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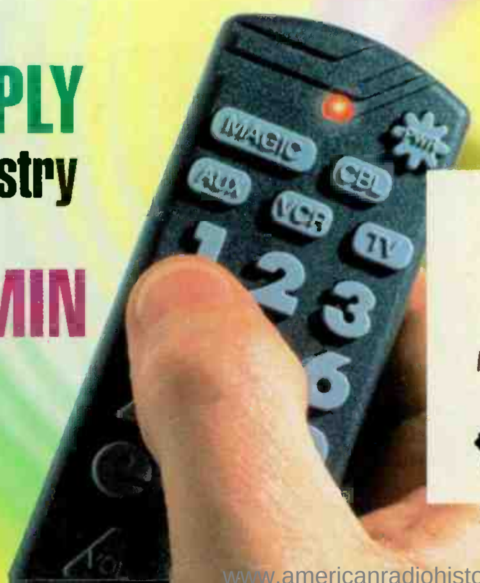


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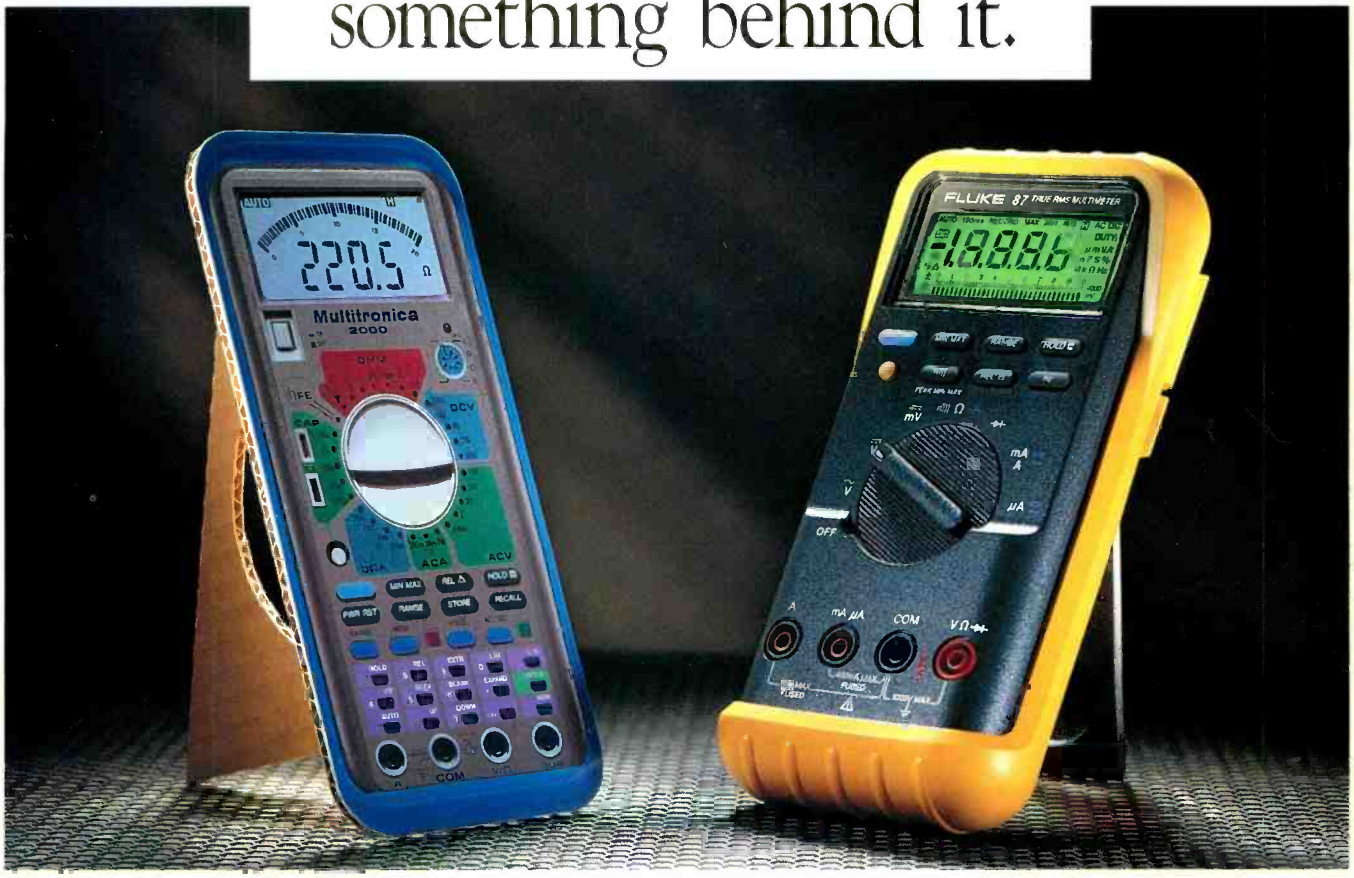


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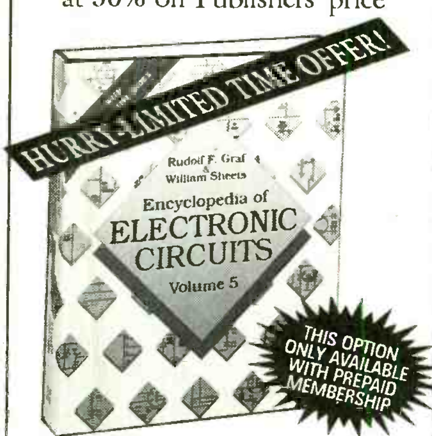


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## ON THE COVER




## BUILD THIS





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# MARCH 1996

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# WHAT'S NEWS

A REVIEW OF THE LATEST HAPPENINGS IN ELECTRONICS

## Sony Wall TV prototype displayed

At Comdex/Fall in Las Vegas, Sony demonstrated a prototype of what it's been calling a "Plasmatron" — a 25-inch diameter, 4-inch deep TV designed to be hung on a wall. The flat-panel televisions are slated for sale in Japan only, beginning in 1996.

The set uses Palc (plasma-addressed liquid crystal) technology that was developed by the display research lab at Tektronix Inc. A plasma-display structure, instead of the usual thin-film transistors or diodes, is used to electronically control the pixels on a screen. The modified plasma-display structure delivers electrons to an LCD instead of visible light to the eye. A three-terminal switching device is formed by a transparent electrode in the LCD portion of the Palc display plus the anode and cathode of the plasma portion. Sony calls the anode/cathode combination "an imaginary electrode."

In a Palc-based set, with its integrated LCD/plasma structure, each TV line is defined by a plasma channel. Adjacent channels are separated by barrier ribs. The cathodes in the channels are scanned sequentially. By driving the appropriate electrode in the LCD portion and the associated anode in the plasma portion of the display, a pixel is selected as light from a backlight is allowed to pass through the channel.

Palc technology is expected to have lower production costs than conventional AM-LCDs. Compared to the color-plasma displays now being developed by some Japanese firms, Palc's relatively lightweight plasma structure is well-suited for consumer applications such as wall-mounted televisions. And it should be easier to improve brightness in the LCD/plasma system than in light-emitting displays such as plasma.

To optimize the Palc technology, Sony has developed a high-precision screen printing process, needed for uniform plasma discharge, and a new color-filter technology that makes economical use of color materials. The technology also required that several LCD-related procedures be optimized, including gap control and insulator fabrication. Sony also designed two custom high-voltage driver ICs—one for the plasma side and the other for the LCD.

The 25-inch prototype displayed 450 TV lines in the 16:9 widescreen format. Approximately 15 inches high by 24 inches wide, the Palc display is just 0.148 inches thick and weighs 1.7 kilograms. It delivers 260,000 colors at 250 cd/m$^2$ of brightness with a 50:1 contrast ratio. No viewing-angle specifications were released, and to date Sony has made no statements concerning pricing.

## Erasable CD-ROMs on the way

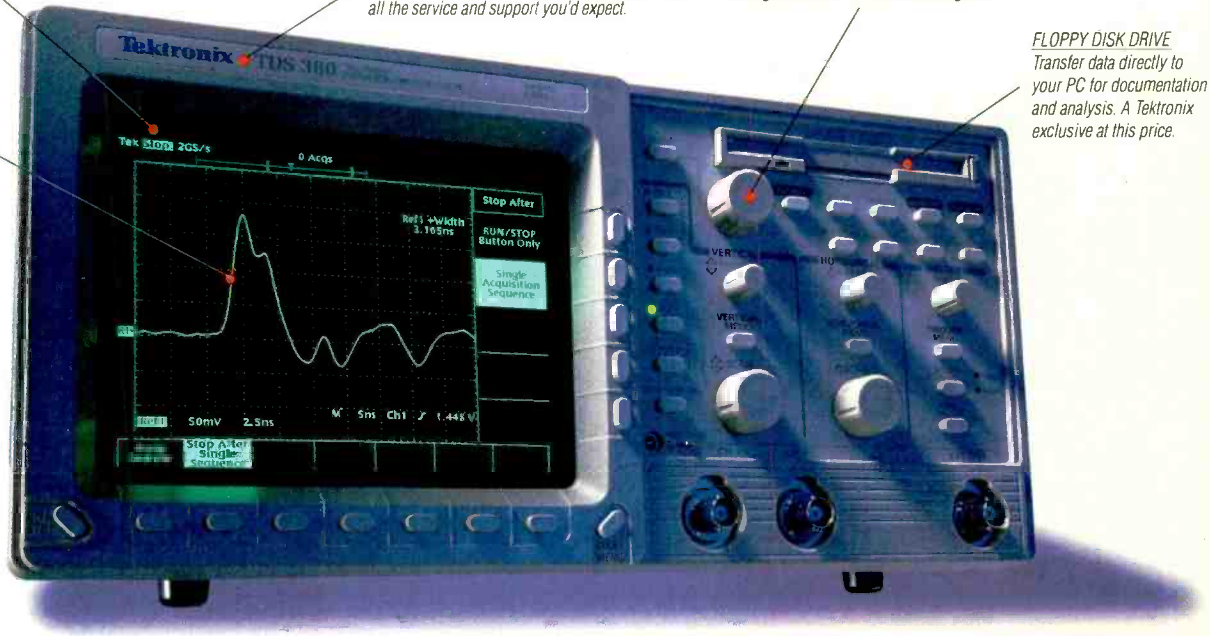
Last fall was a busy time in the on-going saga of erasable CD-ROMs, or CD-Es. The Optical Storage Technical Association debated which of several proposed logical file structures should be adopted, called for tightened laser and data-rate ranges that would make the 650-megabyte discs easier to manufacture, and discussed various copy-protection schemes. Meanwhile, at Comdex/Fall in Las Vegas, Philips Electronics and Ricoh Company Ltd. demonstrated a prototype CD-E disc and drive that successfully performed a direct-overwrite and sector-erase cycle. And an ANSI committee met in Palm Springs, California, with the goal of finalizing a command set that would simplify the integration and use of CD-E drives.

The CD-E format is supported by 10 major manufacturers: Philips, Ricoh, Sony, IBM, Hewlett-Packard, Mitsubishi, Mitsumi, Matsushita, 3M, and Olympus. CD-E disks can be reused many times. CD-E media are expected provide more than 10 year's usage, about 10,000 access cycles. Because CD-E drives use the same basic technology as today's CD-ROM drives, they will be fairly inexpensive to produce. The major difference is that, because CD-E disks reflect less light than standard CDs, the CD-E drives must have a five-times increase in read-write gain.

At the same time, Panasonic, a division of Matsushita, cut prices on another erasable optical technology. Phase-change dual (PD) drives can read CD-ROM disks and write data on PD optical platters. 3M Company is producing and selling PD-compatible media, and Compaq's Pentium Pro DeskPro XL 6150 includes a PD drive.

Although both erasable optical technologies can read today's CD-ROM disks, writing data that can be read on current CD-ROM drives is another matter. In the case of CD-E, the problem lies in the adjustments made to compensate for the disks' lower reflectability. Today's CD-ROM drives cannot read PD media at all.

# Overpowered.




# Underpriced.

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You'll see things the other scopes can't even capture. The new TDS 300 Series also offers FFT and Disk Drives – features others charge hundreds of dollars more for, or don't even have.

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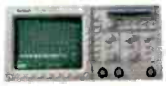

TDS 360, $3,495
*200 MHz, 1 GS/s, DRT, FFT, Disk Drive*

TDS 380, $4,595
*400 MHz, 2 GS/s, DRT, FFT, Disk Drive*

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Pricing for the two technologies should be similar. The prices of the Panasonic internal PD drives have been reduced from $895 to $500.

## Automotive safety and communications system

Prince (Holland, MI), a global supplier or integrated automotive interior and electronic systems, and SkyTel (Jackson, MS), the leading provider in national wireless messaging services, are teaming to manufacture and market "AutoLink," an affordable, complete automotive safety, security, and communications system. AutoLink includes automatic emergency response, theft deterrence, vehicle tracking and immobilization, two-way personal paging, remote vehicle unlocking, driver personalization, navigational guidance, and location-based information services.

The system combines two technologies: Its two-way wireless communications are based on narrowband personal communications services technology, and a differential global positioning system (GPS) receiver provides its navigational, and some security, capabilities. Motorola will supply the two-way paging and GPS hardware. The AutoLink system will have a coverage area equivalent to that of cellular service.

Three separate service packages will be offered. For personal safety, the Emergency Road Assistance package can immediately and automatically contact an emergency response team when an airbag is deployed and send confirmation back to the driver once the response team is on the way. AutoLink can also provide medical information about the driver to the ambulance team. The driver can independently summon police, medical, or roadside assistance at the push of a button even if he is lost —AutoLink provides the vehicle's location to the emergency service

The Vehicle Safety package includes passive theft intervention and vehicle tracking, notifying police if the vehicle is stolen and then pinpointing its actual location; and vehicle location and immobilization, which finds and immobilizes a stolen car.

The Driver Convenience package offers navigational guidance; remote vehicle unlocking; two-way personal paging and messaging; location-based information including the closest ATM or hospital as well as customized data on stock reports, sports scores, traffic reports, and weather/road conditions; fleet management and tracking; and remote diagnostics using the car's onboard body computer. The navigation system uses a central, off-board database. By calling AutoLink's toll-free number, directions based on your current location will be paged to the vehicle. Pressing the "I'm lost" button prompts a new set of directions. Drivers can also be alerted to traffic delays and given alternate routes.

The AutoLink system will be made available as a fully integrated, compact factory-installed option in 1998. Beginning this year, the focus will be on fleet sales, including commercial car-rental services and other car and truck fleets. When installed on new vehicles, service typically will be provided through the vehicle's warranty period. After that, additional service can be purchased on a monthly basis.

**THE AUTOLINK SYSTEM,** when factory-installed in a vehicle, will provide navigational, communications, security, informational, and safety services.

## Holographic data storage under development

A five-year, $32-million joint university/industry/government project to develop holographic data storage systems has begun. Such systems can hold more than 12 times the information of today's largest magnetic hard disk drives and maintain data input and output rates more than 10 times faster than is currently possible.

Half of the funding for the Holographic Data Storage System (HDSS) program is being provided by the U.S. Defense Department's Advanced Research Project Agency (ARPA). The remaining funding comes from the 12 corporate and university participants: Carnegie-Mellon University, GTE Corporation, IBM's Almaden Research Center, IBM's Watson Research Center, Kodak, Optitek, Rochester Photonics, Rockwell, SDL Inc., Stanford University, the University of Arizona, and the University of Dayton. ARPA's aim is to see if the technology could help provide soldiers and command centers with rapid access to the large amounts of information and visual images they need to be successful in the 21st century. The corporate participants anticipate applications in aviation, computing, image processing, and telecommunications.

Holographic data storage systems use lasers to store information as "pages" of electronic patterns within

*continued on page 33*

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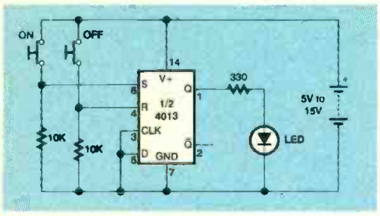
# Q & A

READERS QUESTIONS, EDITORS ANSWERS

## Latching-switch circuit

**Q** *I would like to update my existing mechanical relay latch circuits with state-of-the-art solid-state technology. Do you know of a solid state latch that will provide a positive output of 5 to 12 volts when turned on by a momentary ground to the input? The next momentary ground input should release the latch. — W. E. B., Independence, Mo.*

**A** The latch circuit that you need is called a *flip-flop* and is one of the basic building blocks of computers. In essence, it's a one-bit computer memory. A convenient IC to use is the 4013, a CMOS chip that contains two flip-flops and does not require a regulated supply voltage.




FLIP-FLOP DENONSTRATION. One button turns the LED on, the other turns it off.

Figure 1 shows one way to use a flip-flop as a latching switch. If you apply a positive pulse to its SET input, the output turns on. It remains on until a positive pulse is applied to the RESET input to turn it off. (TTL flip-flops such as the 74LS74 are actuated by negative rather than positive pulses.)

Figure 2 shows how to use one pushbutton switch instead of two. The SET and RESET inputs are grounded, the inverted (–Q) output is fed back to the D input, and the pulses go into the CLOCK input. Each positive pulse makes the flip-flop toggle from one state into the other.

The TLC555 chip in Figure 2 serves two purposes. It inverts the pulses so that you can get a positive pulse from a switch that is connected to ground. More importantly, it also "debounces" the switch. When you press a button, it doesn't just make contact once — the contacts "bounce," opening and closing three or four times. The 4013 would toggle once on each bounce, leading to unpredictable results. The TLC555 uses a resistor and capacitor to smooth out these fluctuations so that each press of the button produces only one pulse. Don't use a plain 555, which may introduce a "bounce" of its own.

In Figure 2, the output of the circuit is shown connected to a conventional magnetic relay, but you might prefer to use a solid-state relay that takes logic-level input. For maximum reliability, connect a 0.1-µF capacitor across the power supply pins of each IC, and be sure to ground all four inputs of the second flip-flop in the 4013 if you're not using it.

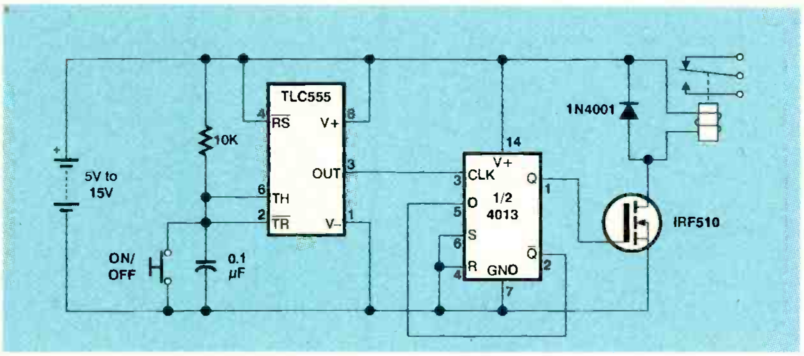
If you need dozens of latches, consider using a microcontroller instead. A suitably programmed microcontroller can do the work of eight or more of the circuits shown here, and can even do its own debouncing by measuring the duration of each switch closure.

## AC clock motors on DC power

**Q** *I am in the process of building a very accurate clock, using a 60-MHz crystal and sending it through a series of decade dividers. My request is for a design of an output stage to handle the clock motors. Can I use four power transistors in an H-bridge circuit? I do not want to use a transformer to drive the clock motors due to the cost and weight. — W. S., Waymart, Pa.*

**A** An H-bridge is a circuit that supplies power to a motor and can reverse the polarity (Figure 3). It's usually used to run a DC motor forward and backward, but we don't see why it wouldn't work with an AC motor, if you reverse the polarity over and over at the right frequency.

