewood, CO 80155
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LSI/CSI
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Melville, NY 11747
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Motorola
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Phoenix, AZ 85008
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NEC
401 Ellis Street
Mountain View, CA 94039
(800) 632-3531
CIRCLE 268 ON FREE INFORMATION CARD

SGS-Thompson
1000 E Bell Road
Phoenix, AZ 85022
(602) 867-6259
CIRCLE 269 ON FREE INFORMATION CARD

Surplus Center
1015 West "O" Street
Lincoln, NE 68501
(800) 228-3407
CIRCLE 270 ON FREE INFORMATION CARD

Texas Instruments
PO Box 809066
Dallas, TX 75380
(800) 232-3200
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Ultrascript/QMS
PO Box 81250
Mobile, AL 36689
(205) 633-4300
CIRCLE 272 ON FREE INFORMATION CARD

Unitrode
580 Pleasant Street
Watertown, MA 02172
CIRCLE 273 ON FREE INFORMATION CARD

often less than useless. And publisher's catalogs carry only their own titles, many of which may be "me too" or appallingly bad.

Instead, you really have to expose yourself to sources that have a vested interest in stocking a wide selection of the best books on special topics.

As your resource sidebar for this month, I have tried to show several sources of unusual books that I've personally found of interest. Let's do a quick rundown...

The foremost source for hacker titles has to be *Lindsay Publications,* who stock an amazing variety of mechanical, machine shop, antique radio, craft, and weird science titles. For automotive electronics, nobody can beat *SAE.* And for electronic music, the *MIX Bookshelf* is first rate.

For astronomy and space books, try *Frontier Space Books.* For robotics, use *Educational Products.* For all the alternate energy and self-reliance, try *Real Goods.* For establishment energy and conservation stuff, *AEE Energy Books.* For signmaking, it's *SignCraft.* For metals and properties of materials, *ASM International.*

It appears that two of the finest technical bookstores in the country are across the street from each other. So, you will want to check out both the *Stanford Bookstore* and the *Computer Literacy Bookshop.* For a direct-mail source of most technical and industrial titles, you also may want to check out *Omega Engineering.*

By far the best place I've found for in-depth reviews of all unusual and genuinely useful books is the quarterly *Whole Earth Review.* I cannot say enough good things about these wonderful folks.

I try to stock my own titles and only the very best PostScript titles of others in my own *Synergetics.*

It seems I've always been attracted to what I call "Tain't Likely McGee" publications on Tesla-was-an-alien free energy, perpetual motion, Pogue carburetors, Newmann engines, and similar off-the-wall goodies. Although Lindsay stocks and honestly reviews a few of these titles, a second and more typical source would be *H&A Industries.*

As a final favorite of mine, *Singing Wind* does specialize in the Western Americana, Southwest Literature, lost mine lore, and an otherwise amazingly eclectic collection of arcania. Since *Singing Wind* has an unlisted address, getting there is half the fun. If you're not one of their kind of people, you'll never find the place.

Well, maybe one hint. Go north on Ocotillo Road out of Benson, Arizona till it feels about right. Then turn right just beyond the seventh cow. Keep the gates the way you find them.

Tellyawhat. I'm sure I've missed plenty of good sources for unusual books. For this month's contest, just tell me about some other genuinely useful place to find specialized or oddball titles. Do include a mailer if possible. We will have a dozen *Incredible Secret Money Machine* book prizes, along with an all-expense-paid (FOB Thatcher, AZ) *tinaja quest* for two going to the very best.

As usual, send all of your written entries directly to me at *Synergetics,* rather than to **Radio-Electronics.**

New tech literature

Free data books for this month include the *Product Selection Guide* from *NEC* on memory, micros, peripherals, and telecom chips; the *i486 Microprocessor* from *Intel;* and the new *Semiconductor Databook and Application Notes* from *Unitrode.*

Two surplus catalogs having great pricing are available through *Hosfelt Electronics* for electronic goodies; and *Surplus Center* for pneumatics, hydraulics, and larger motors.

Compliance Engineering is an unusual trade journal aimed at helping you meet FCC and similar specs. They have a free supplement *Direct Connection: Interfacing to the Telephone Network* available just for you. Ask for Application Note #102.

Reasonably priced vacuum forming machinery is available through *Ron Charles & Associates.* While intended for hobby modelmaking, there should be lots of hacker uses involving prototypes and limited production runs.

Two interesting new prototyping and model materials are the *Komacel* and *Celtec* foamed vinyls. Free samples are available.

The bargain of the month has to

(Continued on page 81)

AUDIO UPDATE

Taking care of your tapes

LARRY KLEIN,
AUDIO EDITOR

CONSIDERING THE RECENT FLOOD OF audio-video components into the marketplace and the very successful efforts made to upgrade video sound, I think it is not inappropriate to devote a column to the care and storage of audio *and* video tapes. Current opinion is that, given reasonable care, the audio and video tapes you made last month should be playable by your children's children—assuming that compatible machines are still available. The major causes of tape deterioration—which I'll discuss in order—are heat, humidity, dirt, stray magnetic fields, and improper handling.

FIG. 1—THESE VIDEOCASSETTE REWINDERS will save your VCR from excess wear and tear.

Heat

Whether blank or recorded, tapes ideally should be stored at a *constant* temperature of, say, 21° Celsius (70° Fahrenheit). The constancy of the temperature is more important than its actual value, because large temperature swings cause expansion and contraction of the tape's base (backing) material. That could result in its permanent deformation as well as oxide shedding. So, avoid leaving tapes in attics or locked cars and keep them away from air conditioners, radiators, heating vents, and direct sunlight.

Humidity

For archival storage, a *constant* humidity of about 15 percent is recommended, but in a typical home the humidity is likely to be far lower in winter and higher in summer. In any case, don't store your audio and videocassettes in a damp basement, and if you've been videotaping out of doors on a cold day, give your tape (and recorder) an hour or so to reacclimate to the indoor temperature before use.

Dirt

Storage sleeves are designed to guard videocassettes against the intrusion of dust and dirt, and they do a pretty good job. But when a cassette is loaded into a VCR, its tape and internal mechanisms are somewhat exposed. It follows, therefore, that it's wise to keep the VCR (and tape-storage area) as dust-free as possible. It also follows that you shouldn't leave a tape "stored" in the VCR unless, of course, you have it set up for timer recording.

There's a certain amount of oxide-coating shedding from any tape during the recording and playing process, but the better the tape, the less it sheds. Modern high-grade audio and videotapes are extremely "clean" in this regard. Unfortunately, the tape stock used for some prerecorded audio and video cassettes is not as a high a quality as it might be.

Although there are perhaps a dozen different brands of video head cleaners on the market, most from reputable companies, many technicians strongly advise against their use. In their view, the only way to thoroughly clean a VCR while avoiding excessive head wear or damage is to return the machine to a factory-authorized service center for cleaning. My own view is that a wet or dry head-cleaning videocassette from a reputable company is unlikely to cause problems if used precisely according to instructions and *only* when a grainy or lost picture shows that its services are needed. As I mentioned, head clogging is rare when new high-grade tapes are used.

If I had followed the advice of those who advocate factory service, by now I would have paid for at least seven or eight cleanings of my old VCR (at perhaps a $50 to $75 a shot) in addition to the inconvenience of getting it to and from the service organization, and not having it available for use while being serviced. Since my older machine doesn't seem to have suffered any ill effects from years of at-home cleanings, it's clear that the money saved by a good head-cleaning cassette more than compensates for any additional head wear it might cause.

Stray magnetic fields

Because the video picture and audio sound are embodied on a tape in the form of complex magnetic patterns, anything that disrupts those patterns—such as strong external magnetic fields—should be avoided. Therefore, don't store tapes close to or on top of sources of magnetic energy such as loudspeakers, amplifiers, and any other electronic component that has a large power transformer. A distance of two to three feet from potential problem areas should be more than adequate. Incidentally, I've heard of cases in which vacuum-cleaner motors caused partial tape erasure, so be careful when cleaning the tape-storage area.

Handling

Some experts advise that stored open-reel tapes and audio and video cassettes be "exercised" by fast-forwarding and rewinding them at least once a year. The purpose is to prevent possible print-through of the audio track and/or adhesion between tape layers. It seems to me that there is no harm in such a tedious procedure, but before you embark on such a long-and-winding road for video, I suggest investing in a videocassette winder, which will speed the process and save wear and tear on your VCR.

The ultra-cautious also suggest storing audio and video tapes in just-played condition (rather than rewound to the beginning, as video-rental places prefer). Their reasoning is that during normal play, tape tension is better distributed throughout the tape layers because of the slow playing speed and because video play is under direct servo control by the VCR, unlike during tape winding. Storage after play *without* rewinding is the practice followed by audio recording studios with their open-reel master tapes. However, its relevance to cassettes, audio or video, is unclear.

It's also generally advised that tapes be stored vertically to avoid possible damage to the tape edges. However, I suspect that the advice is simply a holdover from open-reel days when the tape "pack" would droop toward the bottom flange if the tape were stored horizontally. The tape pack in cassettes is smaller, lighter, and better positioned by its enclosing shells.

I should admit that I tend to leave my tapes unexercised, sometimes half-wound, out of their storage cases, and stored every which way. And in thirty-odd years I've never experienced any audio or video tape problems clearly caused by my negligence. Then again, maybe I've been lucky or simply haven't noticed. **R-E**

"What's the penalty for not rewinding tapes?"

LAWN MOWER

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output (pin 7 of IC4-b) in the positive direction by a few volts. Capacitor C4 is used to create a low-pass filter at the output stage of the D/A circuit. The D/A circuitry and the manual-control input (J4 pin 8) provide the steering input reference to the velocity-feedback loops.

Velocity-feedback loops

Each loop consists of a summing junction, amplifier, PWM, velocity feedback, tachometer circuitry, and inverter/switch. Since the right and left velocity-feedback loops are basically identical, we will discuss the details of the left velocity loop only. Op-amp IC4-d acts as the summing junction and amplifier. The steering reference signals are coupled to the op-amp's inverting input (pin 13) through resistors R24–R28 and R40. Capacitor C5 is used to create a low-pass filter at the amplifier's output (pin 14). After the signals are added and amplified, they are passed through R57 to IC9, a UC3637 *P*ulse *W*idth *M*odulator (PWM) IC, that sends PWM signals to the power board for running the drive motors.

Also contained on the motor-controller board are the grass-sensor amplifiers, which are shown in Fig. 4—

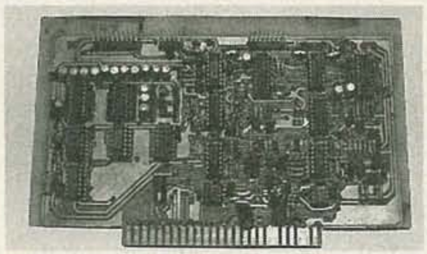

FIG. 5—THE MOTOR-CONTROLLER board fits in one of the motherboard's slots.

we will discuss them shortly. A photograph of the motor-controller board is shown in Fig. 5.

Within the motor housing is a chopper wheel that is used for sensing wheel (and motor) speed. The chopper wheel is shown in Fig. 6. The wheel has gear-like teeth that move through a dual opto-interrupter module as shown in Fig. 7. As the teeth

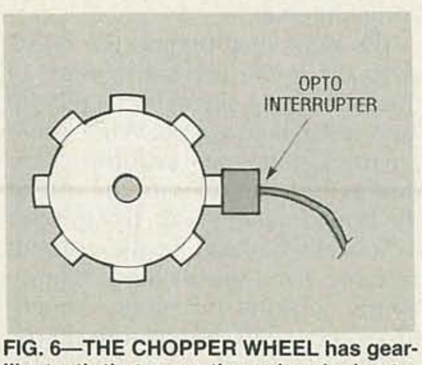

FIG. 6—THE CHOPPER WHEEL has gear-like teeth that move through a dual opto-interrupter module.

move through the opto module, they'll intermittently break the two light beams causing the module's internal phototransistor to turn on and off. The process creates two square-wave outputs, IN 1-1 and IN 1-2, that have pulse widths that are proportional to the speed of the chopper wheel, motor, and drive wheel. Since one light beam is broken before the other, IN 1-2 will always lead IN 1-1 in phase by 90 degrees when the motor is in moving in the forward direction. Figure 8 shows the two square-wave outputs from the dual opto-interrupter module. When the wheel spins in the reverse direction, the phase of the two square waves will switch. In that case, the square wave at IN 1-1 will lead in phase by 90 degrees. That tells the motor-controller circuitry if the drive wheels are moving forward or backward.

The square-wave outputs for the left drive motor are fed to the motor controller board via J3, pins 7 and 8. The signals are buffered by inverters IC1-c and IC1-f and then sent to D-type flip flop IC2-a. The flip flop is used to determine motor direction; forward or reverse. Since the flip flop clocks in data during the 0-to-+5-volt transition at pin 3, 0 volts will be indicated at the Q output (pin 5) when the motor is moving forward. Conversely, +5 volts will be at the Q output when the motor is in reverse.

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DRAWING BOARD

Scrambling and Macrovision

ROBERT GROSSBLATT,
CIRCUITS EDITOR

IF YOU'VE BEEN ALONG WITH US ON OUR magical trip through videoland, you've had enough basic video stuff jammed down your throat to get a high-level executive job at the local network. If you've built the hardware as well, you're in line for the network presidency. The most important thing you should have picked up from everything we've been doing is that the video signal is an extremely complex waveform with strictly defined timing parameters. As with most complex things, however, it's a lot harder to put it together than is to take it apart. Just like a jigsaw puzzle, it may take three weeks to build but it takes only three milliseconds to wreck.

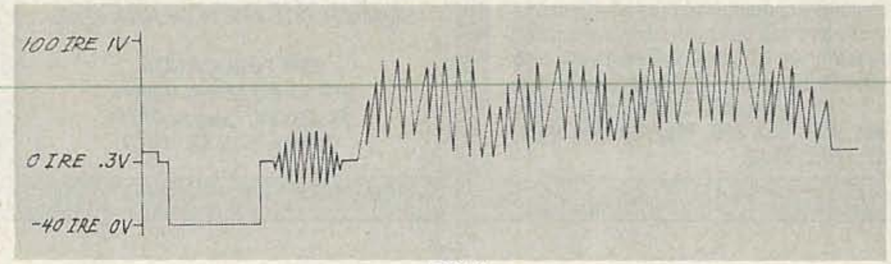

FIG. 1

Modern art aside, the only way you can get an image on the screen is by having all the right signals show up at the right place at the right time. Leave out just one of the required control pulses and the TV set will turn up its nose at the entire signal. If you don't have all of it, you might as well have none of it.

And, before I forget, several people have written asking where they can get the 8284 we used as the master clock generator. Frankly, I'm a bit surprised anyone had any trouble finding it since the chip is carried by most of the mail order houses that advertise in **Radio-Electronics**. All I can say is that even though the 8284 isn't listed in their ads, I know for a fact that it's part of the inventory. Just give any of them a call and, as the man said, ask for it by name.

The picture area

The sync system we've been studying and building is only one part of the NTSC signal - let's not forget that there's no point to having the control signals if there isn't picture there as well. I suppose that some people are such hard-line couch potatoes (now where did that come from?) that they even enjoy an evening of staring at a blank screen. Come to think of it, some of the stuff that shows up regularly on the tube isn't much better. But, then again, four hours of a blank screen means four hours without commercials so maybe it's really not so bad after all.

Since we now know that everything in the NTSC signal is predefined, it shouldn't be any surprise to learn that there are rules for picture information, as well. The illustration of a line of video in Fig. 1 should be an old friend by now, but this time we're going to talk about the picture area rather than the horizontal interval.

The basic idea behind the NTSC standard is the vertical division of the 1-volt video signal into a control area and a picture area. While there are rules for the picture information (just as there are rules for the stuff in the horizontal interval), things are a lot looser when you're talking about pictures. Sync signals have requirements covering placement, amplitude, and width, but picture signals are required only to meet placement and amplitude requirements.