The motor will receive a square wave rather than a sine wave, of course, but that's all right; small clock motors run fine on square waves. Note that the RMS voltage of a square wave is the same as the

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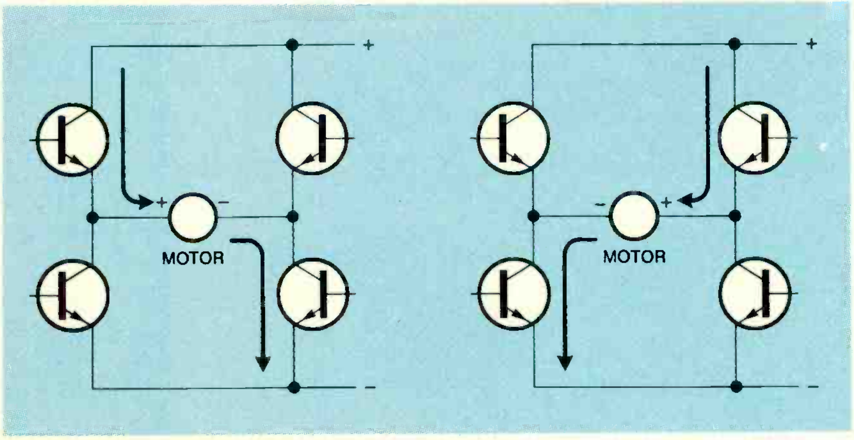



AN H-BRIDGE CAN RUN A DC MOTOR in either direction by turning on two transistors at a time.

peak voltage, so the DC supply should be 120 volts.

One obvious difficulty, in designing an H-bridge circuit, is that half of the transistors operate at high voltage; their bases or gates aren't all at the same voltage level. For that reason, we suggest you the International Rectifier PVD33 "photovoltaic relays," which are actually high-power optocouplers. Each PVD33 contains an LED and a light-actuated power FET. You can use logic-level signals to light the LEDs, and all the LEDs are referenced to the same ground, regardless of the voltages on the FETs. The PVD33 also contains a diode to protect the FET against inductive kickback.

Figure 4 shows a circuit to get you started. Caution: We haven't actually built this, and it may need some further refinement. Note that the input waveforms should include a slight time delay between cycles to ensure that all four transistors never turn on at the same time. You may be able to get away without the time delay, because the PVD33 itself turns on slowly but turns off fast — giving you about a millisecond of "dead time" at the start of each pulse. But be absolutely sure that the "on" pulses for different pairs of transistors don't overlap. The light bulb is there to limit current in case they ever do.

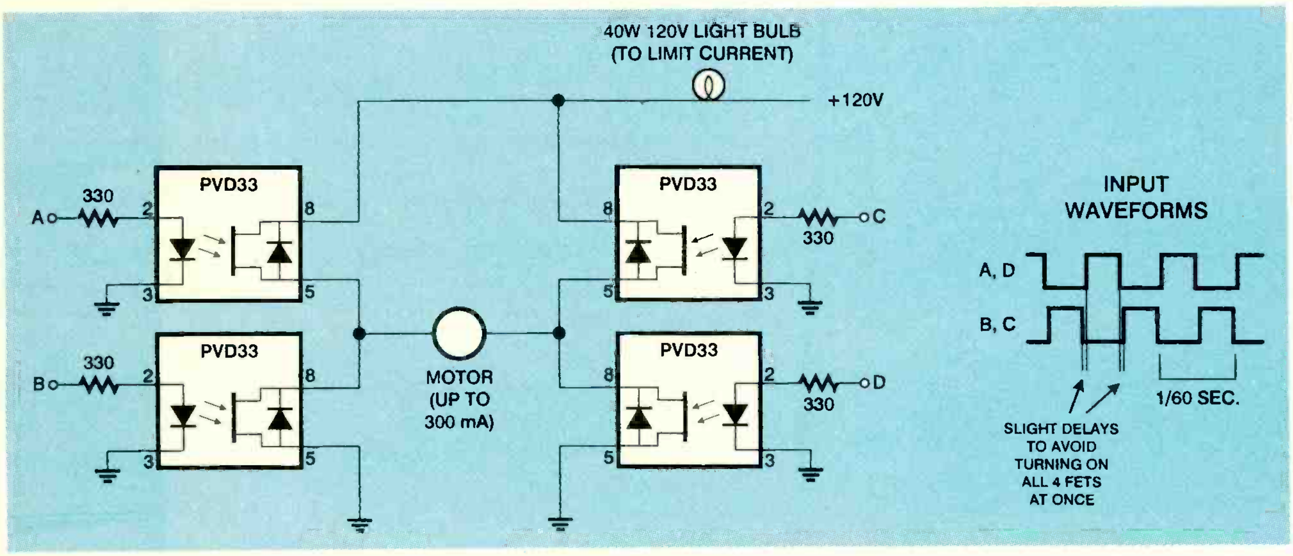
One supplier of PVD33s is Digi-Key (P.O. Box 677, Thief River Falls, MN 56701, phone 800-344-4539). Unfortunately, four PVD33s, at about $7 each, cost more than a small transformer. If you decide to go the transformer route after all, see *Astrophotography for the Amateur*, by Michael Covington (Cambridge University Press, 1995) for a circuit that you can adapt (an electronically controlled telescope drive).

As for the time base: 60 MHz is too fast for ordinary TTL or CMOS ICs. Start with 6 MHz instead. Better yet, use a National Semiconductor MM5369AA chip, which derives an accurate 60-Hz square wave from a 3.58-MHz color TV crystal.

## Fickle reds

**Q** *I have an old 8088 computer with an EGA monitor that works fine except that there is no red color. Once in a great while the red comes back in all its glory for about 10 or 12 seconds. I suspected the monitor at first. Perhaps something grounding the grid of the red gun? Having no circuit diagrams, I decided to ask you if you had any suggestions — other than taking the dang thing out in the field and putting it out of its misery with a shotgun. — J. P. U., Deltona, Fla.*

**A** As you surmise, it may not be the CRT. The first thing to check is the video *cable*; red, green, and blue are carried on separate wires, and a bad connection will inactivate one or more of the three electron guns. On the 9-pin EGA connector, red is on pin 3 and secondary red, used for color mixing, is on pin 2. Disappearing red could also be due to problems with the EGA card itself; have you tried another video card or another monitor? EN




UNTESTED DESIGN IDEA for driving AC clock motors with an H-bridge.

# LETTERS

SEND YOUR COMMENTS TO THE EDITORS OF ELECTRONICS NOW MAGAZINE

## PROTEL EASYTRAX

The January 1996 issue of Electronics Now incorrectly stated the FTP site for Protel Technology, Inc. The correct information is:
FTP site: rocky.protel.com
login:anonymous
password: <your E-mail address>

In addition, you can reach Protel at: http://www.protel.com

When logged in, you'll find much in addition to what was mentioned in the magazine. If you have any questions, comments, complaints, or problems accessing any of Protel's sites, please send E-mail to: masterweb@protel.com.

JIM POEHLMAN
Network Manager
Protel Technology, Inc.

## CARBON-MONOXIDE DETECTOR WARNING

The "Carbon-Monoxide Detector" project featured in the September 1995 issue of *Electronics Now* featured a carbon-monoxide detector "card" with "heads up" printed on the face. The circuit measures the reflection of light off the chemically active spot on the carbon-monoxide detector. I would like to warn your readers of the limitations of the device and advice them of alternatives.

I have used dozens of that exact detector and similar devices, both as space or room detectors and as personal detectors with the clothing clip. That type of detector has also been promoted as a low-cost (usually less than $5) home detector, and has been used on small aircraft.

I have grave reservations concerning the reliance on that device to provide continuous, long-term warning of injurious carbon-monoxide concentrations. First, I have found the useful life of the detector to be a maximum of three months after opening the factory-sealed pack. Second, the detector has no provision to warn when it is no longer affected by carbon-monoxide gas. Finally, the active spot does not return to normal color after exposure to carbon monoxide. In sum, that type of detector can lead to a false sense of security.

Up until about two years ago, the "heads up" type of detector was the only readily available, low-cost warning device in this country. Electronic devices were only available in Canada, Europe, and Japan.

Beginning in 1993, U.S. manufacturers began producing both battery-operated and AC-powered complete detector systems for less than $100. The July 1995 issue of *Consumer Reports* rated 10 commercial units in the $40 to $80 price range. I believe any of those units are far superior to the color-change badge detector.

If an experimenter wants to build an electronic detector, I suggest contacting Figaro USA Inc. (P.O. Box 357, 100 Skokie Blvd., Room 575, Wilmette, IL 60091; 1-708-256-3456). Figaro has solid-state carbon-monoxide sensors, carbon-monoxide IC's, and other solid-state environmental sensors.

DONALD J. KOVACS, P.E.
Au Gres, MI

Write To:
Letters,
Electronics Now Magazine,
500 Bi-County Blvd.,
Farmingdale, NY 11735

Due to the volume of mail we receive, not all letters can be answered personally. All letters are subject to editing for clarity and length.

## HUMMING ALONG

I read with great interest Larry Klein's "Audio Update" discussion of "The Hum" (*Electronics Now*, December 1995). One of the few advantages of my surviving to the age of 74 is that I've accumulated a lot of experience by being in the right place at the right time.

For almost 35 years, my wife and I owned an old farm in southeastern Vermont in the town of Chester. We are teachers and spent our summer vacations there.

Some time in the early or mid 1960's, "The Hum" was reported in New England by one of the major weekly news magazines. As I recall, it was somewhere in Connecticut, or maybe western Massachusetts. It was sufficiently audible to be heard by hundreds of people, and I believe that I, too, heard it at times during the summer months. Our old farmhouse was quite isolated in the mountains, surrounded by "quiet."

I remember it as a very low-frequency hum, more like a sine wave than a fundamental with harmonics. Think of the 20-cps organ not introducing the tone poem "Also Sprach Zarathrustra" by Strauss and you'll be close to the sensation.

After more than 30 years, I don't recall any specific investigation or conclusions, but I think it's significant that it occurs in mountainous regions and during warm weather. The fact that it lasts for weeks suggests that its origin is more likely geological than from the vagaries of changeable weather.

So add this to your list of date/locations. It would be helpful if some competent scientist, well versed in geology, meteorology, and acoustics, was to collect more complete data on a worldwide basis.

JEROME S. MILLER, W8IDP
Grand Rapids, MI

## BATTERIES, 2000 B.G. (BEFORE GALVANI)

I read with pleasure the article entitled "Regulated Power for Electrochemistry" by Edward Barrow (*Electronics Now*, December 1995). I think it was very well written, informative, and succinct. Yet after reading it, I felt compelled to write this letter to correct a misstatement pertaining to the invention of the electric battery.

Earlier this year, while compiling information for a science project for children pertaining to electrochemistry, I came across a very interesting article on batteries. According Harry M. Schwab, the author of "Electric Batteries of 2000 Years Ago," which appeared in the April 1957 issue of *Science Digest*, it appears that the Parthians from ancient Iraq were using electric batteries for electroplating metals made approximately 2000 years before Alessandro Volta and Luigi Galvani "discovered" electric cells in the late 18th century!

Those ancient batteries were made from thin copper sheet soldered, using a 60/40 tin-lead alloy, into the shape of a cylinder approximately four inches long and one inch in diameter. The bottom of the cylinder was sealed by crimping in a small copper disk. (That same combination of metals was used by Galvani in 1786 when he "discovered" the galvanic cell.) The assembly was then placed inside of a small clay vase for support, and an electrolyte was added to the cylinder. It is safe to assume that grape juice or wine, which are high in citric and acetic acid, were probably used as the electrolyte because those were the drinks of choice 2000 years ago. After adding the electrolyte, an asphaltum (or bitumen from Noah's time) stopper, through which projected an iron rod, was used to close the cell.

Anyone who has taken a high-school chemistry class knows that a difference in electric potential exists when two dissimilar metals are immersed into an electrolyte. In an attempt to somewhat duplicate the ancient battery, I assembled one from a copper cylinder, an iron rod, a plexiglass disk, and a Mason jar. After inserting the copper cylinder into the jar, I drilled a hole through the plexiglass disk, inserted the iron rod through it, and glued the disk-rod assembly to the copper cylinder. After adding grape juice (I also used vinegar) to the jar, I carefully attached a jumper wire from the iron rod to the copper cylinder. After an hour or so had elapsed, a visible coating of copper was present on the iron rod (reduction reaction). After disconnecting the jumper wire, I connected a voltmeter to the two metals and found that the voltage potential measured between them was approximately 0.52 volts.

You know, it's amazing what you can discover when trying to develop a science project for children.

TIM E. ROTH
Las Cruces, NM

## MOBILE ELECTRONICS TESTING

The Mobile Electronics Certification Program (MECP) is the only industry-wide, nationally recognized testing program for installers. The benefits to mobile electronics manufacturers, retailers, and installers are clear: By improving the quality of installations, product returns are decreased, consumer confidence is increased, and the level of professionalism in the 12-volt industry is raised.

To date, more than 12,000 installers have taken the MECP test. Some 9000 already have been certified as Installers; as Specialists for autosound, security, and cellular; as First-Class Level Installers; and as Master Installers. For every installer certified, the Consumer Electronics Manufacturers Association's (CEMA) Mobile Electronics Division, which manages MECP activities, estimates that there are four others who could, and should, be certified.

The test schedule for the following two months is as follows: Portland, Oregon, February 1; Chicago, Illinois, February 8; St. Louis, Missouri, February 15; Baltimore, Maryland, February 22; Raleigh, North Carolina, March 7; Houston, Texas, March 14; Salt Lake City, Utah, March 21; Omaha, Nebraska, March 28.

Registration deadlines are two weeks before the tests. More information is available by calling 703-907-7689.

STACY SAUL
Manager, MECP
Arlington, VA

## BUY A MACINTOSH!

Once again, your magazine has pushed aside the "electronics" aspect and has tried to be like one of a bazillion other computer magazines. When I saw the article "So You Want to Buy a New Computer?" (*Electronics Now*, January 1996), I thought "This ought to be good." Just as I thought, your article focused on IBM-compatible computers and just about ignored everything else. Like lemmings all following each other off the edge of a cliff into the Intel Pit of Doom, you happily jumped in line.

Jeff Holtzman's "Computer Connections" column caught my eye. The first line read, "Today's CPU of choice is the Pentium." I would have read the rest of the article, but I was laughing too hard. The latest upgrade in the aging x86 series is the CPU of choice? That's sad. The computer buyer's article briefly states that Intel has fixed the Pentium's "little" math problem. The fact that the problem could ever occur shows how Intel favors quantity over quality.

I think David Letterman said it all when the Late Show Quiz Machine stopped working: "It must be running on a Pentium!"

The article also briefly mentioned the PowerPC chip and how it's only faster than the Pentium with "the very few applications written specifically for the PowerPC." There are many PowerPC native applications. Maybe not from Microsoft, which couldn't write an efficient program even if it knew how. (Almost 30Mb of disk space for a word processor? That's not going on *my* hard drive!)

Maybe you've seen the commercial in which a businessman, standing in front of hundreds of people, is about to give a presentation as soon as he can get his PC to work. The people in the audience yell out advice on how to get the thing running. Then someone yells out the best advice of all: "Buy a Macintosh!"

Pentium is the CPU of choice? Not my choice.

DAVID ZADROZNY
*Morris Township, NJ*

## DEFENDING THE AMIGA

I am responding to the appalling opening paragraph in Don Lancaster's description of the New Tek toaster ("Hardware Hacker," *Electronics Now*, August 1995). He stated that Amiga was "left in a less-than-stellar position after the sale of Commodore." He also said that an internationally known company in bankruptcy court sold its assets at a "yard sale." But to say that the company threw out the baby and drank the wash water was reprehensible. However, it is true that the transaction was bizarre.

The facts are that New Tek wanted to enter the personal computer market, so it made a PC version. Why did Lancaster have to trash the name Amiga along the way? Commodore was purchased by EsCom, a large company with extensive financial resources and a large distributor base in place. The company intends to continue producing and selling the Amiga and to sell rights to the Amiga so it can be cloned. Amiga's future is brighter now than it has been in years.

When New Tek built the toaster for the Amiga, it was a plug-in card. When it decided to build one for the PC, it had to be a stand-alone unit that could only be interfaced with the PC. The PC does not have the video capabilities or operating system to support a plug-in card. New Tek had to make a stand-alone processor and write an operating system that could handle the taxing video demands.

KURT D. SWAIM
*Fort Wayne, IN*

EN

# NEW PRODUCTS

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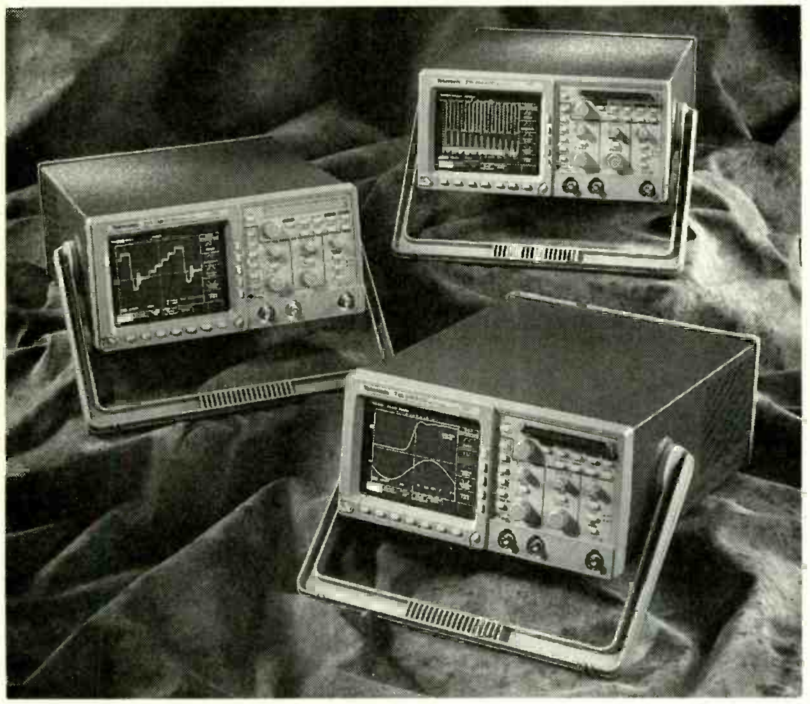
## Digital Oscilloscopes

THE THREE NEW MODELS in the Tektronix TDS 300 series of digital oscilloscopes provide double the performance of previous models, while retaining affordable prices. The 100-MHz TDS 340, 200-MHz TDS 360, and 400-MHz TDS 380 are basic troubleshooting instruments targeted primarily for the education, design, service, and repair markets. The TDS 340's two channels digitize at a rate of 500 megasamples per second, the TDS 360 at a rate of 1 gigasample per second, and the TDS 380 at a rate of 2 gigasamples per second. The $3^1/_2$-inch DOS-compatible floppy-disk drive built into the 360 and 380 models is useful for storing reference waveforms, downloading waveforms and setups, and importing and exporting waveform values into application programs.

All three scopes offer the benefits of digital capability, allowing the user to store setups and waveforms and perform 21 different automatic measurements. They feature Fast-Fourier-Transform (FFT) capability, which is useful for analyzing harmonic content of signals in power supplies, noise in mixed digital/analog systems, line current harmonics, and vibration systems. Tektronix' patented Digital Real-Time (DRT) oversampling technology dramatically reduces aliasing and enables single-shot waveform capture at the instrument's full bandwidth.



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Like earlier models, the three newest scopes offer four acquisition modes: sample, envelope, average, and peak detect. Video and edge triggering capabilities are built-in, along with the ability to capture transients down to 1 nanosecond. The new scopes also feature the same intuitive interface as the rest of the TDS 300 Series.

The TDS 340, 360, and 380 digital oscilloscopes have suggested retail prices of $2495, $3495, and $4595, respectively. A communication option is available for I/O to GPIB, RS-232, and Centronics-type interfaces and VGA monitor output.

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## Leds with low-battery warning

ACCORDING TO LUMEX Opto/Components, their LEDs are the first to incorporate a CMOS chip that provides a low-power signalling function inside a typical T1-3/5 (5mm) LED lamp. The LEDs are aimed at manufacturers of battery-operated end products who need a foolproof way to warn consumers that the battery power is about to drop to zero.

Designed to detect low power in devices powered by two 1.5-volt AA batteries, the LEDs can also accommodate packs of three to six 1.5-volt cells by using external resistors. Applications for the new LEDs include any portable, handheld consumer and industrial products that use AA batteries.

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red and yellow colors. Input voltage can be as low as 2.0 volts, with detection sensitivity of 2.3 + 0.1 volts and standby current of 5-microamperes. Light intensity at 6.5 milliamperes (for red-diffused) is 3-millicandella minimum.

The price range for the special LEDs is from $1.50 to $1 each in quantities of 1000 or more pieces, depending on color and package.

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*290 East Hellen Road*
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*Fax: 1-800-944-2790*

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WELTRONICS CORP. CLAIMS that its AMC DAC8 digital-to-analog converter can vastly improve the sound quality of CDs and laserdiscs played on older CD players, portable CD players with digital outputs, and laserdisc players. The DAC8 features four switched inputs, a tape loop for digital recording, and EIA-standard output. It supports up to 18-bit input data.

The DAC8 offers low-noise, high-

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resolution digital-to-analog conversion using Philips' latest bitstream DAC with continuous calibration up to 18 bits. It provides automatic detection and lock for 32K, 44.1K, and 48K digital signals. Its output provides an optimum signal level for Dolby Pro Logic circuits, eliminating input overload.

The DAC8 D/A converter costs $199.95.

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## Cable management systems

CMS PRO SOFTWARE FROM Wavetek is a Cable Management System (CMS) for the Lantek Pro Series of cable testers. The Windows-based software allows users of the Lantek Pro series of local area network Category 5 and fiber-optic cable testers to maintain and manipulate databases of cable installation information. CMS Pro helps organize and store cable test data and user-defined data. It also generates formatted reports for cable installers and network managers.

The software also allows users to operate the Lantek Pro cable testers


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under remote control of a PC. With the Lantek Pro attached to the serial port of the computers, the user can get complete diagnostics on a suspect cable segment in a matter of seconds. Faults such as bad connectors, cuts in the cable, and transient noise from machinery or transmission equipment can be easily detected and reported to the user.

Cable installers and service providers can use CMS Pro to maintain information and historical data on cable installations, and either store them for future reference or distribute

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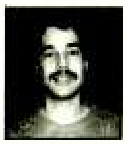

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***Industrial Electrician***
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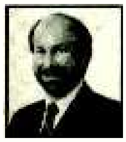

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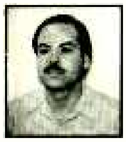
*Dan Parks*
***Marketing Manager/Consumer Products***
*Analog Devices, Inc.*



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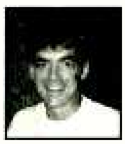

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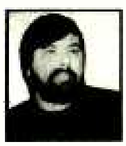
*Daniel N. Parkman*
***Missile Electro-Mechanical Technician***
*U.S. Air Force*



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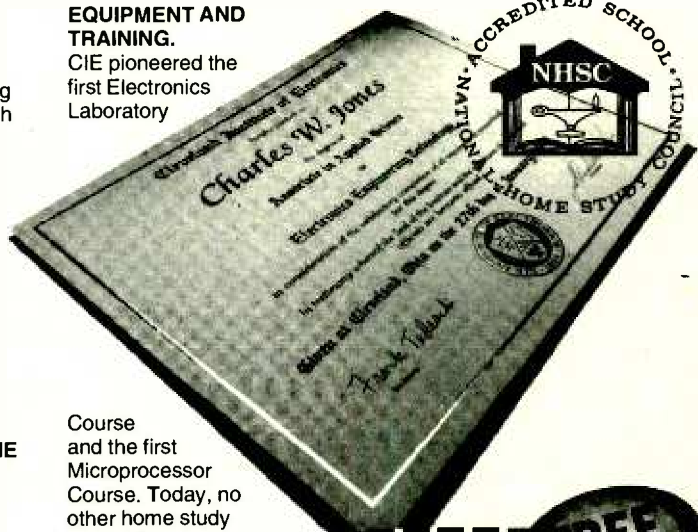


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them, to customers. Network managers can use CMS Pro to keep track of complex cable installations and the associated test data.

CMS Pro 1.0 software has a list price of $295.

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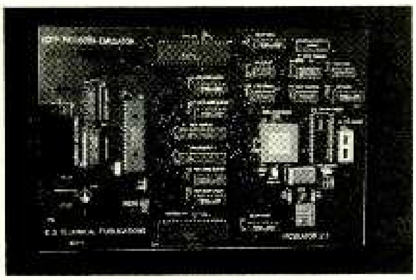
## PIC emulator kit

THE PICULATOR FROM E D Technical Publications is a low-cost, in-circuit PIC165C5X emulation system that comes in kit form. The Windows-based Piculator software allows unlimited breakpoints and on-the-fly modification of PIC program and data memory. Other emulation features include full display of all internal PIC registers including stack, W, and program counter. Each individual register location can be modified by the user via the Windows driver program. Single-step operation is also supported.

Piculator supports the PIC16C54, PIC16C55, PIC16C56, PIC16C57,



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PIC16C58 via the standard PC parallel port. All components, with the exception of the emulation Piculator engine, are standard, off-the-shelf devices. That facilitates any repairs made necessary by harsh development environments. The kit is easy to build and, with its familiar Windows interface, easy to use.

The Piculator kit, complete with Windows supervisory software, power supply, and free technical support, costs $199.

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## Surface-mount monolithic amplifier

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The device is useful for narrow and broadband IF and RF amplifiers in commercial systems. It is manufactured with tight unit-to-unit repeatability and can be supplied in tape and reel packaging.


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The MAV-5SSM monolithic amplifier costs $1.90 each in quantities as small as 30.

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*Brooklyn, NY 11235-0003*
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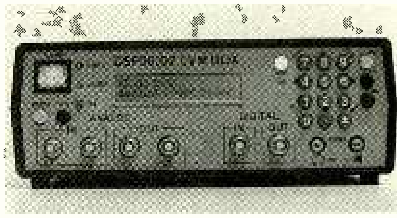
*Fax: 718-332-4661*

## Stand alone digital signal processing lab

DOMAIN TECHNOLOGIES' DSPLab is a self-contained, general-purpose, digital signal processing (DSP) system. User-defined algorithms can be loaded into the unit, programmed into Flash ROM, and then executed. The system consists of six major blocks: a DSP56002 digital signal processor, an analog I/O, a keypad, an LCD display, control software, and housing.



CIRCLE 26 ON FREE INFORMATION CARD

The user can progam an application by using the built in PC interface or by opening the box and replacing the EPROM.

Analog signals can be digitized, processed by the DSP, and converted back to analog. The keypad and the LCD display provide an interface through which the user can set parameters and monitor results.DSPLab is great for DSP algorithm demonstration OEM products and laboratory equipment.

The system comes with the software needed to develop and load user applications. The user can program his application either through the built-in personal computer interface, or by opening the box and replacing an EPROM.

DSPLab has a simple, open architecture. All the blocks are controlled directly by the 40-MHz Motorola DSP56002, which has a highly parallel instruction set, 56-bit accumulators, and 24-bit data busses. Interface details and schematics are provided with every unit.

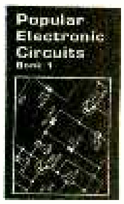
An assembler and a debugger are included with the system. The debugger interfaces with the DSP card through the 56002's OnCE emulation port. Through the debugger, the user can load DSP programs, examine memory, and change registers. The 24-bit symbolic assembler is fully compliant with the Motorola DSP56002 instruction set.

The DSPLab stand-alone digital signal processing system has a total costs of $975.

**DOMAIN TECHNOLOGIES, INC.**
*1700 Alma Drive, #245*
*Plano, TX 75075*
*Phone: 214-985-7593*
*Fax: 214-985-9579*
*E-mail: dsplab@domaintec.com*

EN

# Hobbyist's Paperback Budget Books



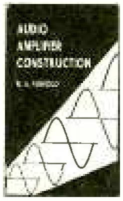

☐ **BP80/98—Popular Electronic Circuits-Books 1 and 2...$11.90.** Contains a wide range of circuits which are accompanied by text giving a brief introduction, circuit description and special notes on construction and setting-up that may be necessary.


☐ **#160—Coil Design and Construction Manual...$5.95.** A complete book for the home builder on how to make RF, IF, audio and power chokes and transformers. Practically every possible type is discussed and calculations are explained in detail.

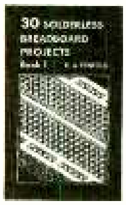
☐ **BP271—How to Expand, Modernize and Repair PC's and Compatibles...$7.75.** All the practical information you are likely to need to upgrade your PC and compatible. Also contains useful information and illustrations to help you with repairs.

☐ **BP276—Shortwave Superhet Receiver Construction...$6.95.** Provides construction details, including coil winding, of a number of advanced-design receivers which should have performance levels at least equal to commercial sets of similar complexity.

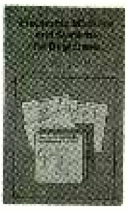

☐ **#223—50 Projects Using IC CA3130...$5.00.** One of the more practical and useful operational amplifiers (opamp), the CA3130 integrated circuit chip is the heart of several easy-to-assemble projects covered in the book. The projects are divided into five categories: audio projects, RF projects, test equipment, household projects and a catch-all miscellaneous group. Ideal for all skill levels.



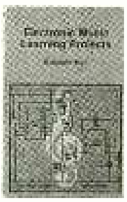

☐ **BP122—Audio Amplifier Construction...$5.75.** Practical designs are featured and include circuit diagram and description, Veroboard or printed-circuit board layout and construction notes. The text is divided into two parts. The first deals with many types of preamplifiers. The second covers power amplifiers from a simple low-power battery type to a 100-watt DC-coupled amplifier using four MOSFETs in the output stage.



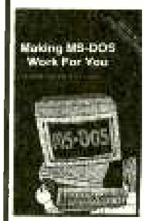

☐ **BP107—30 Solderless Breadboard Projects-Book 1...$5.95.** Each project is designed to be built on a "Verobloc" breadboard and is presented with a brief circuit description, circuit diagram, component layout diagram and components list. Notes on construction and applications are provided. Wherever possible, the components are common to several projects to keep project costs down.



☐ **BP266—Electronic Modules and Systems for Beginners...$7.25.** Shows the reader how to build a number of simple analog and digital circuit modules, all suitable for battery operation, and all based on only 1 or 2 transistors or ICs.

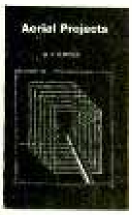


☐ **BP329—Electronic Music Learning Projects...$6.25.** A beginner's book that will assist you in assembling such projects as the Elexylophone, Gildaphone, Melody Ranger, Cordmaker, Appealing Handbells, Electronic Sol-Fa, Tune-up Box and more.



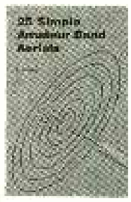

☐ **BP319—Making MS-DOS Work for You—$6.50.** What you need to know first, comes first, however the text is written in a circular style so that the reader can start anywhere in the text. This book is relevant to all versions of both MS-DOS and PC-DOS.


☐ **BP303—Understanding PC Software...$6.95.** Covers main types of PC software, giving details of typical uses, the basics of how they are used and their limitations. Each chapter covers popular software and programs of a similar type.

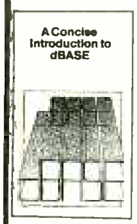



☐ **BP105 Aerial (Antenna) Projects...$5.50.** In this book the author has considered practical antenna designs, including active, loop and ferrite antennas which perform well and are relatively simple and inexpensive to build. The complex theory and mathematics of antenna design have been avoided. Also included are construction details of a number of antenna accessories including a pre-selector, attenuator and filters.


☐ **BP33—Electronic Calculator Users Handbook...$5.75.** The book eliminates the mysteries of the calculator and offers unique ideas for the simplest to most complex calculators. Covers the basic functions plus trigonometric, hyperbolic, logarithms, square roots and powers. Included are formulas and data for VAT, discounts, and mark up, currency conversion, interest, binary and octal numbers, and much more!

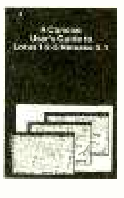



☐ **BP125—25 Simple Amateur Band Antennas...$5.50.** Plans to build antennas that are simple and inexpensive to construct and perform well. From the simple dipole to beam, triangle and even mini-rhombic types made from four TV masts and about 400 feet of wire. After the antenna discussion you will find a complete set of dimension tables that will help you "tune" an antenna on a particular frequency.

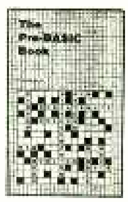



☐ **BP263—A Concise Introduction to dBASE...$6.95.** The most popular data-base program, dBASE, is difficult to master without help. This book helps you spend your time using dBase, not setting it up. A user's guide that covers all the basics up to dBase IV.


☐ **PCP104—Electronics—Build and Learn...$9.95.** Construction details are given to build a circuit demonstrator that is used throughout the book to introduce common electronic components and how these components are built up to useful circuits.



☐ **BP302—A Concise Users Guide to Lotus 1-2-3 Release 3.1...$6.25.** Written to help existing spreadsheet users upgrade to 1-2-3 Release 3.1, which has the ability to work 3-dimensionally with both multiple worksheets and files.




☐ **BP146—The Pre-BASIC Book...$6.95.** Another book on BASIC but with a difference. It concentrates on introducing technique by looking in depth at the most frequently used and more easily understood computer instructions.

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# NEW LITERATURE

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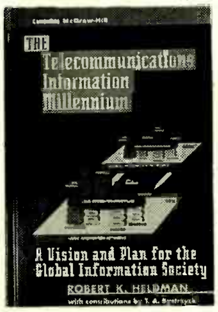
## The Telecommunications Information Millennium: A Vision and Plan for the Global Information Society

*by Robert K. Heldman*
*McGraw-Hill Book Company*
*11 West 19th Street*
*New York, NY 10011*
*Phone: 1-800-2-MCGRAW*
**$24.95**




CIRCLE 337 ON FREE INFORMATION CARD

This forward-thinking book postulates a feasible vision for the future in telecommunications and then presents a well-conceived, balanced plan of action for making that vision a reality. It thoroughly examines and analyzes all the obstacles to, and the many potential benefits of, creating an interactive public information network. It describes in detail the network needed to create a true "information infrastructure," and then presents a realistic blueprint for constructing fully switched, fully interactive public voice, data, and video information network.

Aimed at telecommunications professionals as well as government officials involved in the field, the book uses clear, accessible language to define tomorrow's telecommunications opportunities in terms of today's plans and strategies, the current approaches that successfully match the right network services to the right application. It provides comprehensive coverage of narrowband, wideband, and wireless information, as well as discussions of the information highway and information marketplace. In addition, the book explains the regulatory, financial, and technical hurdles that must be overcome to make a public data network a reality.

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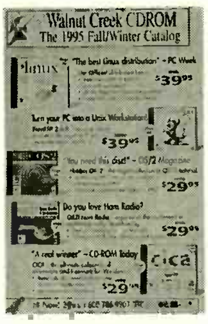
## Fall/Winter CD-ROM Catalog

*Walnut Creek CDROM*
*4041 Pike Lane, Suite D*
*Concord, CA 94520*
*Phone: 1-800-786-9907*
*E-mail: info@cdrom.com*
**Free**




CIRCLE 338 ON FREE INFORMATION CARD

More than 60 high-quality, cost-effective CD-ROMs are featured in this 55-page, full-color catalog. Discs are available for Windows, OS/2, DOS, and Macintosh platforms. Categories include images, text, UNIX, programming, multimedia, and productivity tools.

Several new releases are described. FreeBSD 2.0.5, now expanded into a 2-disc set, is a UNIX-like operating system for the PC that features full networking facilities, from NFS and NIS to SLIPP/PPP, IP routing, IP firewall (security), UUCP, USENET News, and mail software. It is well-suited for almost all networking applications, from end-user Internet access to Internet Service Provision itself. NewT for Windows NT is a hand-picked shareware collection specifically designed to help users get the most form their NT machines. It provides applications, source code and related files, patches and fixes, file editors, games, GNU program, utilities, system programs and utilities, graphics- and network-related programs, screen savers, system information monitors, and sound programs. Raytrace! The Official POV-RAY CDROM, aimed at people interested in viewing and rendering their own computer-generated 3-D images, includes hundreds of images, both full scenes and individual elements. Persistence of Vision (POV) ray tracing software allows users to create impressive 3-D art.

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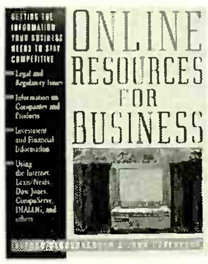
## Online Resources for Business

*by Alfred Glossbrenner and*
*John Rosenberg*
*John Wiley & Sons, Inc.*
*605 Third Avenue*
*New York, NY 10158-0012*
*Phone: 1-800-CALL-WILEY*
**$24.95**



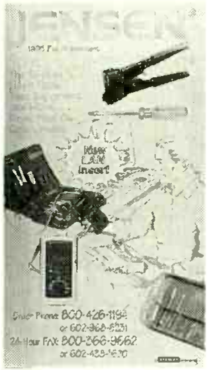

CIRCLE 339 ON FREE INFORMATION CARD

A wealth of business resources can be found online if you know how and where to look. Randomly searching can cost companies exhaustive hours and thousands of dollars.

This book, a complete revision of the 1987 release, *How to Look it Up Online*, significantly narrows the search. It describes today's online services, the type of information that they provide, and how much it costs to obtain that information. It provides keys to using the online services aimed at businesses, such as Lexis/Nexis, Dow Jones, and DIALOG, and consumer services such as the Internet, CompuServe, America Online, and Prodigy. The book offers access to dozens of little-known information sources, including marketing studies and government statistics. It describes sophisticated search strategies, tools, and techniques, and provides information on third-party research firms. The book also provides the going rates for accessing, downloading, and printing information from online sources.

## Tool & Test Equipment Catalog with LAN Insert

*Jensen Tools Inc.*
*7815 South 46th Street*
*Phoenix, AZ 85044-5399*
*Phone: 1-800-426-1194*
*Fax: 1-800-366-9662*
**Free**



CIRCLE 340 ON FREE INFORMATION CARD

This full-color catalog features a special 8-page insert describing dozens of LAN-related items, as well as nine pages devoted to networking in the catalog itself. Besides networking equipment, its 72 pages include comprehensive selections of the most in-demand items from all of Jensen's product categories, including tool kits, cases, test equipment, and products for computer and telecommunications installation, maintenance, and repair. In addition to its regular 100% satisfaction guarantee the Company offers a lifetime guarantee on all Jensen hand tools. Technical staff is available, by phone, to respond to product questions and to provide additional information, as needed. A wide array of new products are offered, including specialty tool kits.

*continued on page 27*

# EQUIPMENT REPORTS

## Goldstar OS-9100P Oscilloscope

*A pace-setting real-time 100–MHz, dual channel oscilloscope for testbench and field work.*

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The Goldstar OS-9100P oscilloscope arrived for evaluation, coincidentally, on the same day that one of our color TVs started to go down. The TV's video display indicated that something went wrong in the video/sync-separator circuit or there about. We decided to put the oscilloscope to work immediately to locate the trouble. The OS-9100P was unpacked, powered up and a shielded probe (one of two supplied with the oscilloscope) connected to the X-axis input. The probing commenced and the trouble was traced to an oxidized solder connection on the PC board. While we were at it, we detected and replaced a decoupling capacitor that didn't do its job cleanly. After the repair job was completed we realized that we had not opened the OS-9100P's Operation Manual. We relied solely on oscilloscope's clearly marked front-panel controls and the flawless performance of the scope. It is exceptionally easy to use.

The Goldstar OS-9100P real-time (analog) oscilloscope is a full-featured 100-MHz, two-channel, dual-trace instrument with automatic focus, and wide bandwidth. It has a 5-inch rectangular screen (4 × 3$^1/_8$-inch) with internal graticule with 10 × 8-centimeter markings, 0.2-millimeter subdivisions along the X and Y axes. The scope's display was designed with a fluorescent scale for the purpose of photographing observed waveforms together with the scale.

### Trigger options

Triggering switch settings are often the most confusing operation to perform on an oscilloscope because of the many options available and the exacting requirements of certain signals. For example, the OS-9100P will not display a horizontal sweep in its normal trigger mode unless a signal is applied.