Although there's no real data shown in the video information part of Fig. 1, a typical line of real video might look exactly like that. The thing that should be obvious in the drawing is that the video information has to be placed outside the horizontal interval and it can't go below 0 IRE units (about 0.3 volts) or above 100 IRE units (about 1 volt). A level of 0 IRE produces a black signal and a level of 100 IRE produces white.

The reason that video levels are usually referred to in terms of IRE units is that, while the signal is supposed to be 1 volt peak-to-peak, some VCR's and other equipment put out different levels. The manufacturers calibrate them before they leave the factory but, as we all know, stuff happens. Most video inputs are clamped by one means or another so that the video signal being fed to it is chopped down to 1 volt but the ratio of picture data to video data is still at the IRE standard. Zero IRE is defined to be roughly one third of the complete peak to peak voltage swing regardless of the actual voltage. A level of zero volts is always −40 IRE units and 100 IRE units (100% white) is always the upper level of the input voltage swing.

Picture information can have an amplitude of slightly less than 100

IRE units. That's because it starts at 7.5 IRE units rather than at 0 IRE units. The area from 0 to 7.5 IRE units are reserved for what is officially referred to as the "set-up level." The top of that (7.5 IRE units) is the black threshold and the bottom (0 IRE units) is the top of sync. You can see that in Fig. 2. Having that small buffer area is a way of acknowledging that things don't always work in real life as nicely as they do on paper. The 7.5-IRE unit gap is best understood by realizing it's just adding a bit of hysteresis to the system. Real-world signals don't always pay absolute attention to the written NTSC video standard.

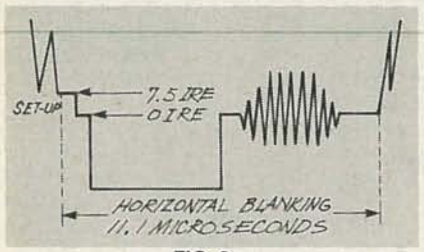

FIG. 2

Making pictures

If you're into abstract impressionism, it's really easy to make video appear on the screen. The only requirements you have to follow are to gate the picture signal with sync and limit the amplitude to the upper 100 IRE units. I don't know what you'll see on the screen but the chances are that if you take pictures of it you'll be able to sell them for some outrageous amount of money. However, if you're into structure, it's going to take a bit more work to have something recognizable show up on the screen.

If you've been around since we started this video stuff, then you already know enough to make something appear on the screen. What's key here is exactly what's meant by the word "something." Getting a screen full of bars or dots is possible with a handful of standard parts. The approach to the design is simple since it's really the same as the one we went through when we were designing the hardware to generate sync.

The simplest case would be a series of vertical bars. All that's needed is circuitry that goes high and low at periodic intervals and is gated by horizontal sync. If it puts out highs at the same place on each line of video you're going to see a series of vertical bars on the screen. If you want to break the lines vertically and wind up with a series of squares, you'll have to keep track of the number of lines and enable the production of highs only on certain lines. It would also be a good idea to reset the entire circuit during the vertical interval so the squares don't do a vertical creep on the screen.

In the interest of space, I'm going to leave the design of the circuit to you. As a matter of fact, it's time for another contest anyway so let's make one out of this. The rules are simple. All you have to do is put an image on the screen. The ones who put the most interesting image on the tube in the most interesting manner will be the winners. What I'm looking for is slick circuitry more than art but I'll take both into account when judging the entries. Since there's an artistic side to this contest, and the difference between garbage and gorgeous is in the eyes of the beholder, there will be several free subscriptions to **Radio-Electronics** available.

Scrambling pictures

Now that we know how video is made, it's worth spending some time to see how it's unmade. Of course I'm talking about some of the stuff that the friendly folks at your local cable company do to the images they send to your house. Unless you've spent the last couple of years with the fish faced people of Neptune, you're aware of the nasty art of video scrambling—both on cable TV and commercial videotapes.

Let's take these one at a time.

Cable companies make extra money selling subscription services and most of them are scrambled to keep you (at least in theory) from being able to watch them without paying. Before we get into what they do to video, I want to make a couple of philosophical points.

The people at the cable companies seem to go absolutely non-linear whenever someone builds their own descrambler and watches their stuff without paying. As far as I'm concerned, any cable company executive who thinks that way is full of...errors in judgment.

At a certain point on the cable, signal ownership transfers from the cable company (that's them) to the subscriber (that's us). The same sort of argument used to be used by the phone company. I'm sure that everyone remembers the days when adding your own extension phone meant risking the wrath of the phone company. They finally got smart enough to drop that attitude and limit their sphere of responsibility to bringing a line into your house. The cable TV companies are still working on the original telephone standards.

If you have cable TV service, it's reasonable to agree that they own the signal as long as the signal is running through their own equipment. That includes their cable, their tuner, and an argument can even be made that they own it all the way to the input jacks of your VCR or TV. Once the signal gets into your stuff however, as far as I'm concerned, it's yours.

If you modify your television to unscramble cable signals, that should be nobody's business but yours. And if that still seems to be questionable, let's suppose you were able to make some kind of optical screen that went in front of the TV and unscrambled the picture, how could the cable companies complain about that? And if you had built a device that scrambled clear reception, you can bet your bottom dollar that the cable companies wouldn't care about that either.

The point I'm making is simple: if the cable company doesn't want me to watch something I haven't paid for, don't put the signal on the line in the first place. The cable company argument that anything I do to unscramble the picture, even inside my own TV, is a theft of service, is covering up the fact that it's cheaper for them to scramble the signal than it is to send it only to people who pay for it.

I must have had this discussion with just about everyone I know and I'm interested in finding out what you think of it. Write in and let me know what you think.

We'll get to the basics of video scrambling next month. First, let's move on to another unpopular video topic: Macrovision.

We've all been hounded by Macrovision and had to live with copies that blink constantly when they're viewed. Since there's lots of easy to get (and legal) equipment around to beat Macrovision, I don't see any reason other than greed for the fact that it's still used. If you want to make copies of tapes that have been infected with Macrovision you can buy (or build) circuitry to eliminate it, but there's a much easier way to do it, and it shouldn't take you more than a few minutes to make Macrovision a thing of the past.

Since the idea behind Macrovision is to put pulses in the vertical interval that confuse the AGC (*A*utomatic *G*ain *C*ontrol) of the VCR used to record the copy, all you have to do is locate the AGC trimmer in the VCR and turn it down. As soon as you kill the AGC, the Macrovision pulses won't have any effect at all. People make arguments that you need the AGC to protect the video circuitry in the VCR, but the video output of most consumer equipment is clamped to about one volt so the chances are that you can live very well without it. If you're really not sure about killing it completely, move the trimmer to the front panel of the VCR. Most VCR's use DC control lines so there's not even a noise problem by adding some wire and a potentiometer to the circuit.

If you're nervous about that, remember that some VCR's don't get messed up by Macrovision. The reason is that either their AGC has been turned way down, isn't working, or isn't there. Save yourself some money by getting the service manual for your VCR and making the adjustment yourself. It's easy to do, and, once you've done it, you probably won't see any difference in the way the VCR behaves and you'll more than likely forget about it.

Macrovision was designed to keep people from making and selling pirated copies of videotapes. Since it's so easy to beat, there's no reason for keeping it around. The real protection for the people selling commercial tapes is the obvious difference in quality between the original and the copy.

Macrovision makes commercial tapes more costly to produce and more expensive for the consumer—and that's all it does. It was a stupid idea when it first appeared, is even more stupid now, and it's time to get rid of it.

Write letters, sign petitions, and I'll talk to you next month. **R-E**

LAWN MOWER

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The square-wave signal IN 1-1 is tapped off IC1 pin 5 and sent to IC5, a frequency-to-voltage converter that produces an analog voltage that represents wheel velocity from the square-wave frequency. The analog switch IC8, which is controlled by IC2-a, is used to select the forward and reverse velocity-feedback signals. When the motor spins in reverse, the velocity-feedback loop requires an inverted signal in order to maintain negative feedback; that inverted signal is produced by IC4-a.