However, the absence of a trace can also be due to an improperly set VERTICAL POSITION control or VOLTS/DIV switch. Setting the TRIGGER mode switch from NORM to AUTO eliminates confusion by causing the time base to run freely when not triggered, thus showing a trace on the screen. The only hitch with auto operation is that signals below 25 Hz, and complex signals, may not reliably trigger the timebase.

The TRIGGER MODE switch inserts a TV sync separator into the trigger chain within the oscilloscope. A clean trigger signal at either the vertical or horizontal rate can be removed from the composite TV video signal.

### Probes

Two identical probes and matching accessories are provided with the OS-9100P. Their coaxial cables are terminated in BNC connectors. Each probe has a attenuation switch setable to 1× (direct connection) and 10×. A PROBE ADJUST terminal on the front panel provides 0.5-volt, peak-to-peak square waves at 1 kHz. Probe compensation is achieved by connecting the probes to the terminal and adjusting the probe's trimmer capacitor for maximum definition of the squarewave.

### Operations and features

Additive and differential operations are forms of two-channel operation where two signals are combined to display one trace. By either adding or subtracting one signal from the other, the resulting trace represents the algebraic sum or difference of the two signals.

X-Y operation does not use the oscilloscopes timebase to generate a horizontal sweep—a second external signal is used. Usually sinewave signals are applied to two inputs and Lissajous figures are viewed.

Two BNC connectors are located on rear panel. The EXT BLANKING INPUT connector receives external signals to intensity modulate the CRT. CH1 OUTPUT provides a buffered, amplified signal for driving other instruments.

The OS-9100P contains two timebases, arranged so that timebase A may provide a delay between the trigger event and the beginning of the B timebase. This feature allows any selected portion of a waveform, or one pulse of a pulse train, to be spread over the entire CRT screen. Delayed sweep can be used with either single-trace or dualtrace operation.

The OS-9100P is priced at $1099 and is available from LG Precision, 13013 East 166th Street, Cerritos, CA 90701. Tel: (310) 404-0101, FAX (310) 921-6227. EN

## The Book of SCSI: A Guide for Adventurers

*by Peter M. Ridge*
*No Starch Press*
*1903 Jameston Lane*
*Daly City, CA 94014-3466*
*Phone: 1-800-420-7240*
**$34.95**

CIRCLE 341 ON FREE INFORMATION CARD

Pronounced "scuzzy," SCSI (Small Computer System Interface) is an intelligent bus for transmitting data and commands between a variety of devices. With the ability to moves data faster than IDE or E-IDE, SCSI offers the performance and versatility needed for serious multimedia applications. The trade-off is its complexity–SCSI can be hard to understand and put to work.

Written for the people who really use SCSI, this book contains clear explanations of what SCSI is, the parts that comprise a SCSI system and what they do, and how SCSI can work for you. It also offers specific, time-saving instructions on who to add SCSI to your PC, including practical, hands-on advice cables, connecting internal and external SCSI devices, terminators, and configuring SCSI devices to work properly in your system. The text is accompanied by twelve appendixes full of reference data, a plain-English glossary, and more than 100 tables.

The book is actually a collection of material authored by several different experts in the field. Each chapter covers a different topic, ranging from how the SCSI bus works to a look at SCSI now and in the future. There are overviews of ASPI and CAM programming, and questions and answers from the major SCSI host adapter manufacturers--Adaptec, DPT, and Future Domain. Dozens of clear, uncomplicated drawings and diagrams illustrate various aspects of SCSI systems. A directory of more than 150 companies that make SCSI hardware and software provides their toll-free phone, fax, and BBS numbers product listings and more. **EN**

BY JEFF HOLTZMAN

# And then there was . . . one?

EVERYONE IS WORRIED ABOUT MICROSOFT AND COMPETITION. IF YOU'RE JUST GETTING STARTED IN THE PC REVOLUTION, THAT MIGHT NOT MAKE ANY SENSE TO YOU. BUT IF YOU'VE BEEN AROUND FOR A FEW years, perhaps you can understand the bittersweet feelings evoked. Either way, in the long run, they'll just be footnotes to history. By "they," I mean Microsoft's former competitors—companies like Lotus and WordPerfect, and soon Apple and Novell, Borland, plus scores of smaller firms.

Lotus, WordPerfect, and Novell: They were the quintessential 80's software firms. They built huge markets in very short periods of time—and lost them just as quickly. Why? Because they rested on their laurels. Because they ignored market trends. Because they were arrogant and blind.

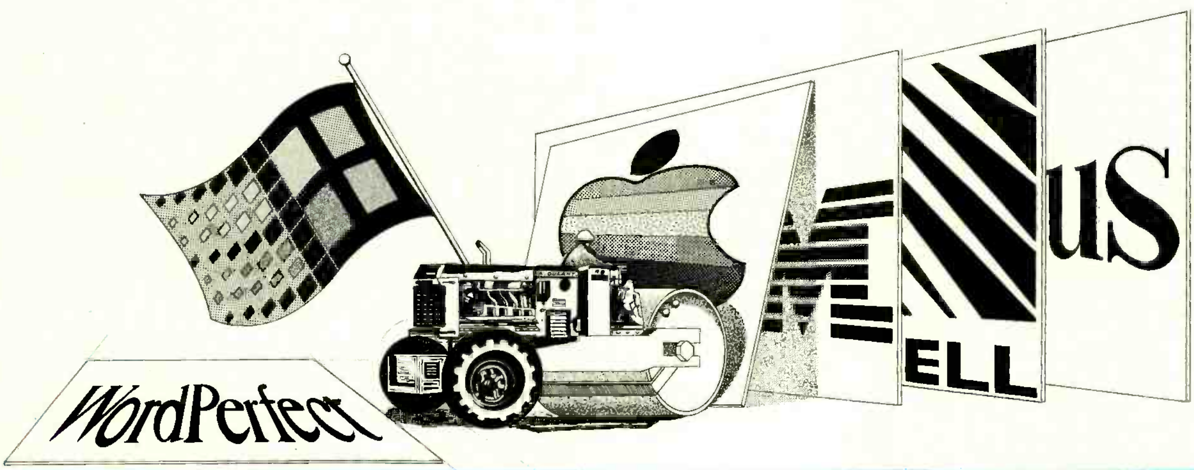
Lotus was not the company that invented the spreadsheet. But Lotus was the company that brought spreadsheets to the IBM PC world. Legions of accountants and MBAs grew up learning about computers through 1-2-3. For roughly a decade, from the early eighties to the early nineties, Lotus was king of the spreadsheet hill. But then along came Excel. And now Lotus is just another division of IBM.

WordPerfect followed more or less the same path. At its peak, it almost completely owned its market. Now the market and the company have shrunk to miniature versions of their former selves. Novell bought WordPerfect less than a year ago, and now is trying to unload it.

And Novell? Novell recently looked back and noticed a steam roller breathing down its neck. Guess what? You-know-who is now doing networking. Rumor has it that Novell itself is now being approached by IBM, HP, and other smaller firms.

IBM of course is the biggest example in the PC industry of how to lose. In little more than a decade its share of the hardware market shrank from 100% to 10%. In all that time IBM still hasn't learned how to market to this industry. OS/2 is a great technical achievement, but a complete loser in every other way. The company's latest strategy involves buying up industry detritus like Lotus. Now *there's* a potent combination.

It's interesting to note how the



# Prepare For a New Future As a LAN Servicing Technician!

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Today's LANs are able to transform individual PCs, departments, divisions, and entire corporations into productive information resources. This dynamic, in-demand technology can be your specialization with NRI training, the ticket to a new, secure future.

Now you can be one of the key technicians able to sell, select, install, use, maintain, and manage office networks. And this know-how will earn you top dollar! Only NRI, the leader in at-home training for over 80 years, gives you everything you need to start a new career or business of your own as a sought-after LAN servicing technician.

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- Two network interface cards
- Thin, Ethernet cable
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- And more!

Using LANtastic, award-winning LAN software, you connect this top-of-the-line system to your existing computer (386SX or better, with hard drive, 3.5" floppy drive, and at least one meg RAM). Then you're set to explore first-hand the tremendous potential of today's LAN technology.

## Lessons cover entire LAN spectrum

NRI's "bite-sized" lessons explain computer electronics and LAN technology step by easy step. Even if you have no experience in this field, you'll be able to understand these expertly written texts because they're loaded with diagrams and illustrations. Plus, they present each subject in clear, everyday language so you won't get bogged down in technical jargon.

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What's more, you have an expert instructor available throughout your training and career. Offering advice and feedback, your instructor will become a trusted mentor, able to help you move up and make good money as a successful LAN servicing technician.

## FREE catalog gives all the details

If the coupon is missing, write to NRI Schools, 4401 Connecticut Avenue, NW, Washington, DC 20008. Or...

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overall PC software and hardware markets have developed. In hardware, many companies make PC's, and no single company owns more than 10% or at most 15% of the market. But the opposite is true in software. There are fewer and fewer companies, and a single company essentially controls the vast majority of the market.

### Countermeasures

There appear to be three schools of thought concerning the "steam roller." One simply concedes the desktop-productivity market to Microsoft. That school of thought says, "We don't know where we're going next, we have no idea how to get there, so we're not even going to try." For example, Lotus became a sheep under shepherd IBM.

The second school of thought tacitly acknowledges that the game as played till now has essentially been lost. So their tack is to try change the playing field. Personally, I think it highly unlikely to succeed, but it is getting a lot of attention in both the trade press and the popular press, so it's worth discussing.

The idea is that both desktop hardware and software as we know them are doomed, and the Internet is the heir apparent. PC hardware is too expensive and too hard to configure. PC software is too complex and too hard to maintain. So dispense with both. Instead, use $500 diskless "Internet terminals" to run "applets" downloaded from the Internet on an as-needed basis for performing common chores such as writing memos or balancing your checkbook. Some liken this model as a return to the mainframe/dumb-terminal paradigm, which is the very antithesis of what the PC revolution is all about.

The companies promoting this point of view are not really part of the PC industry, but they are in very vulnerable positions as Intel and Microsoft surge forward. Sun Microsystems makes UNIX based workstations, servers, and software. Oracle makes relational databases. Oracle has enlisted the help of some far Eastern consumer electronics companies in building prototype internet terminals. And Sun's Java programming language is being promoted as the ideal medium for developing and distributing applets via the Internet.

Oracle has made some half-hearted attempts to penetrate the PC market, with limited success. Meanwhile, Microsoft has been steadily increasing the power of its relational database system, as well as providing greater integration with the operating system, the development tools, and even the applications. In my humble opinion, Oracle is poised to become the next WordPerfect.

Sun is more of a hardware company, but it has essentially no visibility in the PC market. Even if Java in some form or another takes off, it's hard to see how Sun can really benefit. Sure, Sun servers could be running Web server software, but with NT gaining increasing credibility all the time, it's hard to see why corporations are going to want to run Sun boxes in the back room while running Intel boxes on the desktop.

At bottom, the whole Internet Terminal+Java scenario appears to me to be a desperate move by some very scared companies.

### Door number three

The third school of thought is a long-shot at best. But it may hold the only viable alternative. The concept here is of a grass-roots movement, built on an enhanced Linux-like model, that provides a true yet compatible alternative. Here's one way it might work, in fact does work, according to one correspondent who wishes to remain anonymous.

"I have had to deal with several Linux vendors in the recent past. Invariably, they have been super capable, and you don't see that in the quality of the reps any of the major companies (including Microsoft) have sent our way. . . .

We supply semi-custom packages for telecom, avionics, land/marine mobile, and broadcast equipment manufacturers. Our field involves HPIB (IEEE-488) interface and control. . . .

We are developing a complete front end on the Linux platform under Open Look. That isn't revolutionary, but under commercial Unix we would have to become distributors and pay a steep fee with each package sold, or else require customers to buy UNIX licenses in addition to our software. . . . Now, we need only throw in a $25 Linux distribution disc and a configuration floppy, and the customer simply runs the install routine."

Just as electronics was in the sixties and seventies, and PC's in the eighties, Linux is becoming the technical hobby of the 90's. Can it evolve into something with broad-based appeal? Only time will tell.

### E-mail

Solipsism and Cyberspace was the title of my December column. It brought in several interesting responses. For example, Jim Moore says, "I thought that your article was excellent. I am, however, surprised to know that you think that DOS is dead. DOS was never born. I am sure somebody found it under a rock somewhere."

Actually, Bill did find it under a rock somewhere. The guy who wrote the original version of DOS, Tim Paterson, "borrowed" much from CP/M, the 8080/Z80-based OS of the time. Tim eventually got $1 million after suing Microsoft.

Babak Sehari writes, "I think you did a good job this time! Specially about philosophy and science. This was opportune because I am getting my Ph.D. in Electrical Engineering this December. I would like to add that philosophy and science have done much interaction with each other.

For example, philosophers condemned scientists to death, because of their un-PC opinions (e.g., Galileo and Copernicus). On the other hand, science is based only on observation, not reasoning.

How do we know our spaghetti-wired instruments are functioning properly? How do we know the things we see are real? For years, we were measuring the weight of materials and thinking of it as mass. For years we thought of the Earth as the center of the universe. For years our observations and our science misled us."

I would only add "and continue to do so." The public at large has a gross misunderstanding of what science is, as well as exactly how it relates to technology.

Tony Kurth writes, "Just wanted to thank you for the piece you wrote. I think all engineers, especially EE's, have an introspective point of view that your writing addresses admirably. When your studies and your job reveal truths from available analogies, you can't help but get involved in looking for meaning in all things in life. . . . Have you read *Turn Signals Are the Facial Expressions of Automobiles*? . . . . excellent book. Similar thoughts to yours, and can be enjoyed by anyone with an engineering background. The author really destroys the expression 'real time'."

Last, Andrew Kohlsmith writes, "Personally, I'm a diehard DOS guy, but I can see the writing on the wall. . . . WinSloth, WinSloth 95—they're just clown suits for DOS. OS/2 is nice, and while extremely powerful, the almost completely vertical learning curve throws off all but the most diehard of power users. I found that the utilities in the Bonus Pack, while good, are quite buggy. . . .

Linux, on the other hand, is an operating system I've fallen in love with. Don't like something? Recompile it. Bug? Fix it, you've got the source code. Channels in the Internet Relay Chat are devoted to Linux, and they're full of real programmers who can help you with your problems, unlike the "tech support" you get with other operating systems and software.

"The learning curve for Linux is fairly steep, although being a DOS guy gave me a definite advantage. My 10+ years of C and ASM programming also come in handy with this OS. . . . Documentation is one thing that Linux lacks in a big way.

I've found that the book, *Special Edition Using Linux: The Most Complete Reference*, from Que (ISBN: 0-7897-0100-6) to be excellent. . . . The CD has the complete Linux, including full source code and the GCC compiler, a very intuitive setup program, documentation, the XFree86 windows environment and more."

Contact me by E-mail to leave comments and suggestions for future columns at jkh@acm.org. EN

## WHAT'S NEWS

*continued from page 6*

the volume of special optical materials. A million or more data bits are placed on each page, and thousands of pages can be stored in a material no larger than a small coin. Because there are no moving parts and all the information in each page is accessed simultaneously in parallel, the technology has the potential for very rapid access to any of the stored data. Potential applications include satellite communications, airborne reconnaissance, high-speed digital libraries, rugged storage for tactical vehicles, and image processing for medical and military purposes.

The HDSS program was formed to develop several key components and to integrate them into separate write-once and rewritable systems that demonstrate the technology's potential capacity of 1 trillion bits or more and a data-throughput rate of at least 1 billion bits per second. Its initial goals are to develop a high-capacity, high-bandwidth spatial light modulator used for data input; optimized sensor arrays for data output; and a high-power red-light, semiconductor laser. At the same time, HDSS researchers will explore issues pertaining to the optical systems architecture, data encoding/decoding methods, signal processing techniques, and the requirements of target applications.

## Personal Communications Service launched

Vice President Al Gore used a Motorola handset to make the first official call on the nation's first broadband Personal Communications Service (PCS) system, launched last fall in the Washington/Baltimore area. The PCS system incorporates 100% digital technology in lightweight, palm-sized handsets that combine a portable telephone, text pager, and answering machine in a single device. The call, made from the White House to Baltimore, introduced American Personal Communication's (APC) Sprint Spectrum system. EN

# MINI METROLOGY LAB

***Build a stable voltage standard as the first step in constructing a mini metrology lab.***

**CONRAD R. HOFFMAN***

METROLOGY, THE SCIENCE OF MEASUREMENT, is one of the oldest sciences, and it is an essential ingredient of all other sciences. When the Egyptians built the pyramids, they relied on measurements whose precision we can confirm to this day. The measure of time was also of great importance, as seafaring navigation required accurate time to determine longitude. But the development of the ship's chronometer is another story.

Here, of course, we are concerned with electrical metrology: the science of electrical measurements. Every area of electronics requires that measurements be made. Even when extreme accuracy isn't critical, there is much satisfaction in making measurements accurately and confidently.

The Mini Metrology Lab described in this series will give you two new capabilities. First, it will let you make high-accuracy DC measurements, typically much better than a 4½ digit meter. Second, it will provide you with the standards necessary to calibrate other test equipment to the same accuracy.

The project will also give you hands-on experience with precision measurement techniques, and highlight the more subtle error sources that affect these measurements.

The traditional tool for making very precise DC voltage measurements is based on a slide-wire potentiometer and a galvanometer. That circuit compares a known voltage standard against an unknown voltage. It was the only high-resolution voltmeter until the 1960s.

The instruments used for making such measurements are known as potentiometers. The heart of the instrument, as its name implies, is a potentiometer or variable voltage divider. A basic potentiometer circuit is shown in Fig. 1.

After the unknown voltage is connected to the circuit, the voltage divider is adjusted until the meter indicates zero, or a null reading. The null indicates that the voltage at the tap on the potentiometer is identical to the voltage of the unknown sample. The value of the unknown voltage is then read from the divider setting. A continuous potentiometer is shown for simplicity, but a multi-decade switched divider is normally used because it achieves much better accuracy and stability.

There are several important advantages to this method:

*Thanks to Jim Williams and Mark Gordon of Linear Technology Corporation for their assistance with the design of the Mini Metrology Lab.

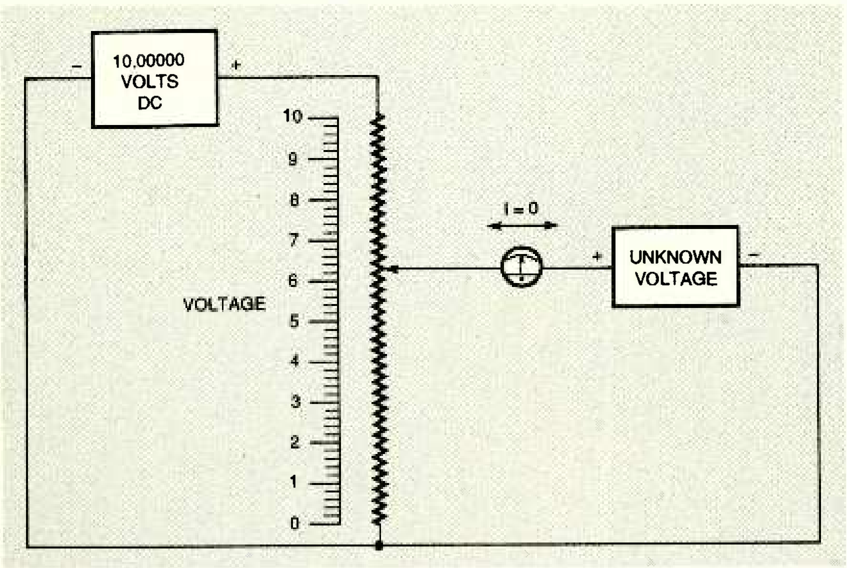



FIG. 1—THE POTENTIOMETER CIRCUIT was the only high-resolution voltmeter until the 1960s. At null, the voltage of the divider equals the voltage of the unknown, and no current flows between them. Here, the wiper is 61.25% up the voltage divider, so the value of the unknown is 6.125 volts.