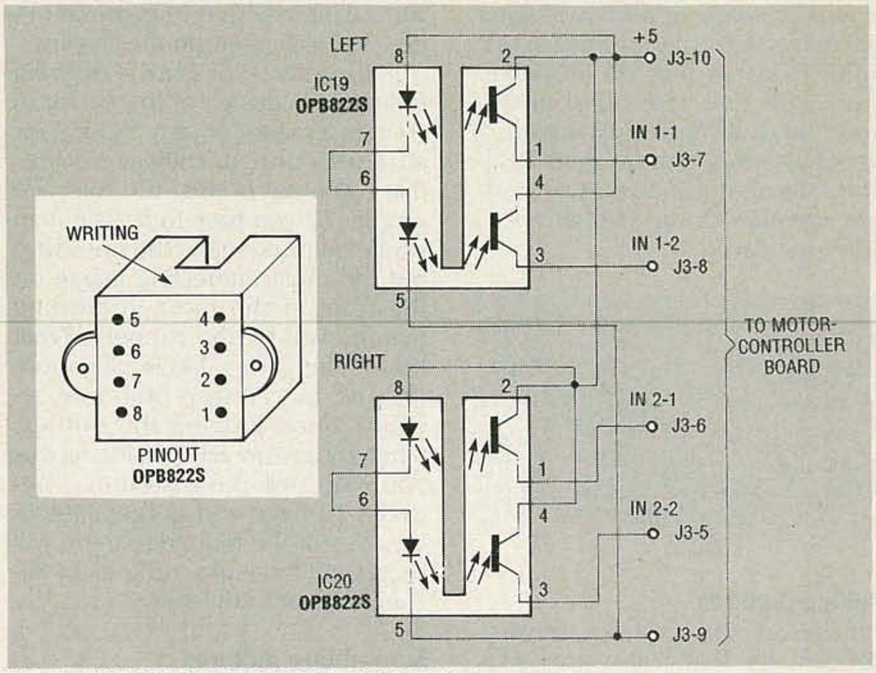

FIG. 7—THE OPTO-INTERRUPTER MODULES keep track of wheel movement.

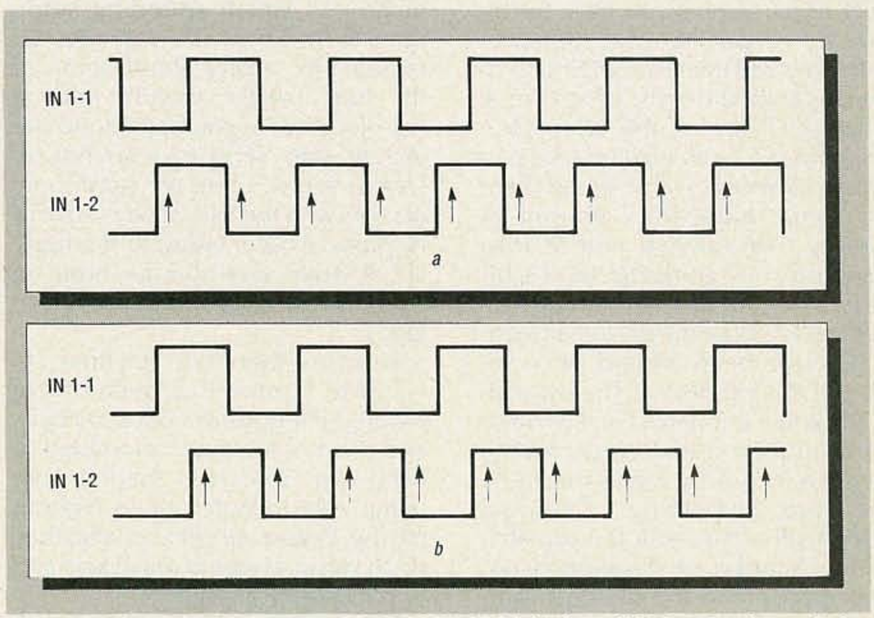

FIG. 8—WHEN THE LEFT WHEEL GOES FORWARD (*a*), pin 5 of IC2 is at 0 volts, and when the left wheel goes in reverse (*b*), pin 5 is at 5 volts.

Pulse-width modulators

The pulse-width-modulator function is performed by two UC3637 PWM IC's, IC9 and IC10. Pins 9 and 11 are the input to the PWM IC's, pin 4 is the "forward" output signal, and pin 7 is the "reverse" output signal. When the left wheel is moving forward, the analog input voltage to pins 9 and 11 will vary between +0.7 volts

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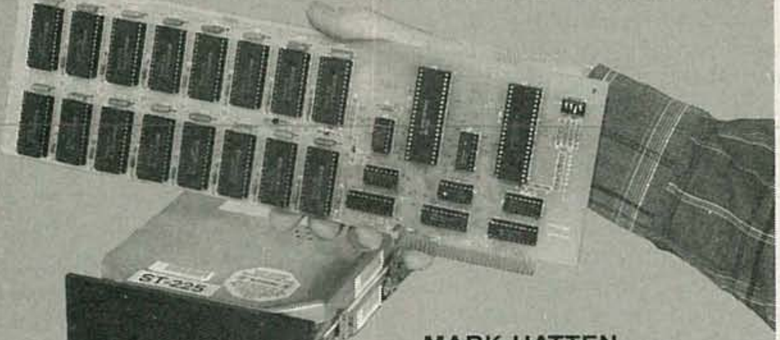
COMPUTER DIGEST

BUILD A SOLID-STATE DISK DRIVE



MARK HATTEN

Retain important PC data with this inexpensive battery-backed RAM disk.

Wouldn't it be nice if you didn't lose memory contents every time you turned off your PC? And wouldn't it be nice to have a RAM disk that didn't tap into your regular memory, whether conventional (0–640K), extended (above 1 MB), or expanded (bank-switched beneath 1 MB)?

If you think that either would be nice, then you'll be interested in our static RAM disk. It's a full-length card for any 8- or 16-bit expansion slot; you can install 32K–512K of static CMOS RAM's on the board. The board has provision for an optional battery backup system so the card will retain its contents even after the main system loses power. That capability could be useful in remote data logging or industrial use.

You can build the board for well under $100, not counting the cost of the RAM. A double-sided PC board is available, as are complete kits and assembled units. The complete assembly-language source code for the RAM disk is also available, allowing custom modifications.

Hardware overview

The circuit consists of three main sections: the RAM array, the bus interface circuit, and the battery backup circuit. Figure 1 shows a block diagram.

The static RAM portion consists of a maximum of sixteen 32K × 8 CMOS static RAM's (SRAM's), divided into two banks. The address and data lines of all SRAM's in both banks are driven by IC1, an 8255 configured as a triple parallel port. Port A drives the low-order address lines (A0–A7), Port B drives the high-order address lines (A8–A14), and Port C drives the data lines (D0–D7).

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EDITOR'S WORKBENCH

Letters

Several items in recent columns have provoked questions from readers. Following are my responses.

M. Delez of Juneau, AL asked for clarification on what I meant by stating that the number of jobs in hardware servicing would shrink (see Editor's Workbench, April 1990, p. 70). Mr. Delez is seriously considering a career in computer and audio/video servicing, and wonders what he should do. As stated in the article, I was talking about *component-level* servicing (and R&D work). Perhaps I should have made it clearer that higher-level servicing—board swapping and the like—will continue to be a high-activity sector of the job market.

A. Kusnevick of Paxton, IL asked for clarification on the ROM-scan routine that a PC BIOS executes when booting (discussed in conjunction with Annabooks' PromKit, in the March 1990 Editor's Workbench, P. 72). In particular, he wondered where the byte that specifies the number of 512K blocks of memory is located. In a ROM that is to become a BIOS extension, the first byte contains 55h, the second byte contains AAh, and the third contains the length specifier, which specifies the number of 512-byte blocks in the ROM. The fourth and fifth bytes contain the address in the ROM where the initialization routine is stored. If the checksum of all bytes in the ROM equals zero, the BIOS saves its current location on the stack and calls the init routine, which should end with a FAR RET to continue the boot process and turn control over to COMMAND.COM.

Another reader took me to task for my statement in the April 1990 column (p. 70), that few of the modern generation of word processors allow you to type and format equations in a quality manner. He included a sample printout of the same equation shown in the magazine as rendered by WordPerfect 5.1. My excuse is simply the fast-changing character of this business; I wrote that column shortly before WordPerfect 5.1 was released. You may also be interested to know that Ventura Publisher with the Professional Extension has an equation editor. So does Word for Windows, which also has a BASIC-like language that allows you to *solve* equations as well as display and print them.

On a related note, I just received an advertisement for a program called Exact that loads as a TSR and pops up within your word processor. The program allows you to see expressions as you type them, and apparently to use your word processor to print them as well. More than twenty word processors are supported. Contact Technical Support Software, Inc., 72 Kent Street, Brookline, MA 02146 (617) 734-4130 for more information. If there is sufficient reader interest, I'll get a copy of the program and check it out.

Of course, displaying and printing equations is only icing the cake. The real work consists of deriving the equation, making the calculations, and plotting the results. And that leads us to a really neat software package called Derive.

Fun with Math

Derive is simply amazing. In the company's words, "Derive is a menu-driven symbolic math system for personal computers. Derive does numerical and symbolic equation solving, exact and approximate arithmetic, calculus, trigonometry, and matrices. Derive Plots expressions in 2D and 3D on monochrome and color graphics monitors."

One might add that it does all that without requiring a 386, or a math coprocessor, or lots of memory. A PC compatible, 512K of RAM, and a single floppy are all you need; a graphics display is also nice for viewing plots. Hercules, CGA, EGA, VGA, and several other formats are supported. Derive also runs on the NEC PC-9801. The program will run faster on faster machines, of course, but it won't use more than 640K of memory or a coprocessor, even if either or both happen to be present.

The following are several examples of what Derive can do. (Solutions will be presented below.)

- Compute π to 70 decimal places.
- Simplify algebraic expressions $(X+1)/(1-X^2)$.
- Factor large numbers (987654321)
- Perform complex-number arithmetic manipulation
- Find symbolic limits, do differentiation, find Taylor series, manipulate vectors and matrices, etc.
- Solve just about any computable equation to just about any desired degree of precision.
- Plot just about any equation of one or two variables.
- Generate an expression in a form suitable for inclusion in any BASIC, FORTRAN, or Pascal program.
- And that just scratches the surface.

Features

Derive comes on a single floppy disk; the executable file is about 227K. The disk also includes several sample files containing various expressions useful for various types of calculations. Installation consists simply of copying the files to your working disk.

The program works using an amalgamation of Microsoft Word style menus and WordStar keystroke commands. Command menus appear near the bottom of the screen; you execute a command by highlighting it and pressing the Enter key, or by pressing the capitalized letter in the command.

You use the Author command to type in and edit expressions. Each expression is numbered; expressions scroll up the screen each time you add a new one. You can't edit an expression after pressing Enter, but various editing commands allow you to copy parts of previously entered expressions into the current one. And the Build command allows you to build up a complex expression from previously entered ones.

After entering an expression, you can simplify it, factor it, expand it, solve it, plot it, or save it. Of course, you can also load previously saved expressions.

Derive includes several features that simplify expression entry. For example, you don't have to enter an asterisk to indicate multiplication. Variables are normally a single letter, but you can configure the program to use multi-character names. Variables and constants can be designated by the Greek letters in the IBM PC character set by pressing an Alt-key combination (e.g., Alt-P for π).

Derive includes all common operators and functions (+, −, *, ÷, exponentiation, log, ln, sqrt, abs, sin, cos, tan, cot, sec, csc, max, min, RMS, VAR, STDEV), and numerous others. You can also write your own functions, and declare constants to be used in calculations.

Internally, Derive stores every rational number as an integer or a ratio of integers. Irrational numbers (e.g., SQRT(2)) are stored in symbolic form. You can force Derive to compute results in exact, approximate, and mixed modes. In exact mode, all computations are done using integers and symbols, so there are no round-off errors.

In approximate mode, irrational numbers and fractional results of rational operations are rounded. You can set the number of decimal places after which rounding occurs. So if you really want to know what π to 500 decimal places is...

In mixed mode, rational numbers are computed exactly, while irrational numbers are accurately approximated.

Exact mode provides the most precision, but requires the most memory; approximate mode computes fastest and uses the least memory.

You can also specify separately the display mode (rational, decimal, scientific, or mixed; and number of display digits), and number base. For the latter you can specify different values for input and output, thus allowing Derive to function as a number base converter. Derive accepts number base values between two and thirty-six.

You can plot any one- or two-variable equation. A single variable gives a 2D plot; two variables give a 3D plot, as shown in Fig. 1. In either case you can alter several parameters to vary the appearance of the plot, including scale, number of "tick" marks on the axes, and viewing angle of a 3D plot. It's particularly fascinating to view a 3D plot from different angles. Unfortunately, Derive includes no print module, so to print a plot, you'll have to rely on a third-party screen-print utility.

Derive's initial screen is where you enter expressions and where Derive displays results. If you choose to plot an expression, Derive switches to another screen. However, you can split the screen into several windows, each of which may be either an expression window or a plot window. Figure 2, for example, shows a three-window screen at VGA resolution. Window 1 contains several expressions; note that expression 27 (y/x) is highlighted; that is the current expression. Window 3 shows a 3D plot of that expression, and Window 2 shows a 3D plot of expression 26 (x/y).

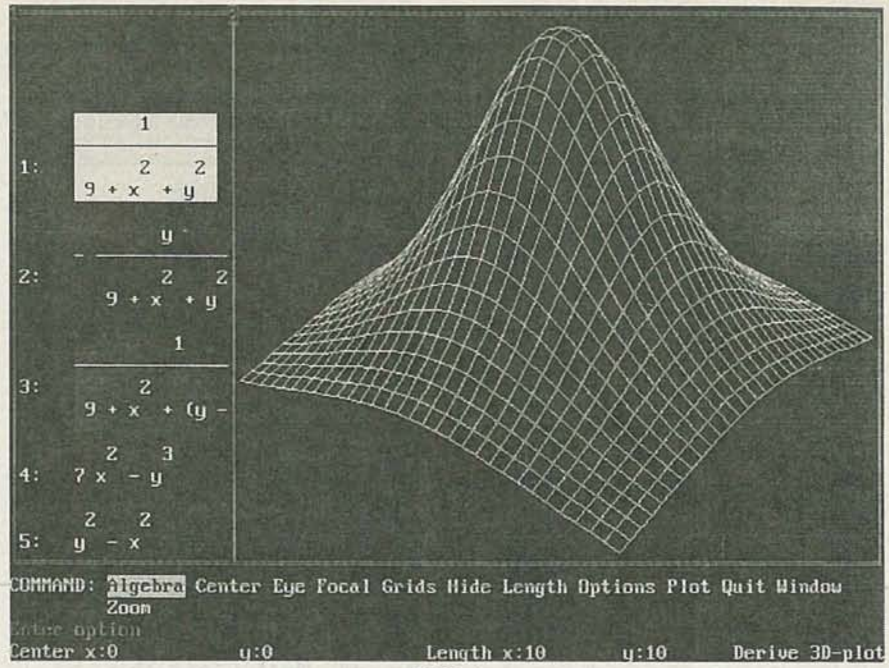

FIG. 1

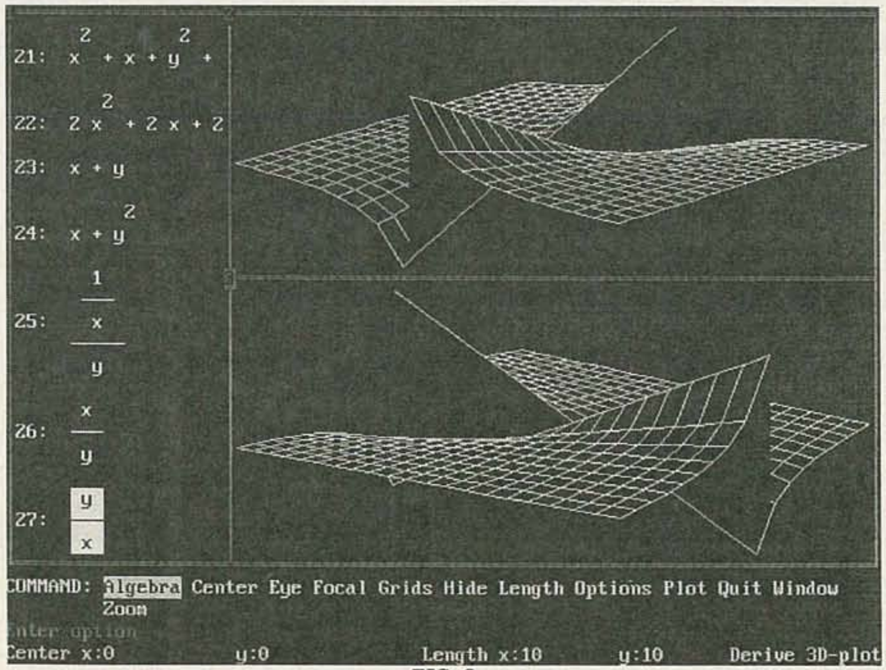

FIG. 2

Using Derive

To say that Derive can do all of those things does not in the least say how much fun it is to use the program. And it's obvious that you can have fun with Derive, regardless of your prior mathematical training. You might also learn something in the process.