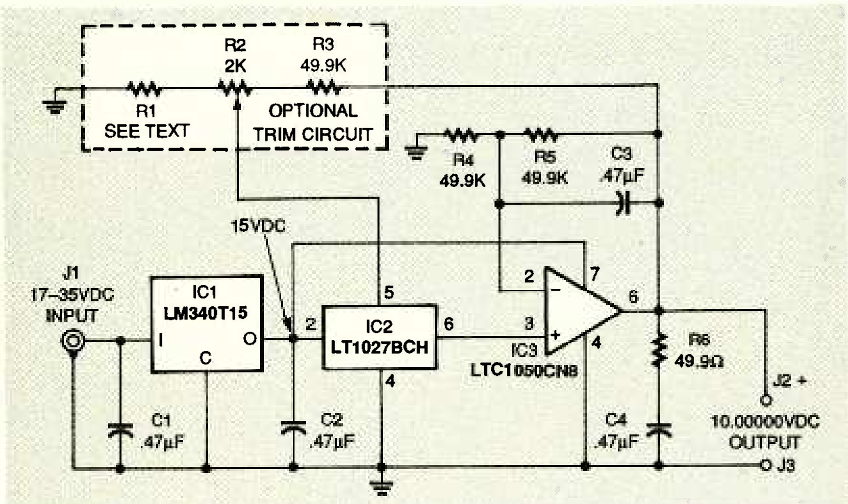



FIG. 2—THE VOLTAGE STANDARD is built around the LT1027 voltage-reference IC. Although the device is pretrimmed within ±0.05%, optional trim circuitry can be installed.

**1.** The accuracy of the meter is not important, because it is used only to determine the null point. Of course, it should be sensitive and repeatable.
**2.** Once nulled, there is almost no voltage difference between the divider output and the source being measured. As a result, almost no current flows, and there is no significant loading of the device that is being measured.
**3.** The voltage divider relies on ratios, not specific values of resistance. It can be checked for accuracy by the user, whenever desired.
**4.** Only the voltage standard needs to be independently calibrated.
**5.** It is one of the most accurate techniques available, and is still used today to verify the performance of other instruments.

The complete Mini Metrology Lab that we'll describe will consist of a voltage standard, a null detector, and a Kelvin Varley voltage divider. These can be configured as described above, or can be used separately for various other measurement and calibration purposes.

Carefully built, these classic tools will yield accuracy far beyond what you may be accustomed to. No special equipment is required, and it is not a difficult project. You will need only patience and a good digital voltmeter.

## Circuit description

The heart of the voltage standard is the LT1027BCH voltage reference IC manufactured by Linear Technology Corp. It sports a temperature coefficient of two parts per million per degree Celsius (2 PPM/°C), and it comes pre-trimmed within ±0.05%. Provision for optional trim circuitry is included on the board however it requires an additional resistor selection step.

To eliminate sensitivity to input-voltage variations, the incoming supply is regulated at 15 volts DC. This is accomplished with a conventional LM340T15 voltage regulator, which powers both the reference IC and the output amplifier.

The LT1050 amplifier doubles the 5-volt output of the LT1027 to the desired 10 volts DC. It is chopper-stabilized, providing far lower drift than a conventional op-amp. Noise filtering is provided by the 0.47 µF capacitor across the feedback resistor. Note that the LT1050 does not have the output drive of a bipolar device, thus the slightly higher than normal feedback resistors. You should not try to use the voltage standard with loads below 10 kilohms. The 0.47 µF/49.9 ohm output network improves stability when cables and capacitive loads are driven.

## Selecting resistors

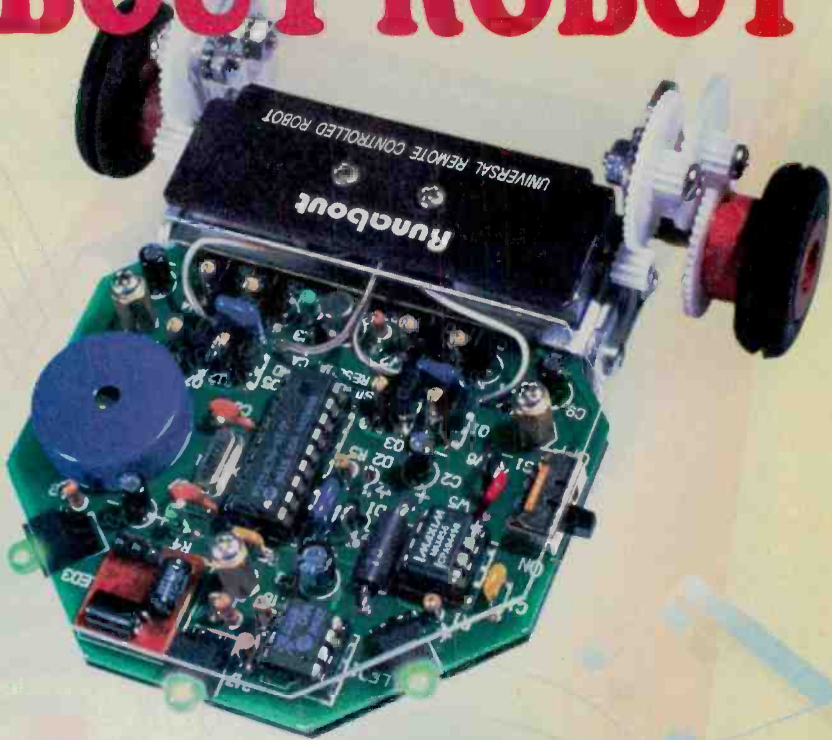
The ratio of R4 and R5 sets the gain of the output amplifier, and must not change with temperature. To achieve this stability, the feedback resistors must have matched temperature coefficients (tempco).

A commercial manufacturer would simply order matched wirewound or bulk foil parts with the tempco needed. Unfortunately, large minimum-order requirements and high prices force us to seek another solution for this project.

*Continued on page 65*

# BUILD THE RUNABOUT ROBOT

DAN RETZINGER




***The Runabout robot's 17 functions are controlled by a universal TV remote control.***

SOME TIME AGO, SOMEONE LOOKED around his living room and noticed that a number of remote controls were accumulating on the coffee table—one for the TV, one for the VCR, one for the cable box, and one for the stereo. No doubt that observation led to the invention of a device now readily available in many retail stores, namely the universal remote control.

The universal remote control is a device that you can program to operate almost any TV, VCR, or cable box. It doesn't matter what brand TV/VCR/cable box you own. You simply look up a code in the instruction manual, enter it into your universal remote, and the corresponding device can be controlled.

With universal remote controls now being so readily available and inexpensive (in the $10 to $20 range), it is tempting to use one to control yet another device. This article describes the Runabout, a small desktop robot that can be controlled from almost any universal remote control.

**Features**

The Runabout can be controlled with virtually any infrared universal remote control. The mode used to control the Runabout is the same mode that controls any Sony brand television. Therefore, you need only program your universal remote for a Sony TV, and it will control the Runabout. Also, if you have a Sony brand television, your non-universal Sony remote will also operate the Runabout.

The Runabout is controlled by 17 keys on the remote including channel-up, channel-down, volume-up, volume-down, number keys 0 through 9, and a few others. Various keys tell the Runabout to move forward or reverse, turn right or left, or stop. Some keys enable the Runabout to produce sound effects through a built-in piezoelectric speaker mounted on the Runabout's PC board. Other keys flash Runabout's three LED "headlights."

The Runabout also has an on-board 16-kilobit, non-volatile memory that enables it to remember movement sequences. There are six selectable memory banks, each with 127 steps of memory. This means you can have the Runabout repeat its movement and produce sound effects automatically. You can store six sequences each with up to 127 steps and, with the press of a button, the Runabout will replay the sequence. Sequences are stored and remembered even if power is temporarily turned off or the batteries die.

The on-board infrared receiver is sensitive enough for a control range of up to 25 feet. You can select two speeds—a high range and a low range. The Runabout requires only two AAA batteries for operation.

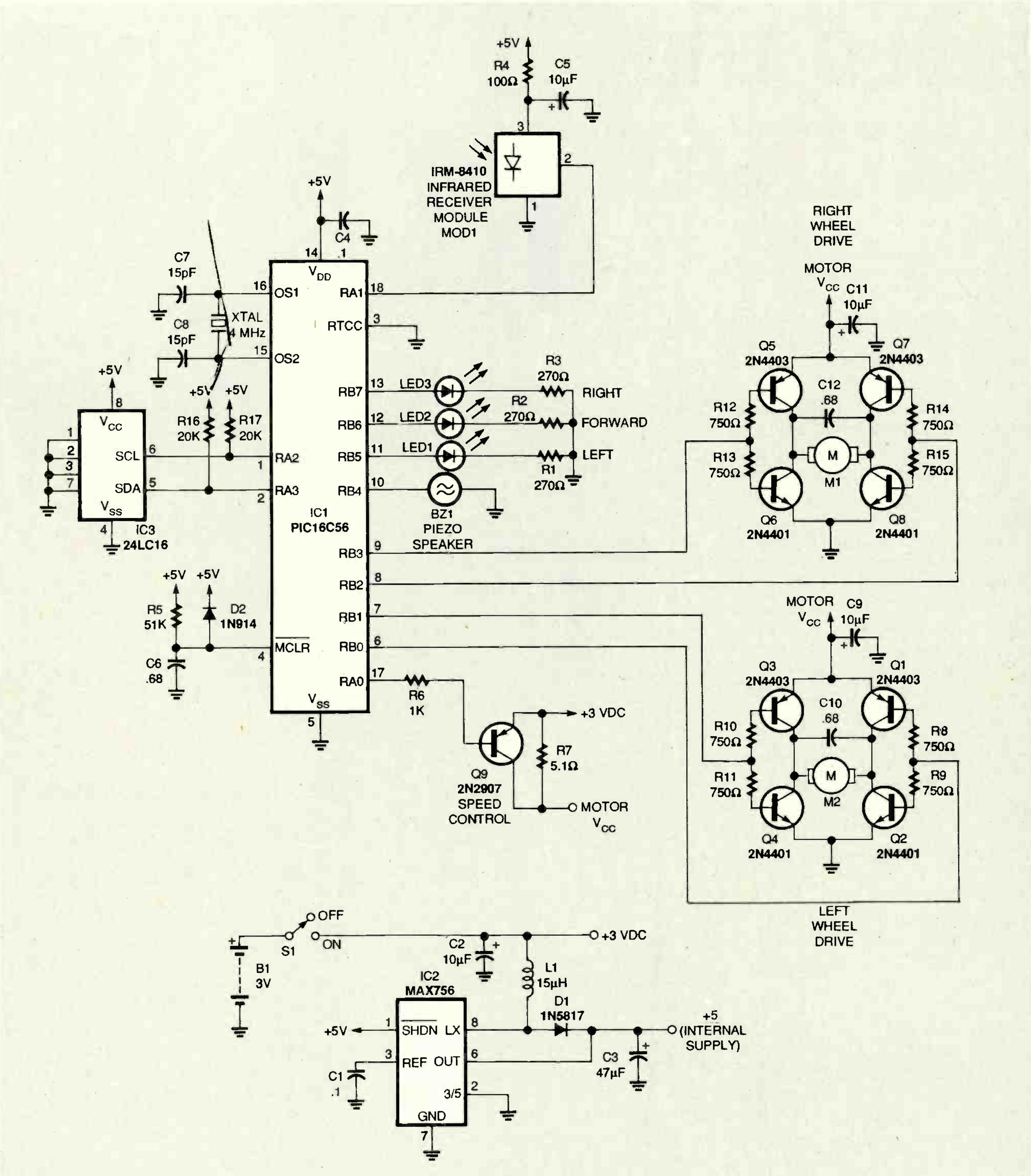



FIG. 1—RUNABOUT SCHEMATIC. The "brain" of this device is a Microchip Technology PIC16C56 eight-bit CMOS microcontroller with built-in EPROM.

## The circuit

Figure 1 is the schematic diagram of the Runabout circuit. The "brain" of this robot is IC1, a Microchip Technology PIC16C56 eight-bit CMOS microcontroller with built-in EPROM. The PIC16C56 is housed in an 18-pin DIP package that contains a central processor, clock, EPROM, RAM, a timer, and 13 TTL/CMOS-compatible input/output (I/O) lines.

Control information from the universal remote control is received by an infrared receiver module, MOD1. The IR receiver module outputs a low-level TTL-compatible signal whenever it receives a pulse of infrared light from the remote control. Therefore, whenever a button is pushed on the universal remote, the receiver module outputs a serial bit-stream unique to that particular button.

The receiver module then feeds the bit stream to micro-

*Continued on page 54*

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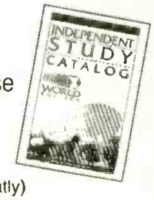


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# BUILD THIS THEREMIN

## *Build Theremax—a theremin for the 1990's!*


JOHN SIMONTON

LAST MONTH, WE DESCRIBED THE circuitry behind Theremax. This month, we show you how to build it.

Although all of the signals in Theremax have frequencies below 1 MHz, it's important to build the unit carefully. Keep the point-to-point wiring as short as possible, and leave plenty of space between the four oscillators to minimize oscillator lock.

The easiest way to build the electronics of Theremax is to make or buy the printed-circuit board, which was presented last month. The component-placement diagram for the board is shown in Fig. 3. If you construct the circuit or just parts of it on perforated prototyping board, try to follow this layout as closely as possible since care has been taken to isolate parts of the circuit that might interact. Note in particular the use of a star ground point with traces emanating from circuit board point "G", and the grounded lands that encircle each oscillator. Make sure the metal cans of the inductors are grounded as well.

For the most part, Theremax is very forgiving of the specifics of components. For example, almost any NPN silicon transistor will work in place of the 2N4124s specified—2N3904s or 2N2222s will be fine. Even the inductor values are not very critical, and you will find that most suppliers carry IF transformers and local-oscillator coils that can be made to work in the circuit, probably without even changing the operating points of the transistors. Make sure the "cans" you use have a tapped primary (you may have to reverse the ends of the primary to get the tap closer to the collector end) and a secondary (polarity doesn't matter here).

Do not substitute silicon diodes for the germanium types used in the ring modulators. The forward voltage drop of silicon diodes makes them inappropriate here. The other critical components are the ceramic disc capacitors used in the tank circuits. These must be NPO types to minimize oscillator drift with changes in ambient temperature.

Connect the front-panel controls and jacks to the lettered pads on the circuit board with No. 22 AWG stranded wire, as shown in Fig. 4. Note that you must mount some of the fixed resistors between solder lugs on the panel controls, as shown. Mount the LEDs by twisting their cathode leads to their current-limiting resistors and soldering. Mount the front panel to the lectern case from the inside; the controls are exposed though a hole that's routed-out in the front of the case.

The shapes of the case pieces have been kept as simple as possible. (See Fig. 5.) Assemble the case with simple butt joints, countersunk screws, and glue. (See Fig. 6.) The case for the prototype was cut from clear white pine and finished with walnut-tinted tung oil. If you start from scratch, you may choose other materials and configurations. If you decide on a metal case, make sure that the antennas are insulated from it.

Form the antennas from No. 6 AWG copper buss bar—the kind that power companies use for ground connections. This material was chosen for its malleability and ease of fabrication. Reformable antennas can be easily shaped for experimental purposes. For example, zig-zag pitch antennas might give a different means of obtaining vibrato—you could hold the pitch hand vertical while running it up and down, rather than waving it closer to the antenna. You can form the volume antenna from a length of the buss rod and bend it in any appealing, roughly loopish pattern. While the specific shapes that you choose for the anten-

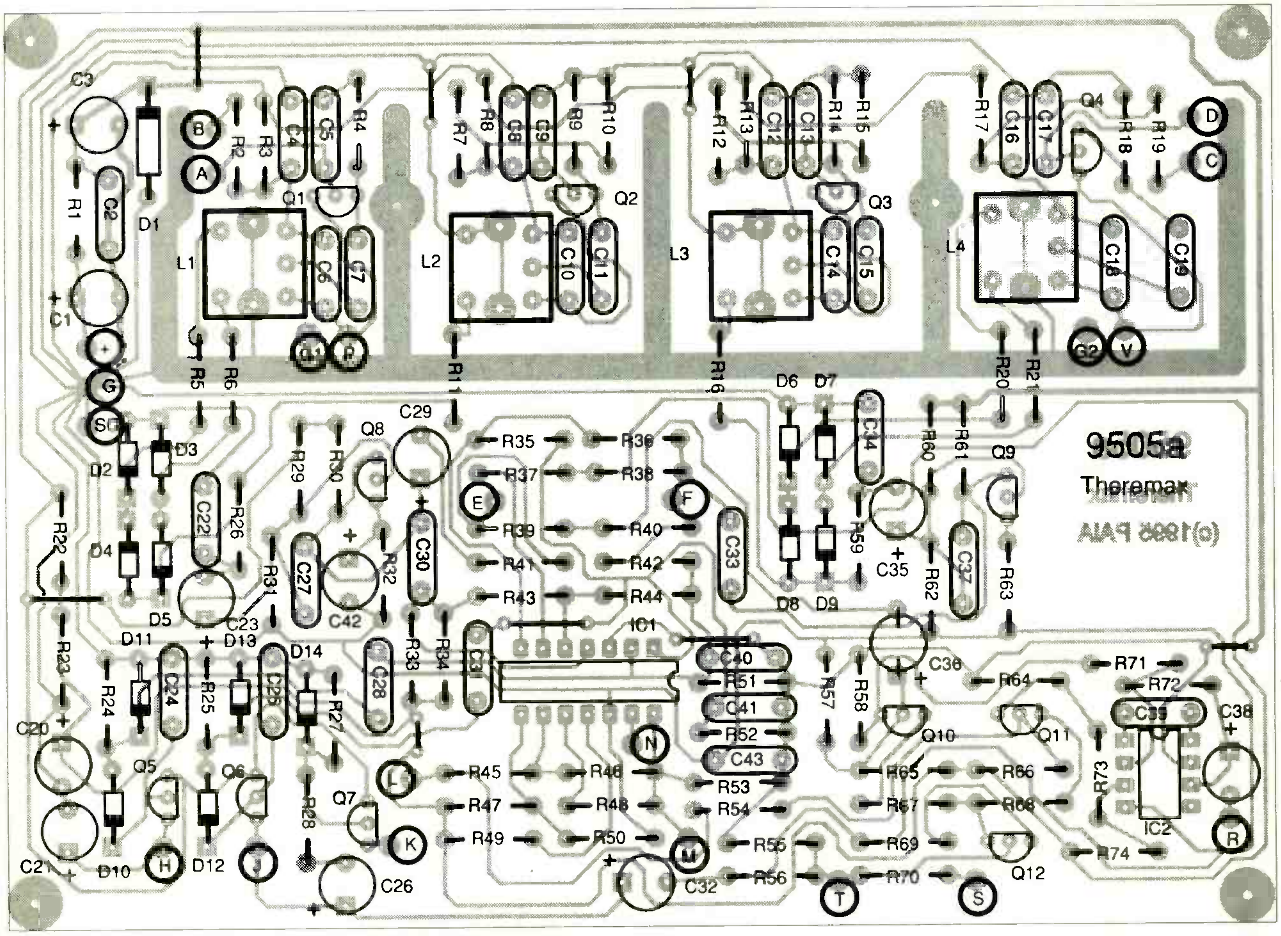



**FIG. 3—PARTS-PLACEMENT DIAGRAM for the Theremax circuit board. The lettered pads connect to off-board components.**

nas are pretty much up to you, be sure to keep them at right angles to one another to minimize interactions between them.

Mount the antennas to the case by passing them through 3/16-inch holes drilled in the end panels. Secure them to the back of the case with large washers, wing nuts and No. 8 flat-head screws that pass through loops bent at the end of the buss rod, as shown in Fig. 7. Make the connection to the antennas with RG-174/U coaxial cable. Ground the shield only on the circuit-board end.

Make the bottom of the case from metal to form a ground plane that cuts down on any interactions between the pitch and volume sections. Mount the circuit board to the bottom plate with standoffs and 4-40 hardware. (See Fig. 8.)