In playing with Derive, I followed the basic sequence of my mathematical education. To start learning how to use the program, first I tried some basic arithmetical expressions. Confidence grew quickly, so I tried some algebra. I remembered plotting various equations ($y=x^2$, $y=x^3$, etc.) by hand in high-school algebra. So I typed in a simple equation and issued the plot command. Instant gratification. Since it was so easy, next I tried variations on basic themes ($y=x^2+1$, etc.). In that way I could see instantly how changing different constants and variables affected a given type of equation.

Then I was off into trigonometry. First it was sin (x). Next was 2 sin (x). Then sin x^2. You get the idea.

With 3D plots, you could easily spend hours trying different equations, different viewpoints, etc. Even my wife, a decidedly non-mathematical person, got involved. "Let's try just one more..." The point is that Derive is a superb educational tool. It's also a serious and powerful tool for scientists, mathematicians, and engineers. It's therefore *highly* recommended.

Here are solutions to the questions posed above.

1. 3.141592653 589793238 462643383 279502884 197169399 375105820 974944592 307816
2. $-1/(X-1)$
3. $3^2 \times 17^2 \times 379721$ ◗CD◖

Exploring Math With Derive

Derive comes with a user's manual that is really a reference guide for those who already know what they are doing. If you're interested in Derive from an educational point of view—either for yourself or for someone else—you'll want to check out *Exploring Math from Algebra to Calculus with Derive, A Mathematical Assistant.* The author is a professor of mathematics, and it is obvious that he sincerely wants to find ways of teaching people about math, not just the wizards, but the rest of us as well, and that he thinks Derive can assist the process. The book is extremely friendly in both the way it is written and in the way it is laid out.

Chapter 15 of the book describes how the author has used Derive to teach math to students at various levels, including first-year calculus students, first-year algebra students, fifth graders, and first and second graders. Seriously. How many pieces of software have you seen that could be used by graduate engineers and first graders? If you're still in school, know someone who is, or need a brush-up, Derive and a copy of this book should be high-priority items. ◗CD◖

ITEMS DISCUSSED

- Derive ($200), Soft Warehouse, Inc., 3615 Harding Avenue, Suite 505, Honolulu, HI 96816. (808) 734-5801.
  CIRCLE 246 ON FREE INFORMATION CARD
- *Exploring Math from Algebra to Calculus with Derive, A Mathematical Assistant,* by Jerry Glynn, published by MathWare, 604 E. Mumford, Urbana, IL 61801.

RAM DISK

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A second 8255, IC2, drives the chip select ($\overline{CS}$) inputs of all SRAM's. Port A drives IC11–IC18, Port B drives IC19–IC26, and Port C is not used.

The bus interface consists of a group of buffers and gates that isolate the circuit from the PC expansion bus, and they're also used to decode a set of I/O port addresses for passing data and control information.

The battery-backup circuit consists mostly of several diodes that isolate the optional battery from the PC's power source. We'll discuss the hardware in more detail next time.

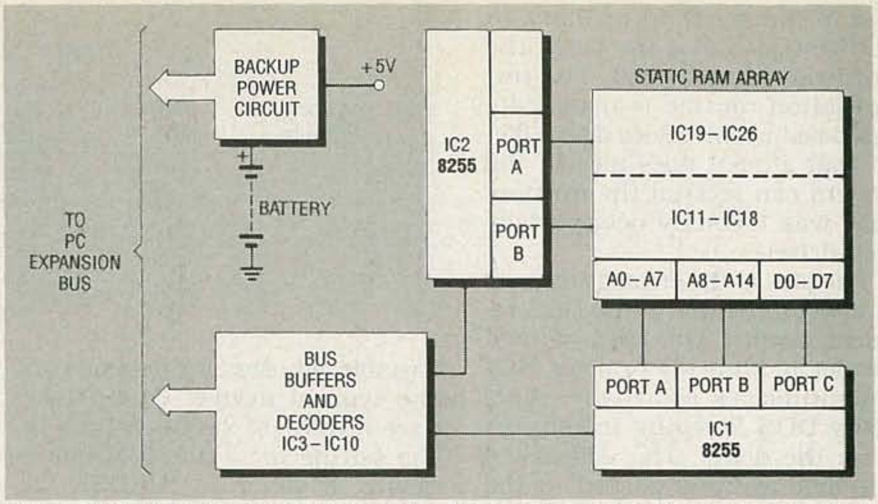

***FIG. 1.** THE STATIC RAM DISK consists of three major subsystems: an array of as many as sixteen 32K CMOS static RAM's, a bus-interface circuit, and a battery-backup circuit.*

Software success

Success for the PC has come about in part because of the expandability of the system. A good part of that versatile expandability is due to the concept of the *device driver.*

A device driver provides a means of adding special features to DOS in such a way that those features appear to be an integral part of DOS. In fact, DOS itself comes with several built-in device drivers.

- ANSI.SYS is a device driver that provides a standard way of dealing with the display system.
- DRIVER.SYS is a device driver that lets you add high-density floppy disks to older machines, and to refer to the same physical disk drive by several different drive letters.
- VDISK.SYS is a device driver that emulates a disk drive using either conventional or extended memory.

Manufacturers of special equipment often supply their own device drivers. For example, network interface cards, CD-ROM drives, and some types of hard disks require device drivers.

What all device drivers share is the fact that, if a driver is to be used, it must be loaded from disk every time a PC boots. How does DOS know which device driver or drivers to load? Via the CONFIG.SYS file.

CONFIG.SYS is simply an ASCII text file; each driver that DOS is supposed to load must be specified on a separate line in the file. (CONFIG.SYS also specifies several operational parameters particular to your machine; see your DOS manual for details.)

The structure of a device driver line in CONFIG.SYS is as follows. Spaces are shown for clarity, but must not be included, except between the name of the driver and the optional parameters.

DEVICE = [drive:][\PATH\]
[DRVNAM][PARMS]

First comes the phrase DEVICE =. Then comes an optional drive and an optional path and subdirectory where the driver is stored. If no drive is specified, the boot drive is assumed. If no path is specified, the root of the boot drive is assumed.

Next is the name of the driver itself. The name must follow normal DOS file-naming conventions: a name with a maximum of eight characters, plus a three-character extension. Common extensions include SYS and BIN, but neither is required. Last come any optional parameters the driver might require.

As you've probably guessed by now, the SRAM disk uses a device driver to talk to DOS.

Types of device drivers.

There are two types of device drivers: character and block. As the names suggest, a character driver deals with information character by character, and a block driver deals with information in larger chunks called blocks. The size of the block can vary within certain limits set by DOS.

Examples of devices that use character drivers include the serial and parallel ports. Examples of devices that use block drivers include the floppy and hard disk drives.

Generally speaking, a block driver can operate more efficiently than a character driver, because there is less overhead involved in each transfer of information to or from the device controlled by the driver. With some physical devices (disk drives, for example) you know that each time you request some information, you'll get, say, 512 bytes.

However, you can't always use a block driver. With a serial port, for example, you can obtain only a byte at a time. The SRAM disk could have been implemented as either a character or a block driver but, for the sake of efficiency, has been implemented as a block driver.