## Testing and tuning

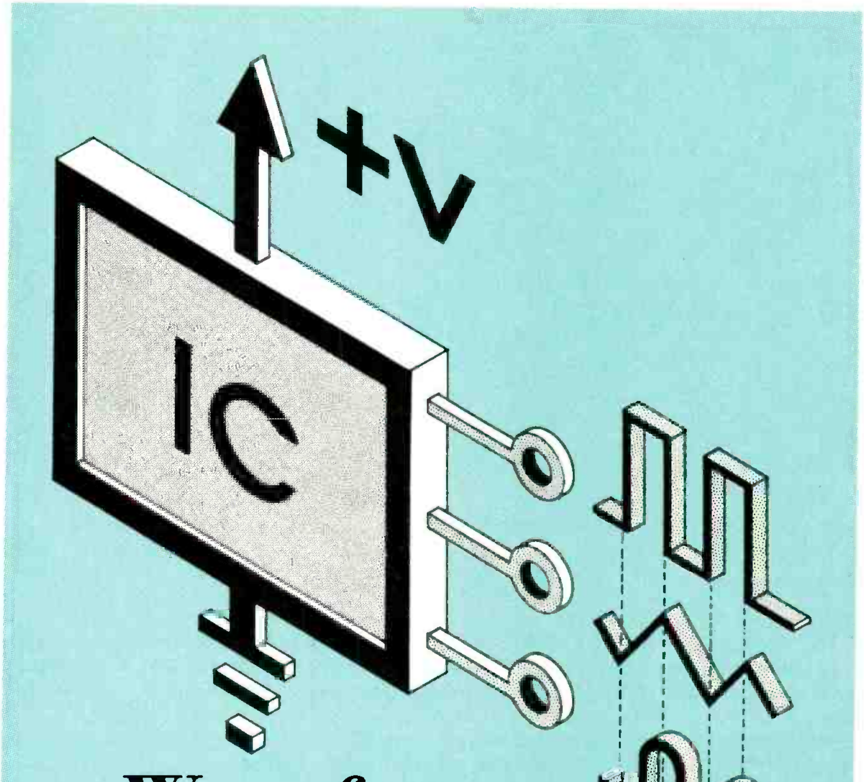
After examining your work carefully—looking for solder bridges, incorrectly placed or oriented parts and so on—it's time to power up. Plug the power adapter into a wall outlet and turn on the power switch, S1. You should immediately see the POWER LED light. If you don't, stop. Re-examine your work, and find out why.

Begin testing and initial tuning by setting the front-panel controls so that the PITCH TRIM and VOL TRIM controls are at about the midpoint of their range. Set the PITCH CV, TIMBRE and VELOCITY controls fully counterclockwise, and rotate the VOLUME control clockwise to its maximum setting. Connect the audio output of Theremax to the input of a hi-fi, instrument, or general-purpose amplifier.

Verify the operation of the oscillators and set the heterodyning pairs to the same frequency. With an oscilloscope, look at the voltage of the emitters of the oscillator transistors (Q1 to Q4) and observe the 500-kHz to 900-kHz sine waves with amplitudes of about 250 millivolts peak-to-peak, and DC offsets from ground at about a volt. As the slugs of heterodyning pairs of oscillators are adjusted, the beat frequencies—0 to 10 kHz, 0.5 volts peak-to-peak sine waves—can be seen at the collectors of the amplifier transistors Q8 or Q9. They'll have a typical DC offset of 5 to 6 volts above ground. First turn the slugs of L2 and L3 clockwise until you feel resistance (don't try to "tighten" them), then back them out about a half turn. Now adjust L1 while watching Q8's collector. At some point in the rotation of the slug, you will see a sine wave that builds in amplitude while decreasing in frequency, then goes to zero before once again increasing in pitch. The zero (null) point is your target. Do the same thing with L4 while watching for zero beat at the collector of Q9.

*Continued on page 69*

RAY MARSTON




# Waveform Generator Circuits

**_Learn how to generate square and rectangular waves for timing, communication, and control, and apply that knowledge to your circuit designs._**

SQUARE AND RECTANGULAR WAVES are required for digital clocks, computers, and communications, and modulated pulses control motors, switching power supplies and pulsed radar. The generation of symmetrical square and asymmetrical rectangular waves permits the transmission of coded signals and the regulation of power. Earlier articles in this series focused on the generation of symmetrical sinewaves.

**Squares and rectangles**

Squarewaves are nonsinusoidal waves that can be generated directly or derived from sinewaves. (Triangle waves and sawtooth waves are other examples of nonsinusoidal waves.) A squarewave is said to be symmetrical if the waveform widths or time duration of both of its states are equal. Figure 1-a shows a squarewave with its zero-volts reference midway between its two peaks. The *period* is the unit of time required for one cycle of the signal to repeat itself, and it is expressed in units of time.

A pulse can be a one-time (or one-shot) signal and have no period, as shown in Fig. 1-b. However, waveforms comprised of repetitive pulses are typically called *rectangular waves*. Whether one-time or repetitive, pulses are characterized by *pulse width*, measured in units of time, and *peak-to-peak amplitude*. If they are repetitive, they are, like square waves, also characterized by period, measured in units of time, as shown in Fig. 1-c.

Figure 2 zooms in on a single pulse to define other characteristics. Pulses are not perfect rectangles; they are actually closer to trapezoids with rounded corners. As a result, their parameters are defined to account for these variations from a perfect rectangle. *Amplitude* represents 100 % of pulse height. Because pulses do not have truly vertical leading edges, their slope is defined by *rise time*, measured in units of time from 10 % to 90 % of amplitude. Similarly, their trailing edge slope is also measured in units of time from 90 % of amplitude to 10 %.

Because of their trapezoidal shape, *pulse width* is defined at the 50 % level of amplitude. The time relations between pulse width and period can vary. (The squarewave is a special case of a rectangular wave in which pulse width is equal to half of the period.)

Three more terms apply to all rectangular waves: *duty cycle*, *duty factor*, and *repetition rate*. Duty cycle is the ratio of pulse width to signal period, expressed as a percentage. (For square waves, it is always 50 %). Duty factor is the same as duty cycle, except that it is expressed as a decimal rather than a percentage. Repetition rate describes how often a pulse train occurs. This term is frequently used instead of frequency when describing these waveforms.

In telecommunications and amateur radio, the term *mark* (the time duration of pulse current) is substituted for pulse width, and the term *space* (the time duration of zero pulse current) applies to the time duration of zero waveform ampli-

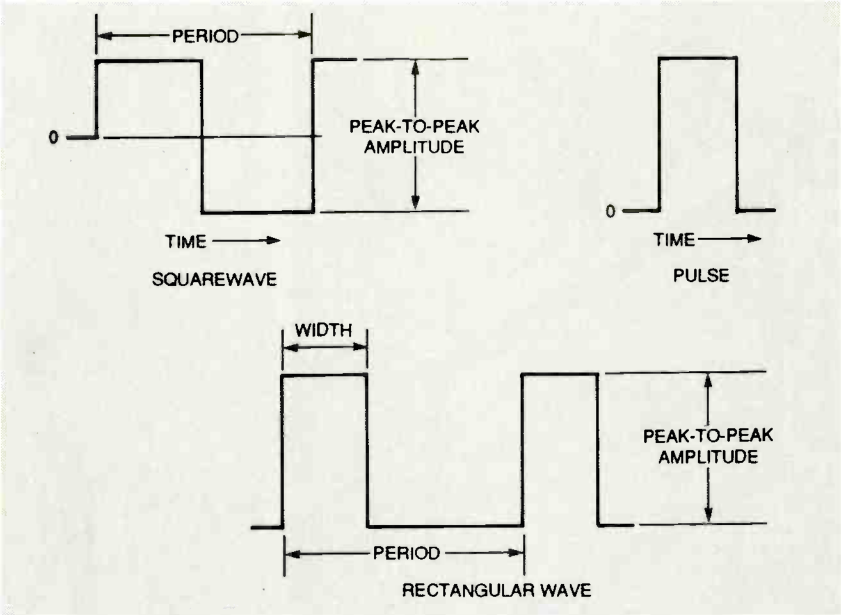



**FIG. 1—SQUARE AND RECTANGULAR WAVEFORMS. The squarewave has equal positive and negative widths (a). A one-shot pulse waveform (b), and a rectangular wave with a pulse width less than half of its period (c).**

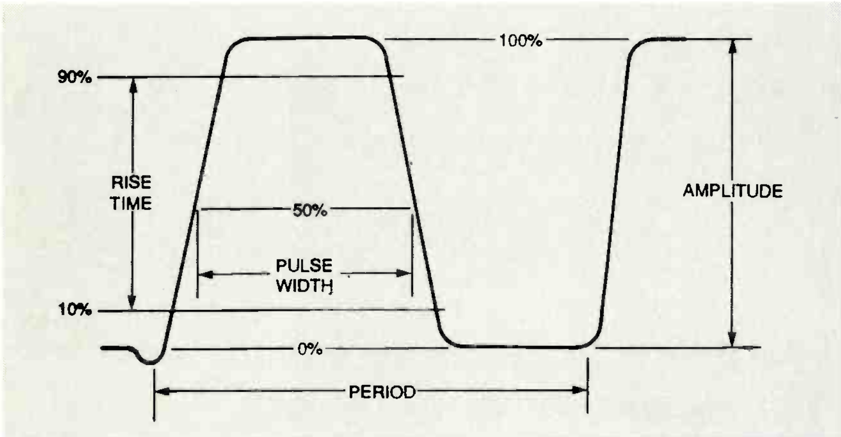



**FIG. 2—PULSE PARAMETERS. The terms are defined to allow for the generally trapezoidal shape of a typical pulse.**

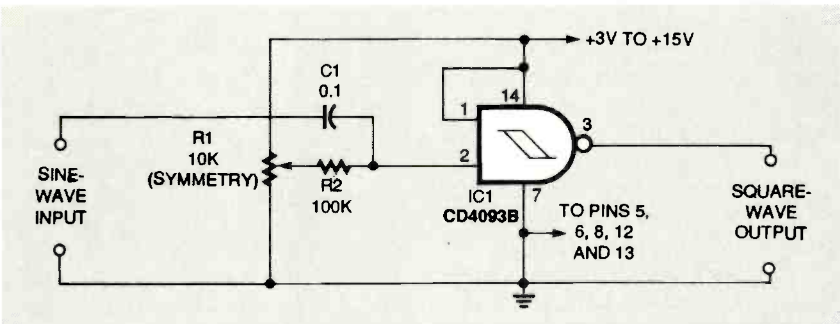



**FIG. 3—A SINE-TO-SQUAREWAVE converter made from one gate of a CMOS Schmitt trigger IC.**

tude. Thus, the sum of the mark and the space equals the signal period, which, in turn, is the reciprocal of the frequency ($1/f$).

### Sinewaves-to-squarewaves

High-quality squarewaves can be generated by sinewave-to-squarewave converter circuits. An example of one of these circuits is the Schmitt trigger shown in Fig. 3. Four of these circuits are available at low cost in the CD4093B, a CMOS quad 2-input NAND Schmitt trigger IC. Each of the four circuits in this IC function as a two-input NAND gates with Schmitt-trigger action at both inputs.

The simple converter circuit shown in Fig. 3 is formed by wiring potentiometer R1, resistor R2, and capacitor C1, as shown, and then disabling the inputs of the three unused Schmitt-trigger circuits by grounding them. This circuit produces excellent squarewaves with typical rise and fall times of less than 100 nanoseconds when the output is loaded by a 50-pF capacitor. The Schmitt trigger's threshold can be set by 10-kilohm potentiometer R1.

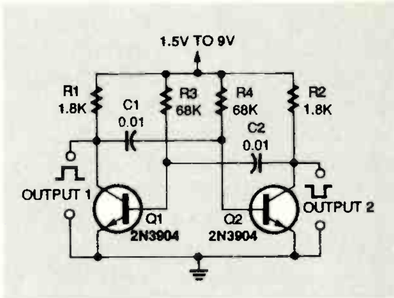



**FIG. 4—A TRANSISTORIZED astable multivibrator that oscillates at 1 kHz.**

Note: Remember that the CD4093B and the other CMOS ICs mentioned in this article are subject to damage or destruction by electrostatic discharge (ESD). Take proper precautions by storing the devices in approved conductive packages or containers. Wear a grounded wrist strap when handling these ICs, and do all assembly work on a grounded conductive desk or benchtop work surface.

### Astable squarewave circuits

Squarewaves can be generated by a two-transistor *astable* or *free-running multivibrator.*. Figure 4 is a schematic for a 1-kHz astable multivibrator that will run from a 1.5- to 9-volt power source. A cross-coupled oscillator, the pulse widths and periods of this circuit are deter-

*Continued on page 77*

IN DECEMBER, WE PRESENTED THE circuitry for an electrochemistry power supply. This month, we finally wrap things up with construction details.

**Sheet metal work**

The prototype unit was packaged in a standard two-part aluminum case, as shown in Figs. 7 and 8. It measures 8×5×2-inches. All components are mounted in the lower half of this case, as shown in the photograph Fig. 7. Tape the front panel hole-drilling template Fig. 9 on the 2×8-inch vertical panel of the case that is to be the front panel.

Centerpunch the centers of all holes to be drilled for front-panel-mounted components (R33, R34, S1, S2, S3, S4, and two banana-plug jacks). Mark and centerpunch the locations of the four corners of the rectangular window to be cut for the LED display and the two holes for mounting the display board to the front panel. Drill all of the holes to the appropriate diameters for mounting those components, and cut out the rectangular window for the LED display.

With the large circuit board template, locate, centerpunch and drill the four holes for mounting the circuit board in the base of the case. Then, using the drilled holes in the mounting bracket of transformer T1 as a template, centerpunch and drill the two holes for mounting T1 to the bottom of the case. Finally, on the back panel of the case, centerpunch and drill two mounting holes for the heatsink and one hole for the linecord. Insert a protective grommet in the linecord hole.

Refer to the assembly drawing Fig. 8. Before mounting the components on the front panel, you might want to apply decals or other labels to identify each control function, as shown on template Fig. 9. Mount all of the front-panel-mounted components with their ring nuts. Fasten the LED display circuit board to the panel with screws and nuts. Cut a small rectangle of 1/16-inch thick red plastic 1¼ × 1⅛ inches as a filter, and cement it over the window cutout for the LED display.

When mounting transistor Q2 (TO-220 case) to the heatsink, as shown in Fig. 8, insert an electrically insulating mica washer coated with silicone grease between the heatsink and the transistor tab to isolate Q2 from the heatsink. (The insulator avoids raising the case 16 volts above ground because the transistor's metal tab is connected to its emitter.)

Refer to assembly drawing Fig. 8. Before mounting either transformer T1 or the circuit board to the case, cut the required number of 4- to 6-inch lengths of hookup wire (No. 18 and No.22 AWG) and strip their ends. Solder all wire connections between the circuit board and the panel- and base-mounted components before fastening them in the case.

Mount the circuit board to the base of the case with screws and nuts with three nuts inside the case to act as standoffs to isolate the circuit board wiring from the metal case. Attach the knobs to the shafts of R33, R34, and S2. Apply the adhesive feet to the bottom corners of the case.

Carefully examine all wiring and solder joints to verify that

***Build this regulated electrochemistry power supply and learn about electrolysis and electroplating. Then plate small objects to protect them and improve their appearance.***

# Regulated Power *for* Electrochemistry

## PARTS LIST

**All resistors are ¼-watt, 10% unless otherwise stated.**

R1—1200 ohms
R2—1.0 ohm, wirewound , 1 watt
R3—820 ohms
R4, R6, R14, R15—10,000 ohms, 1%
R5, R7—100,000 ohms, 1%
R8, R10—1000 ohms
R9—33,000 ohms
R11—68,000 ohms
R12—2,000,000 ohms
R13—47,000 ohms
R16 to R29—3000 ohms
R30—3900 ohms
R31—10, 000,000
R32—86, 000 ohms
R33—panel potentiometer, 10,000 ohms, linear taper, ½ watt, Mouser 31VC401 or equiv.
R34—panel potentiometer, 25,000 ohms, linear taper, ½ watt, Mouser 31VC403 or equiv.
R35—trimmer potentiometer, 10,00 ohms, vertical mount

**Capacitors**

C1—2.2µF, tantalum electrolytic
C2—0.1µF, polyester film
C3—0.1µF, polyester film
C4—0.3µF, polyester film
C5, C6—22pF, ceramic (see text)
C7, C8—0.010µF, polyester film
C9—10µF, tantalum electrolytic
C10—4700µF, aluminum electrolytic
C11, C12, C13—0.010µF, polyester film

**Semiconductors**

D1—1N5239B, Zener diode, 9.1 volts, 500 mW
D2—1N5237B, Zener diode, 8.2 volts, 500 mW
BR1—, bridge rectifier, 1.5 ampere, 200 PIV, General Instrument WO2 or equiv.
Q1—2N3705, NPN transistor, TO-92
Q2— MJE3055T NPN power transistor, Motorola or equiv.
IC1—CD4521B CMOS 24-stage frequency divider, Harris or equiv.
IC2—CD4011UB CMOS quad 2-input NAND gate, Harris or equiv.
IC3—CD4046B CMOS phase-locked loop, Harris or equiv.
IC4, IC6, IC7—CD 4518B CMOS dual BCD up-counter, Harris or equiv.
IC5—LM358 dual operational amplifier, National or equiv.
IC8, IC9—CD4543B CMOS BCD to seven segment decoder driver, Harris or equiv.
IC10—MC7812 three-terminal positive voltage regulator, Motorola or equiv.
DISP 1—MAN6740, light-emitting diode display, 0.56-inch dual digit, common cathode, RHDP, red, 7-segment or equiv.

**Other components**

S1, S3— toggle switch, miniature SPDT panel-mount
S2—rotary switch 3-pole, 12-station
S4—pushbutton switch, nonlatching, push-to-make
XTAL1—crystal, 4.194304 MHz, 2-pin metal case
TR1—transformer 120 volts to 6 volts, panel-mount
J1, J2—banana plug jacks

**Miscellaneous:** main circuit board; dual-digit LED circuit board; metal project case, two part (see text); heatsink (see text); knobs for two potentiometers and one switch; No. 18 and No. 22 AWG stranded, insulated hookup wire; No. 28 AWG flat ribbon cable; 120-volt AC linecord with plug; linecord grommet; red plastic filter for LED display DISP1 (1-14 × 1½ inches—see text); assorted nuts, lockwashers and screws; four adhesive rubber footpads, solder, silicone grease.

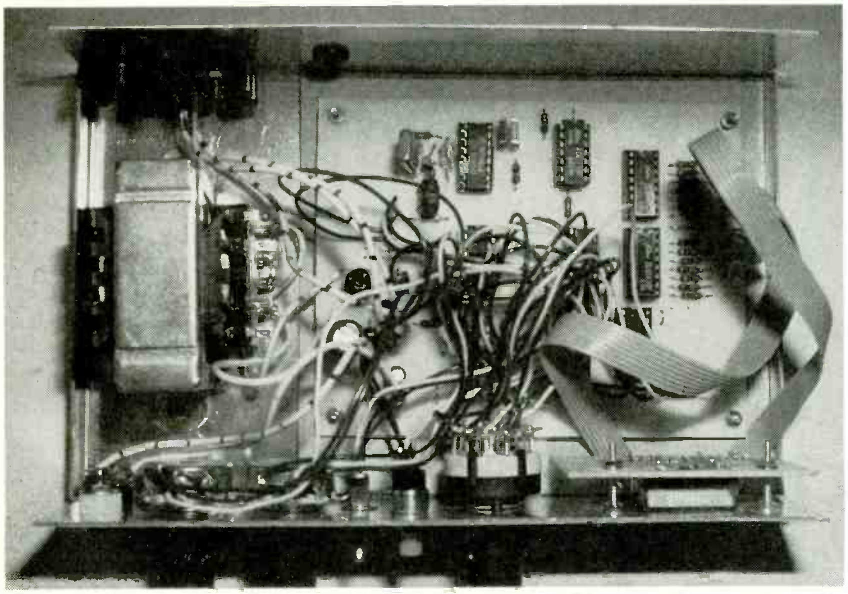


**FIG. 7—AUTHOR'S PROTOTYPE with cover removed: a 120- to 6-volt AC transformer T1 is at left, and the circuit board is at right.**

they have been made correctly. Look for cold solder joints or inadvertent solder bridges, and make any corrections at this time. Insert the nine DIP-packaged ICs in their sockets, exercising the proper precautions when handling the CMOS devices to prevent them from being damaged or destroyed by ESD. *Caution:* Wear a grounded wriststrap before removing the CMOS ICs from their ESD-protective packaging.