Driver components

A driver consists of three main components: an initialization routine, a strategy routine, and an interrupt routine.

The initialization routine is generally called once, when DOS loads the device driver. Its job is to set up pointers to the BIOS parameter block (BPB) and to the end of the driver in memory. In addition, it must initialize the hardware as required. The initialization routine is usually located last in the device driver file, so that after it does its job, the system can reclaim the memory that was formerly occupied by that driver.

The task of the strategy routine is to get a pointer to the DOS request header. The DOS request header is an array of bytes that communicates what type of activity DOS is trying to request from the driver. The address of the byte array is passed to the driver using register pair ES:BX.

The interrupt routine is what does the actual work. It can perform various types of operations, some of which are mandatory for block drivers, and others for character drivers. We'll discuss some of the more important operations now.

MediaCheck detects whether the storage media was removed or tampered with. BuildBPB (Build BIOS Parameter Block) deals with that occurrence. For example, DOS calls BuildBPB whenever it detects that a floppy disk has been changed. In our driver, MediaCheck always returns an OK sign to DOS. Because of that, BuildBPB will be called only once, when the drive is initialized.

The input and output routines pass sectors of data to and from the disk. They use a buffer area specified by DOS in the request header. The number of bytes per transfer can not exceed 64K (the maximum size of a memory segment). If a file is larger than 64K, DOS will read or write the file in 64K chunks until the entire file has been transferred.

Structure of a driver

Every device driver has a device header that occupies the first few bytes of the file. Our device header is shown in Table 1. The first entry (Nexdev) is there to provide a means of letting DOS link each device driver to the next. DOS fills in the links as it loads each driver; the last driver in the chain has −1 (FFFFh) in the Nexdev field.

The next entry is the attribute variable, whose value depends on the type of device. Our driver uses a value of 2000h, which is the setting for a non-IBM block device. If you run CHKDSK on the RAM drive, it returns a *Probable non-IBM disk* warning because of that value, but otherwise functions normally.

The next two entries are the addresses of the strategy and interrupt routines.

The last entry is an eight-byte field that is used differently for block and character devices. For a character device, you would assign a name like CON, PRN, LPT1, etc. For a block device, the first byte contains the number of physical devices that are being controlled by the driver, and the remaining seven bytes are undefined.

The BPB

Another important data structure in a device driver is the BIOS parameter block, or BPB. The BPB is a data structure that tells DOS everything it needs to know about the format in which information is stored on the specified device. The BPB is located in the first sector of a disk, and it includes several items, as shown in Table 2.

The first item in the BPB contains the number of bytes per sector. The next item specifies the number of sectors per cluster. If you're unfamiliar with the term *cluster* (also known as the allocation unit), it specifies the smallest number of sectors that can be allocated to store a file. For example, if ten clusters were allocated to a file, and if the BPB defined four clusters per sector, then the file would consist of forty sectors. Even if a file is only a single byte in length, it requires a full cluster on the disk.

Different versions of DOS use different cluster sizes. DOS 3.3 generally allocates four sectors per cluster (depending on overall disk size); DOS 2.x allocated 8 sectors per cluster.

The default allocation unit in the static RAM disk is one sector/cluster, but you could alter that value to be any power of two (2^0, 2^1, 2^3, etc.).

The next item in the BPB is the

TABLE 1—DEVICE HEADER

```
nexdev      DD    -1
attribute   DW    02000H
            DW    STRATEGY
            DW    INTERRUPT
            DB    1          ; number of devices
            DB    (7) DUP ?  ; used for char name
                             ; if char driver
```

Parts List

Resistors

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

R1–R5 .... *4700 ohms*
R6–R21 .... *22,000 ohms*

Capacitors

C1–C16 .... *0.01 µF polyester*
C17 .... *10 µF, 10 volts, electrolytic*

Semiconductors

D1, D2 .... *1N914 switching diode*
IC1, IC2 .... *8255 programmable peripheral interface*
IC3 .... *74LS245 bidirectional bus buffer*
IC4, IC5 .... *74LS244 octal bus driver*
IC6 .... *74LS138 three-to-eight line decoder*
IC7 .... *74LS85 four-bit comparator*
IC8 .... *74LS04 hex inverter*
IC9 .... *74LS00 quad NAND gate*
IC10 .... *74LS08 quad AND gate*
IC11–IC26 .... *43256-10 Static RAM*

Other Components

SW1 .... *four-position DIP switch*
B1 .... *four AA cells, with holder (optional)*

TABLE 2—BIOS PARAMETER BLOCK

BPB	EQU	$	
BPB_SS	DW	512	; sector size in bytes
BPB_AU	DB	1	; sectors per cluster
BPB_RS	DW	1	; sectors for boot sector
BPB_NF	DB	1	; # of FAT tables
BPB_DS	DW	16	; # of Directory entries
BPB_TS	DW	1024	; # of total sector
BPB_MD	DB	0FEH	; media descriptor
BPB_FS	DW	4	; # of sectors/FAT(S)
;BPB_ST	DW	00	; These variables would be
;BPB_NH	DW	00	; drive.
;BPB-H5	DW	00	; used for a real disk
BPB_PRT	DW	BPB	; Pointer to this table

number of sectors reserved for the boot sector. The boot sector of the BPB contains a short program that starts the process of loading DOS from disk. DOS itself contains the remainder of the loader program.

The next entry specifies the number of *F*ile *A*llocation *T*ables (FAT's). DOS uses the file allocation table to keep track of which sectors have been used, which are free, and which are physically damaged. DOS normally maintains two copies of the FAT; to conserve space, our driver maintains one.

Next in the BPB comes the number of directory entries. This value specifies the number of files that can be present in the root directory of a disk. (Subdirectories are actually files, so the number of subdirectories is limited only by the available disk space.) DOS 3.3 typically allows 512 directory entries; again, to conserve space, our driver allows 16.

The next BPB entry contains the total number of sectors contained on the disk. This value represents the total size of the disk, including space occupied by boot sectors, FAT's, etc. In our case, the total number of sectors (TS) can be determined from this formula:

TS = (32768/512)*(number of SRAM's)

The next entry is called the media descriptor; it specifies the type of media being used, the number of sides, etc. Our driver uses the code for a single-sided floppy-disk drive.

Following the media descriptor is a field that specifies the number of sectors that must be allocated to each copy of the FAT.

Several other fields in the BPB are defined for use with physical disk drives, including the number of sectors per track, the number of disk heads, and the number of hidden sectors. Our driver does not need to use any of those fields.

Obviously, the subject of device drivers is complex; for detailed information, the best work that was found by the author is called *Writing MS-DOS Device Drivers* by Robert S. Lai.

Next time, we'll discuss hardware operation in detail, and then show how to build and initialize the drive. ◆CD◆

Ordering Information

Note: The following are available from
Hatronics
145 Lincoln Street
Montclair, NJ 07042
(201) 783-7264
(201) 245-6614 (BBS, join the Hatronics conference)

Bare PC board **$50**
Kit with 0K RAM **$90**
Kit with 128K RAM **$155**
Kit with 256K RAM **$220**
Kit with 512K RAM **$322**
Assembled and tested unit, 0K ... **$135**
Assembled and tested unit, 256K **$255**
Assembled and tested unit, 512K **$395**
All orders add $10 for shipping and handling. .. **New Jersey orders add 6% sales tax.**

HARDWARE HACKER

continued from page 68

be *Jerryco's* stock #79106 copy-machine chassis. This is a wide dual-bin input feeder and registration assembly for $10.50. As is, its a great electromechanical treasurer trove. With some stupendous hacking effort, you might convert it into a fake Kroy Kolor machine, an automatic dual bin laser feeder, or find some unique robotics applications for it.

Arlin Shepard of *Lazer Products* tells me he has at long last found a few more *Canon* fusing units. We looked at these several columns ago for Kroy Kolor, lamination, and for dry-film printed-circuit bonding.

Adobe Systems has released their new black book, otherwise known as the *Adobe Type I Font Format.* This has all of the previously secret insider stuff on their encrypting, compacting, and the hinting of high-quality typography. I do have a few copies on hand here if you need one.