### Testing the circuit

Plug in the linecord and apply power to the circuit. Test it first in the constant-current mode by measuring the output voltages at three points while moving the knob on potentiometer R33. The inputs to operational amplifier IC5-a should track each other from 0 to 9 volts. Similarly, the output of the operational amplifier should track the settings on potentiometer R33,—but always about 1 volt higher than the inputs.

Switch to the constant-current mode and, with a multimeter connected in series with a 10-ohm, 1-watt resistor to simulate a load. Potentiometer R33 should vary the current. However, once a level of current has been set, altering the value of the load resistor should have no effect on the current that is being measured.

The principal limitation of this circuit is that its output voltage can only rise to 10 volts. This effectively limits the con-
*Continued on page 74*

BY DON LANCASTER

# Electronics potpourri

*Replacing a transformer, variable-gain amplifiers, new AGC amplifier IC's, introduction to digital potentiometers, and more*

ONE RECENT HELPLINE CALLER WANTED TO REPLACE A MYSTERY POWER TRANSFORMER ON AN OLDER DIGITAL ALARM CLOCK. FIRST, PLEASE NOTE THAT TRANSFORMERS DO *NOT* BURN OUT BY THEMselves. They always have help.

If you replace a transformer and don't fix the underlying problem, the new transformer will also burn up. The most likely causes of transformer failure are a shorted filter capacitor, a bad power diode, or a blown regulator. Less likely are lightning damage, input surges, or physical abuse. Of course, some four-year-old who thinks that the clock is a piggy bank is yet another possibility. (I once saw a floppy disk drive completely filled with 35-mm photo slides.)

If at all possible, contact the manufacturer of the clock radio, or pick up the service information in *Electronic Servicing*, on-line, or by using one of those electronic repair classifieds. An accurate schematic makes things far easier.

Usually you are able to guess the secondary voltage by working back from the ratings of the filter capacitor or the regulator. A 7805 regulator needs four or more volts of headroom, so maybe something in the +10-volt range for raw supply power. To get from the DC output voltage to the AC transformer voltage, add one for each diode drop and then multiply by 0.7. Or something like 8.4 volts in this example. Call it nine even.

The cubic volume of any 60-hertz transformer pretty much determines its power rating. Maybe 5 watts for a one inch cube, 20 watts for a two, and 60 for a three.

Sometimes it is easiest to replace the entire supply with a wall mounted one. Another ploy is to pick any old larger 24 volt transformer and use a Variac or autotransformer to *slowly* bring the input voltage up to where things seem to be operating properly. A "somewhat higher" input should be just about right.

If all else fails, a final emergency procedure is to take the transformer apart and count the turns. The turns ratio is the same as the output voltage ratio. But note that the loaded output voltage might typically be 20 percent or so lower than the turn ratio indicates.

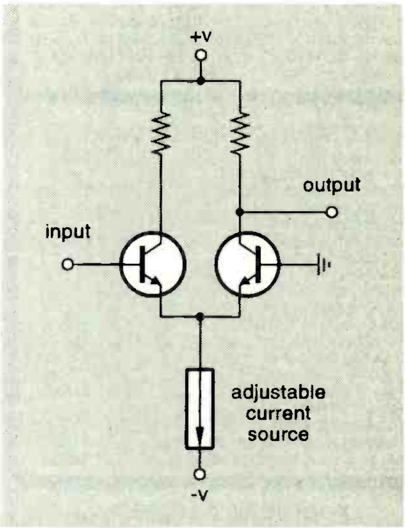



**FIG. 1**—A DIFFERENTIAL AMPLIFIER can be viewed as an emitter follower driving a grounded–base stage. The current linearly sets the gain.

## Electronic gain control

There are many reasons why you might control the gain of some circuit stage electronically. In AM radio, this is called automatic volume control. AVC causes local and distant stations to output at nearly the same volume. In a television set or communications gear, an AGC or automatic volume control does nearly the same thing.

A gain-control device known as a compressor might bring microphone inputs up to some uniform level for recorders or mobile radio communications. A similar compressor misused in a TV studio can make commercials more obnoxious. In electronic music applica-

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US Internet email access link: SYNERGETICS@GENIE.GEIS.COM.

tions, a VCA (voltage-controlled amplifier) can set the attack-sustain-decay of an envelope waveshape.

The *manner* in which gain varies with the controlling current or voltage can be quite important. The obvious *linear* choice usually has a restricted dynamic range. A *log* (or "by decibels") choice is often better for audio or communications.

Active filters and other frequency-tracking applications work best with an *inverse* gain relationship. You usually want to change some time constant, and time rate is the inverse of frequency.

Regardless of what they are called, all electronic gain-adjustment circuits

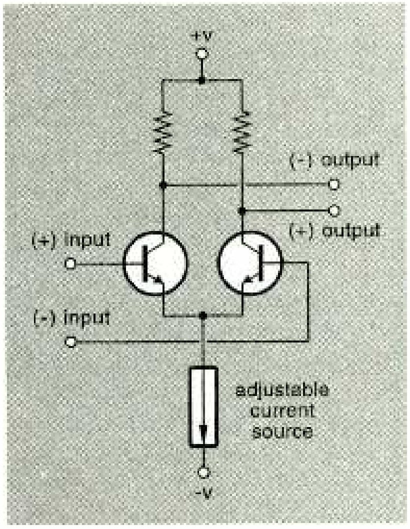


**FIG. 2**—A FULL-FEATURED differential amplifier offers balanced inputs and outputs. Common-mode signals are ignored.

are really a class of devices known as two-quadrant multipliers, in which a unipolar DC level is multiplied by an AC input signal to set the gain and produce an AC output.

One of the earliest gain controls was a vacuum tube called a remote cutoff pentode. The grid spacing was nonlinear, causing parts of the tube to stop amplifying before other portions did. As you increased the negative grid bias, the gain of the stage would progressively diminish.

The current gain of a transistor is a function of collector current. Certain early transistors were designed such that their beta-Vs-collector-current curve gave a linear gain, and thus gave an AGC action.

The most popular gain controlling schemes in use today involve ...

## Differential amplifiers

The differential amplifier is by far the most significant analog circuit of all time. Differential amplifiers have many amazing properties, one of which is that their open loop gain can be controlled easily and remotely.

I've shown a differential amplifier in a single ended form in Fig. 1. Using matched transistors and zero input, the current from the current source should split evenly, half going to the left and half to the right. As the input voltage goes positive, the split changes, with more current going left. If the input swings negative, extra current goes to right. The output will be an amplified and noninverted replica of the input, usually with at least a little voltage gain.

You might think of a single-ended differential amplifier as an emitter follower that drives a grounded base stage. This particular emitter follower has a gain of 0.5, since its output impedance is driving an identical load.

The gain of a grounded base stage is the ratio of its input resistance to its output resistance. In this case, the input resistance is the impedance of a emitter-base diode.

*A diode's impedance changes with the current through it.* Using a crude formula of $26/i$, where $i$ is the current in milliamperes, half a milliampere through a diode can provide you with a small-signal impedance of 52 ohms.

The key point: If you increase the current from your current source, the gain goes up. And vice versa. One use of a differential amplifier is as an electronic gain control.

Sometimes the current source itself is adjusted by an external control voltage. Other times, a circuit called a current mirror can be used. Current mirrors let you "bounce" a control current off a negative supply rail or whatever, giving you a choice of voltage or current control.

Let's say you have a 2.5-kilohm load. If half a milliampere from the current source goes to the right, that stage shown will have a gain of nearly 50. The left stage has a gain of 0.5 because it is driving a load equal to its output impedance. The total voltage gain will be something near 25.

A fully balanced differential amplifier is shown in Fig. 2. The difference between the input voltages is amplified and becomes the difference between the output voltages. Besides doubling the gain, you pick up a tremendous new advantage: Any hum, noise or other signals that bounce the inputs up and down together are ignored!

This amazing property is called common mode rejection. Among its other benefits, CMR largely ignores power-supply hum, bias shifts, and certain input ground loops. You also have the choice of using inverting or noninverting outputs, or using both inputs at once.

In a lot of applications, negative feedback is applied around one or more differential amplifiers. That is what op amps are all about. Such a feedback overrides the gain settings of individual internal stages.

Also note that the supply current is constant, regardless of input signal levels. The current from the current source is just shifted right or left, but it always gets back together at the positive supply terminal.

A final unique feature of differential amplifiers is that they limit cleanly and quickly on overdrive. The output voltage can go no higher than the supply, and no lower than the load resistance times your maximum current source value. Transistor saturation can be prevented easily. Such clipping circuits are important for FM mobile radio communications or TV audio.

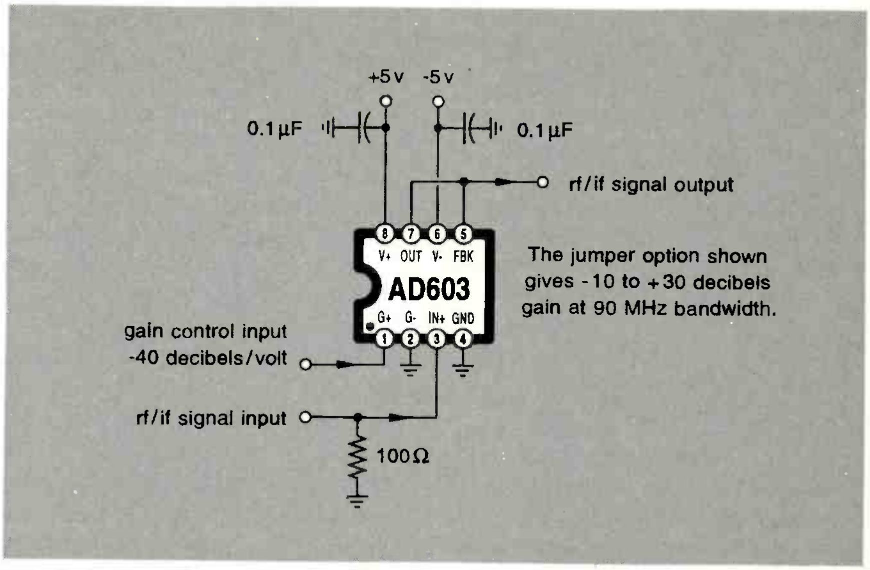

**FIG. 3**—THE ANALOG DEVICES AD603 low-noise variable gain amplifier. The control voltage works "by decibels" with a sensitivity of -40 dB/volt.

One classic differential-amplifier gain control IC is the CA3080 transconductance amplifier. It was around eighty cents last time I checked. Full details on this device appear in my *CMOS Cookbook*.

## A new AGC circuit

*Analog Devices* has just come up with a new, low-noise AGC chip that seems really impressive. The AD603 variable gain amp is shown in Fig. 3. Its bandwidth is your choice of 9 or 90 MHz. The gain is controlled by decibels with a sensitivity of 40 dB/volt. Stages can be cascaded for additional control range.

The new chip uses a somewhat different approach to variable gain: An electrically adjustable attenuator is placed in front of a fixed-gain amplifier. The input noise is quite low. Noise-figure problems can be further minimized by use of two stages with a "progressive build" or "delayed AGC" scheme. In which the second stage has its gain reduced ahead of the first stage. A free data sheet has further schematics and applications.

## Digital potentiometers

There's also some fairly new kids on the electronic gain control block. These are *digital potentiometers* or EEPOTs, which work just like an old fashioned resistance decade box. Typically, there'll be 64, 100, or 256 series resistors, and you will apply a command of one sort or another to select a tap.

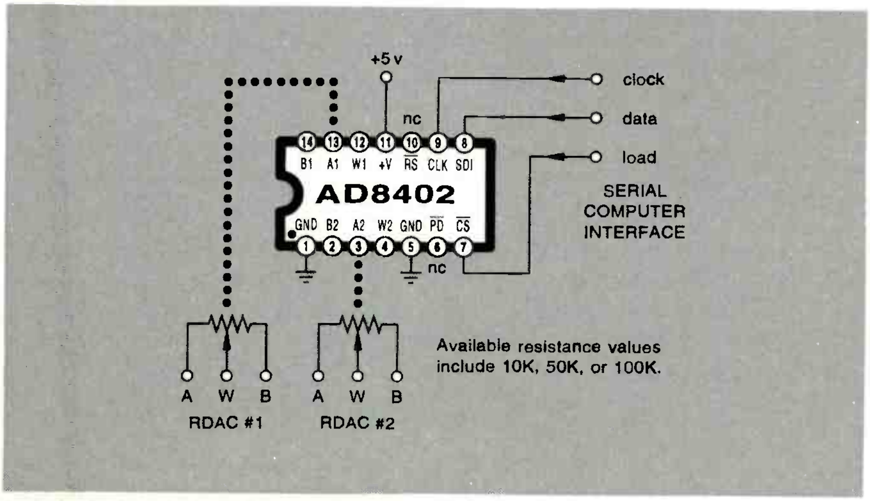

**FIG. 4**—THE ANALOG DEVICES AD8402 dual digital potentiometer. Ten bits of serial data pick a potentiometer and set it to one of 256 different "wiper" positions.

One advantage of digital potentiometers is that they replace analog trimmers. They are easily set under automatic computer control, and they do not drift out of specification with time.

Disadvantages of EEPOTs include the limited number of steps and certain slight nonlinearities caused by the internal MOS switches. Even with 256 steps, one end or the other could get real cramped if you really do need log or inverse-gain relations.

You can cascade digital pots for more resolution. The 20% maximum gain nonlinearity of a direct cascade can be eliminated by buffering with an op-amp. But with 4096 to 65,536 available levels, it's usually easier to precalculate your correct setting.

You usually have your choice of rheostat or potentiometer modes. The rheostat choice gives you a simple variable resistor. The potentiometer mode gives a resistance ratio, just like a normal volume control.

Typical total resistance ranges are 10, 50, or 100 kilohms. Lower values are not too practical because of the on resistance of the MOS switches that are in the signal path.

Signals that are applied to the potentiometers themselves can be analog, digital, or DC levels. But their levels always must remain somewhere between the supply voltage and ground.

Two examples are the dual AD8402 or the new quad AD8403 from *Analog Devices*. I've shown the basic setup in Fig. 4. These chips can be controlled by a serial clock and data stream, following the formats shown in the data sheet.

Ten bits of data are needed. Two address which potentiometer is chosen, and eight decide the switch position. The total time to change the switch position depends on the input clock rate. The minimum time is about 450 nanoseconds. Thus, you can make over half a million gain changes per second—if you really want to. The Basic Stamp or another PIC microcontroller is ideal for this sort of control use.

A sneaky "cascade" trick lets you control any number of chips with a three-wire interface. This is done by connecting the serial data out of the first stage to the serial data in of the second. The first ten data values get "used up" by the first stage. All the "extra" data values during a load get passed on. The second ten values will get grabbed by the second stage, and so on down the line.

These particular chips are volatile. They forget their previous values on power down. Thus, you will have to reinitialize them each time power to your circuit is reapplied.

Current from the 3 or 5 volt supply can be as low as 5 microamperes.

Be sure to carefully read the data sheet for more use details. Pin 6 can be used to disable the outputs, while pin 10 can be used to force both pots to their "mid wiper" position.

Another very interesting chip is the *National* LM1973 three-channel audio attenuator. Each channel has a digitally controllable log attenuator with a 76 decibel range. As with the AD4802, a three-wire digital serial control is used.

Leading sources for other digital potentiometers include *Xicor*, *Dallas Semiconductor*, *Burr-Brown*, *Analog Devices*, and *National Semiconductor*. Bunches of variations are available that accept serial input data, that remember their old setting on power down, offer log steps, or an up-down count action. We might look at these in more detail in a future column.

Speaking of switched resistors, I have just picked up some classic resistance substitution boxes. Some fine four-decade *Shallco* switchable 0.1-to 100-decibel audio attenuators, too. Let me know if you need a few.

## Robotics

For this month's resource sidebar, I thought I'd gather together some of the more obvious sources for hobby robotics. They're local clubs, mostly, with a few key suppliers thrown in.

For a number of reasons, low-end hobby robotics has never really taken off. First, because those urban-lore "trashcan" and "android" style robot forms are absurdly useless. One of the favorite tricks in any beginning robotics class is to ask them to design a robot that cleans the dishes after a meal. Only one student out of twenty ever picks up on the fact that *Sears* has been selling a solution for decades.

A second problem is the mix of skills needed for robotics—everything from electronics to software design to mechanical engineering to kinematics to marketing. Pretty near anything mechanically intensive and made in small experimental quantities for an ill-defined market is likely to price itself out of reach. And mass market toy robots have to contend with stiff distributor and retail markups.

The folks at *Mondo-tronics* have long been known for their robotic "muscle wire" products. These have been refined into their new Electric Pistons—actuators with one pound of force and almost one inch of reach. Extension time is two seconds using five watts of power input. The maximum cycle rate is four cycles per minute.

To me, the Nitinol shape-memory products certainly have some unique niche uses. But their glacial speeds and high power needs seems to lock them

### NAMES AND NUMBERS

**Analog Devices**
PO Box 9106
Norwood MA 02062
(617) 329-4700

**Burr-Brown**
6730 S Tucson Blvd
Tucson AZ 85706
(520) 746-1111

**Dallas Semiconductor**
4401 Beltwood Pkwy S
Dallas TX 75244
(214) 450-0400

**Electronic Servicing**
PO Box 12487
Overland Park KS 66282
(913) 492-4857

**GEnie**
401 N Washington St
Rockville MD 20850
(800) 638-9636

**Hewlett-Packard**
PO Box 10301
Palo Alto CA 94303
(415) 857-1501

**Lindsay Publications**
PO Box 538
Bradley IL 60915
(815) 935-5353

**National Semiconductor**
2900 Semiconductor Rd
Santa Clara CA 95052
(800) 272-9959

**Quality Semiconductor**
851 Martin Ave
Santa Clara CA 95050
(408) 450-8063

**Shallco**
308 Components Drive
Smithfield NC 27577
(919) 934-3135

**Synergetics**
Box 809
Thatcher AZ 85552
(520) 428-4073

**Xicor Inc**
1511 Buckeye Dr
Milpitas CA 95035
(408) 432-8888

## HOBBY ROBOTIC RESOURCES

**American Science & Surplus**
3605 Howard Street
Skokie IL 60076
(708) 982-0870

**Appliance**
1110 Jorie Blvd CS 9019
Oak Brook IL 60522
(708) 990-3484

**Appliance Manufacturer**
29100 Aurora Rd #200
Solon OH 44139
(216) 349-3060

**Atlanta Hobby Robot Club**
PO Box 2050
Stone Mountain GA 30086
(404) 972-7082

**Automotive Industries**
PO Box 2056
Radnor PA 19080
(215) 964-4876

**C&H Sales**
PO Box 5356
Pasadena CA 91107
(800) 325-9465

**Connecticut Robotics Society**
190 Mohegan Drive
West Hartford CT 06117
(860) 233-2379

**Dallas Personal Robotics Group**
5112 Hardaway Circle
The Colony TX 75056
(214) 625-4454

**Design News**
8773 S Ridgline Blvd
Highlands Ranch CO 80126
(303) 470-4000

**Edmund Scientific**
101 E Gloucester Pike
Barrington NJ 08007
(609) 573-6250

**Machine Design**
1100 Superior Avenue
Cleveland OH 44144
(216) 696-7000

**Mondo-tronics Inc**
524 San Anselmo Ave #107-20
San Anselmo CA 94960
(800) 374-576

**Nashua Robot Builders Club**
133-A Haines Street
Nashua NH 03060
(603) 595-5953

**Northern New Mexico Robotics**
MSD434, LANL
Los Alamos NM 87545
(505) 667-2902

**Palo Alto Robotics Club**
561 Hyannis Drive
Sunnyvale CA 94087
(408) 749-8815

**PARTS - Portland RoboTicS**
821 SW 14th
Troutdale OR 97060
(503) 666-5907

**PHD Inc**
PO Box 9070
Fort Wayne IN 46899
(800) 624-8511

**The Robot Group**
PO Box 164334
Austin TX 78716
(512) 288-9135

**Robotics Society of America**
1264 8th Avenue
San Francisco CA 94122
(415) 661-8068

**Robotics Society of So California**
10471 S Brookhurst Street
Anaheim CA 92804
(714) 535-8161

**Rockies Robotics Group**
13702 E Lehigh Ave Unit E
Aurora CO 80014
(303) 680-9324

**Seattle Robotics Society**
PO Box 665
Mill Creek WA 98012
(206) 483-0447

**Sensors**
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Peterborough NH 03458
(603) 924-9631

**Small Parts**
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Miami Lakes FL 33014
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out of ever really hitting the big time. A powerful, fast, and efficient "electric muscle" still remains rather elusive, which is why all of the big boys still use pneumatics.