Turning to my own products, I've put together a special new *Lancaster Classics* package of six of my finest hardware books plus that complete *Hardware Hacker II* reprint set which covers everything that has appeared in these **Radio-Electronics** columns.

Finally, I've got a new and free mailer for you which includes dozens of insider hardware hacking secret sources. Write or call for info.

As always, this is your column and you can get technical help and off-the-wall networking per that *"Need Help?"* box. The best calling times are weekdays 8–5 in *Mountain Standard Time* Let's hear from you. **R-E**

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TUBES: "oldest," "latest." Parts and schematics. SASE for list. **STEINMETZ,** 7519 Maplewood Ave., RE, Hammond, IN 46324.

ENGINEERING software, PC/MSDOS. Hobbyists — students — engineers. Circuit design $49.00, PCB layout $99.00, Logic simulation $29.00, FFT analysis $69.00, Mathematics $39.00, Circuit analysis $29.00. Call or write for free catalog. (614) 491-0832, **BSOFT SOFTWARE,** 444 Colton Rd., Columbus, OH 43207.

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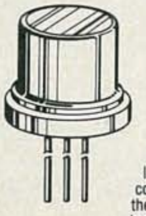

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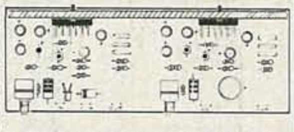

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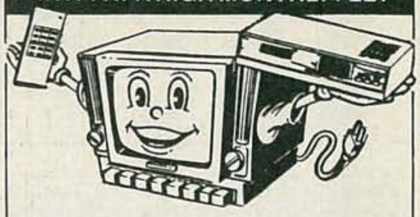

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LAWN MOWER

continued from page 74

(minimum speed) to +8.0 volts (maximum speed). Pin 4 will have an active PWM output and pin 7 will remain at −10 volts. Conversely, when the left wheel moves in reverse, the input voltage will vary between −0.7 volts (minimum speed) to −8.0 volts (maximum speed), and the voltage at pin 4 will remain at −10 volts. Therefore, each drive wheel can be made to move in the forward or reverse direction by simply changing the polarity of the input signal at pins 9 and 11.

Driver transistors

Transistors Q1–Q12 are used as drivers at the output of the PWM IC's (IC9 and IC10). Those transistors are required to convert the ±10-volt drive signal from the UC3637's into a 0- to +30-volt drive signal required by the power MOSFET's (contained on power board) to turn the drive wheels. As the forward output signal (IC9 pin 4) rises to +10 volts, Q2 will turn on and ground the R73-R72 junction. That causes Q1 to turn on and +30 volts to be applied to the power MOSFET inputs (J22 pin 25). When the forward output signal drops to 0 volts, Q2 will turn off and Q3 will be turned on. That causes the voltage at J22 pin 25 to quickly return to 0 volts. The resultant output is an amplified PWM signal that varies between 0 and +30 volts. The process is identical for the outputs at pin 7 of IC9 and pins 4 and 7 of IC10.

Sensor amplifiers

There are 15 identical grass-sensor amplifiers contained on the motor-controller board (see Fig. 4). The outputs are identified as BD1–BD15. Since all the amplifier circuits are identical, we will describe only the operation of the BD1 amplifier.

The input to the amplifier is AC coupled by capacitor C27. SIP-resistors R95 and R96 provide transistor-array IC16's bias voltage. (In order to conserve as much space as possible, transistor arrays IC16 and IC17 were used for most of the amplifier circuits instead of discrete transistors.) Transistor IC14-a provides an amplified output at its collector with the help of pull-up resistor R97-a. The output is coupled to inverter IC14-a for buffering and signal inversion. The TTL output of IC14-a (pin 2) is sent to the CPU board through J22 pin 2 for processing.

Motherboard

The motherboard provides the interconnections between the CPU board, the motor-controller board, and the power board. The motherboard is a simple two-sided PC board that contains three edge connectors. The schematic diagram of the motherboard will be shown next month.

Next month

Unfortunately, you'll have to wait until next month for details on how to build the motor-controller board and also the motherboard. We'll also provide foil patterns for the main and motor-controller board if you wish to etch your own PC boards. We will show you how to assemble all of the mechanical components and wind up with the completed working unit. **R-E**

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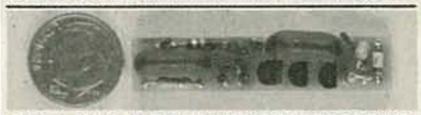

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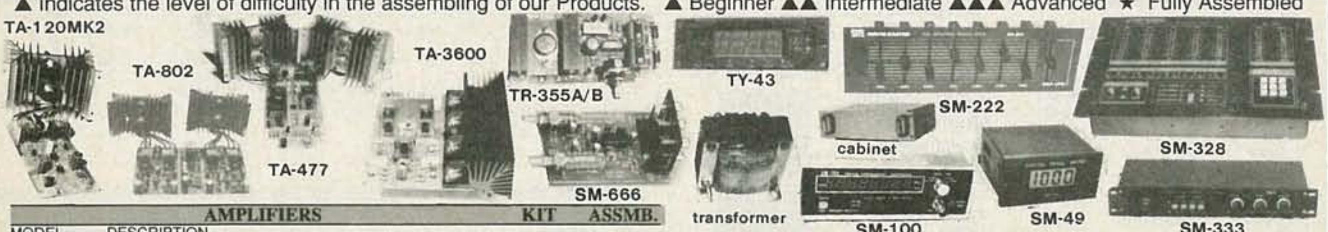

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TA-802	80W+80W DC Stereo Main Power Amp ▲▲.	45.94	59.72
TA-820A	60W+60W OCL DC Pre-Main Stereo Amp ▲▲.	40.39	49.37
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TR-503	O-50V 3A Regulated DC Power Supply ▲▲.	15.75	22.65
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TY-36	AC/DC Quartz Digital Clock ▲.	18.00	25.20
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LG-1684	4"	16"	8"	TA-322i, TA-323A, TA-377A	24.64
LG-1924	4"	19"	11½	TA-802, TA-820A, TA-1500, TA-120MK2, TA-800,	30.00
LG-1925	5"	19"	11½	TA-477, TA-800, TA-1500, TA-1000A	33.00
LG-1983	2¾	19"	8"	TA-377A, TA-2800, TA-2200, TA-120MK2	26.50

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002	72VCT 3A	TA-322i, TR-503, TA-323A, TA-400	21.00
003	80VCT 6A	TA-477	27.00
004	48VCT 6A	TR-120 MK2	21.00
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4164-100	100ns, 64Kx1	$2.75
4164-120	120ns, 64Kx1	$2.39
4164-150	150ns, 64Kx1	$2.15
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41256-80	80ns, 256Kx1	$3.75
41256-100	100ns, 256Kx1	$3.15
41256-120	120ns, 256Kx1	$2.95
41256-150	150ns, 256Kx1	$2.59
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511000P-80	80ns, 1 Megx1	$12.95
511000P-10	100ns, 1 Megx1	$12.35
514256P-80	80ns, 256Kx4	$13.45
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6264LP-10	100ns, 64K (CMOS)	$6.95
6264LP-15	150ns, 64K (CMOS)	$4.95
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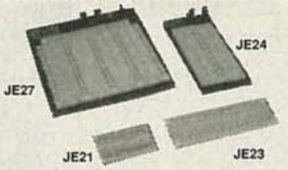

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JE23	6.5 x 2.125	830	0	$6.95
JE24	6.5 x 3.125	1,360	2	$12.95
JE25	6.5 x 4.25	1,660	3	$17.95
JE26	6.875 x 5.75	2,390	4	$22.95
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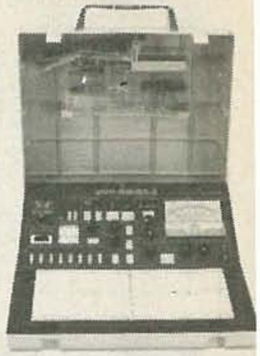
Prototype Design Stations

WM2



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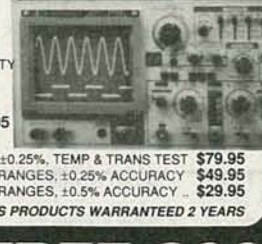

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