At any rate, Mondo-tronics is now offering a Robot Store, which is kind of a one-stop source for small hobby and educational robots. A free catalog includes a new robot club directory, portions of which have been added to our resource sidebar.

By far, the finest robotics source anywhere ever still remains *Small Parts*, which stocks everything a hardware store never heard of. Three other "must know" low-end robotics sources include *C&H Sales*, *American Science & Surplus*, and *Edmund Scientific*. All of which have free catalogs that are available on request.

Robot-specific magazines seem to come and go. Instead, the industry trade journals which I've found that consistently include the most useful ongoing robotics information in them are *Machine Design*, *Design News*, and *Sensors*. Also useful are *Automotive Industries*, *Appliance* and *Appliance Manufacturer*.

A more detailed review of robotics magazines and opportunities appears as NUTS16.PDF on GEnie PSRT. It is also included in my *Resource Bin*.

Your best starting point may be to pick up a meeting or two at one of the regional robotics clubs. Many of these also have newsletters and run competitions.

By the way, I've just picked up a cute little orphan *Armdroid I* student robot, which is up for adoption. I also have bunches of *PHD* precision industrial automation sliders, rotary actuators, grippers, sensors, and cylinders (all of it big time serious pneumatics)at great prices. Write, E-mail, or give me a call if you have any interest here.

There are three new robotic web sites:

*comp.robotics.misc*
*www.robotstore.com*
*www.ncc.com/ncc/refaq*

### New tech lit

*Quality Semiconductor* has a new and free catalog on its *Quick Switch* products. These are useful for network switches, for crossbars, and programmable interconnects. I'm looking at several of these for shared SCSI communications uses.

*Hewlett-Packard* has a free new *IrDA Data Link Designer's Guide* and kit, used for the newly emerging wireless infrared communications standard.

Such a deal: The most powerful electron microscope in the U.S. is now offered for remote experiments, via the Internet. To submit a proposal, you can contact

*http://ncem.lbl.gov/ncem.html*

Two new reprints from *Lindsay Publications*. The first one is *The Boy Electrician* by Alfred Morgan. It was originally published in 1940 and was

*continued on page 64*

## RUNABOUT ROBOT

*continued from page 38*

controller input RA1. That input informs the microcontroller what action to take. (See "The Universal Remote Control" sidebar).

A 24LC16 16K-bit electrically erasable serial EEPROM (IC3) stores the Runabout's memory. Movements, and other Runabout functions can be stored here for later recall. All information is sent to and from the EEPROM in a serial fashion. The 24LC16 is housed in an 8-pin DIP and retains all information even with power removed from the circuit. As with all non-volatile RAM devices, there are some limitations. This EEPROM will remember information for only 40 years, and can be written to only one million times!

Connected to four pins of the PIC16C56 are two standard "H-bridge" motor-control circuits made up of transistors Q1 through Q8. The H-bridge configuration allows either pin of a motor to be forced to the positive motor supply or to ground. The Runabout's motors can be stopped, run forward, or reversed. Through independent motor control, the Runabout has the ability to turn left, right, stop, and move forward or reverse.

Transistor Q9 is a switchable shunt across R7 that acts as Runabout's speed control. With the transistor on, a full 3 volts is available to the motor H-bridge circuits (high range). With the transistor off (low range), approximately ½-volt drops across R7 and reduces the motor's speed. The speed control switch is toggled by a button on the universal remote control.

A Maxim MAX756 (IC2) boosts the battery voltage (+3 volts) to +5 volts necessary for the PIC16C56 and the serial EEPROM. The MAX756 is a high-efficiency, CMOS, step-up, DC-DC switching regulator. Housed in an 8-pin DIP, an internal MOSFET power transistor permits high switching frequencies. The output is maintained at a regulated +5 volts DC even though the battery voltage may vary between +1 and +3 volts.

The PIC16C56's clock circuit can be controlled by a standard quartz crystal, a resonator, or a simple RC combination. To obtain high-frequency accuracy, a quartz crystal was selected. Good frequency stability is necessary to keep Runabout's internal software routines synchronized with the bit stream output from the IR receiver module.

Three LED's are connected to separate ports on the PIC16C56 (RB5, RB6, AND RB7). These act as the Runabout's headlights, and each can be controlled individually. A piezo speaker connected to RB4 (pin 10) produces sound effects. Components R5, D2, and C6 provide a stable reset signal to the PIC16C56 whenever power is applied to the robot.

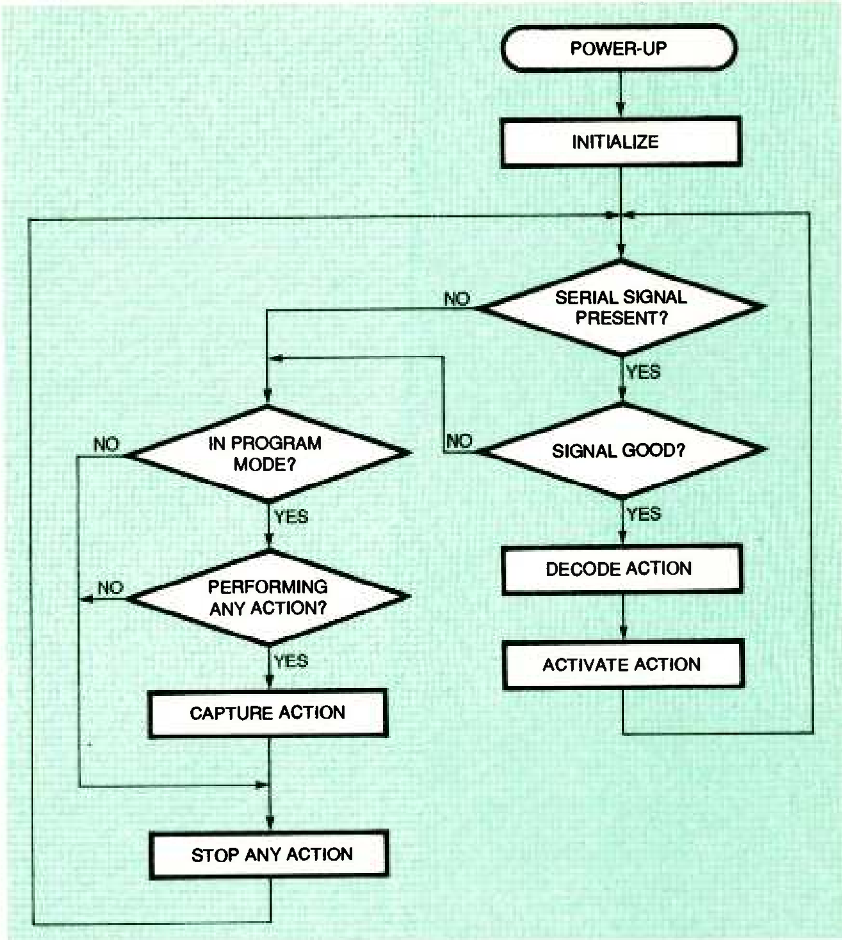



**FIG. 2—SIMPLIFIED FLOWCHART. The software waits for serial information from the receiver.**

### Software

The main function of the software is to wait for serial information from the receiver, decode it, and carry out actions dictated by the serial bit-stream. A simplified flow chart is shown in Fig. 2.

On power-up, the output pins and various registers within the PIC16C56 are initialized. The processor then waits for a serial transmission to be received. The validity of a received code is checked, and if good, it's decoded. The processor then carries out the proper action by activating motors, sounding the piezoelectric speaker, flashing the LEDs, entering or exiting the program mode, or running one of the stored programs.

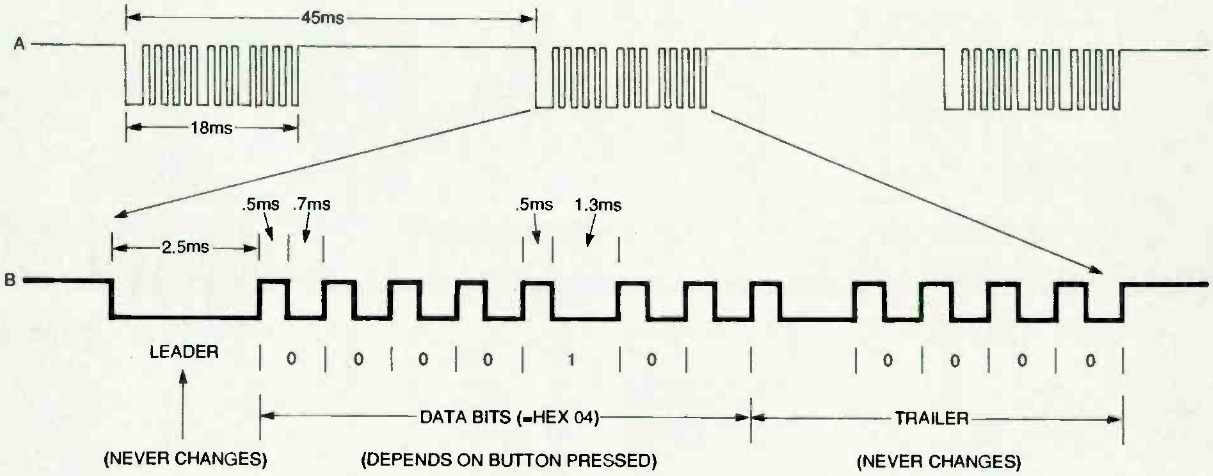
When the serial transmission ceases (when the button is let up on remote), the processor determines whether it's in its program mode, and if it is, it

## THE UNIVERSAL REMOTE CONTROL

Today's TVs, VCRs, and other consumer electronics are commonly controlled by wireless remote controls. The remote typically has an infrared LED, which transmits pulsed light to a phototransistor or photodiode in the receiver unit. A unique serial code is produced for each key pressed on the remote control. Manufacturers of consumer electronics have devised many different infrared serial pulse encoding schemes to control their products.

The manufacturers of universal remote controls have successfully developed products that can emulate almost all serial control schemes used by electronics manufacturers. To use a universal remote control for a particular brand TV, you set up the remote with a two- or three-digit code from the manual supplied with the remote (the manual has many brands listed in tables). The remote control will then emulate all the original manufacturer's control codes. Universal remote controls usually have a few mode-change keys, so you can instantly re-assign the control to operate other devices (VCR, cable box, etc).

A typical serial control code for the up-channel button for a Sony brand TV is shown below. An expanded portion of the signal is also shown. The low levels in the waveform correspond to the presence of IR light, and the high levels represent no light. With the key held down, the code repeats continuously every 45 milliseconds. Within each code burst is a series of long and short pulses that defines binary data bits. As shown, a 0.5-millisecond high followed by a 0.7-millisecond low translates to a zero bit while a 0.5-millisecond high followed by a 1.3-millisecond low defines a one. The code translates to hexadecimal 04. Ω




checks if any actions are currently being performed. If an action is being performed while the processor is in its program mode, it is stored in serial memory. If the processor isn't in its program mode, any actions controlled by the processor are stopped.

The "capture action" step shown in the flow chart is where information is sent to the serial EEPROM (24LC16). The information sent is simply a series of bytes corresponding to the actions carried out. A time-code byte is also sent to the memory. Upon playback, the bytes are accessed in the order stored.

### Building the Runabout

All of the necessary components including the PC board, gears and motors, top acrylic cover, and sheet metal pieces to build the Runabout as pictured are available from the source given in the Parts List. Foil patterns are provided if you wish to make your own PC

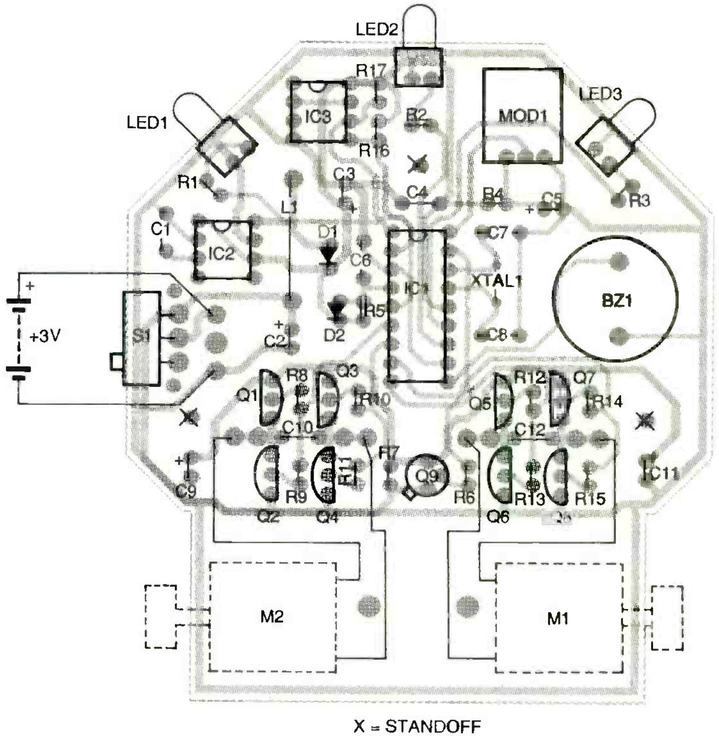



**FIG. 3—PARTS-PLACEMENT DIAGRAM. The circuit board holds the electronics and serves as the Runabout's chassis.**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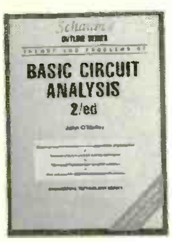


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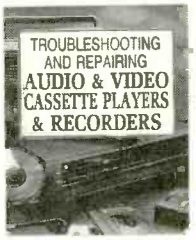


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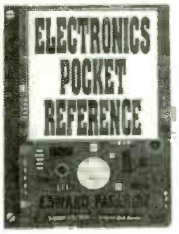


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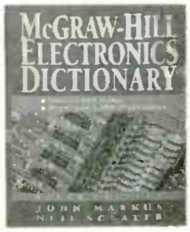


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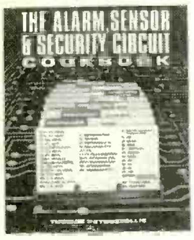


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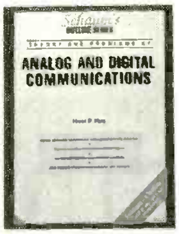


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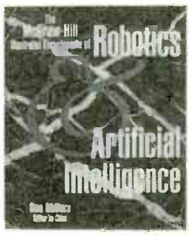


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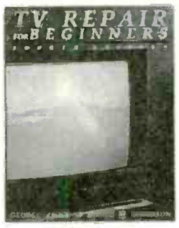


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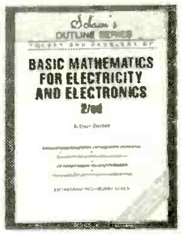


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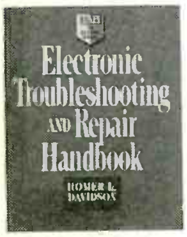


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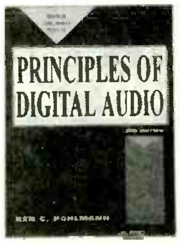


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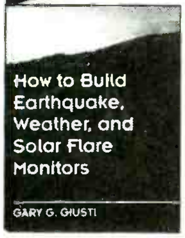


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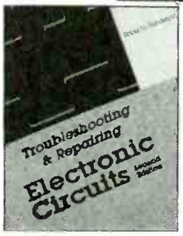


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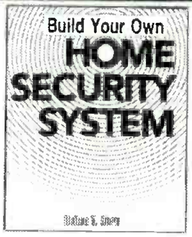


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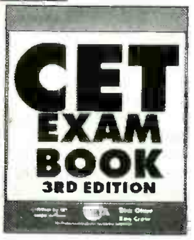


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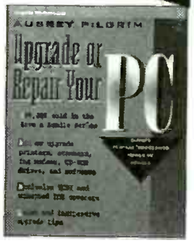


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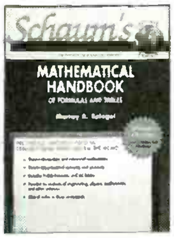


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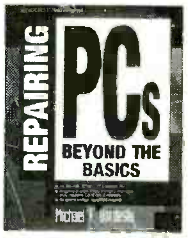


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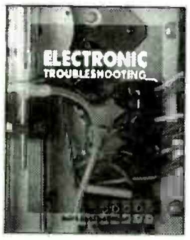


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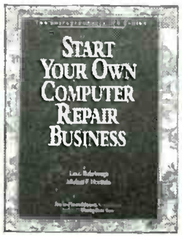


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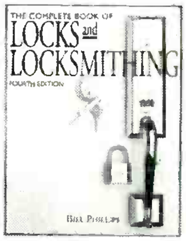


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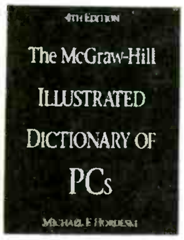


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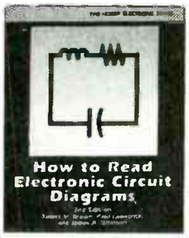


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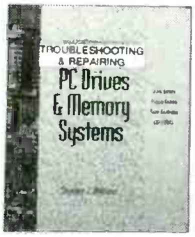


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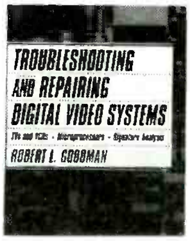


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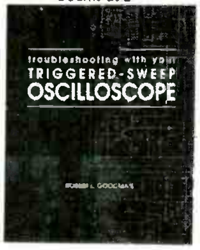


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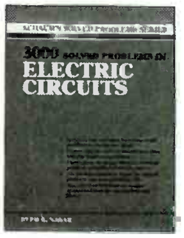


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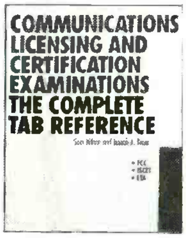


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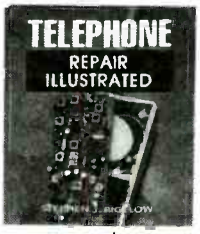


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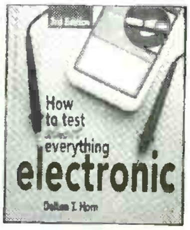


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board. Pre-programmed PIC16C56's are available from the same source and the HEX code is posted on the Gernsback BBS (516-293-2283) as part of a file called RUNABOUT.ZIP.

### The circuit board

The circuit board not only holds the electronics, but acts as the Runabout's chassis. Therefore, it must be assembled first. Figure 3 is the parts-placement diagram. Start by installing the components with the lowest profile—the IC sockets, LEDs, and inductor. Then proceed with the taller parts—the resistors, transistors and capacitors. To conserve space, the resistors are mounted vertically, with one leg bent 180 degrees down parallel to the other.

During assembly, be sure to keep the height of all components lower than the length of the standoffs that hold the top acrylic cover— refer to the mechanical assembly instructions. This will allow the top cover to be mounted without pressing down on any parts. Similarly, try to trim all the component leads on the bottom of PC board to an even length of approximately 1/16-inch. That length will allow the bottom PC board cover to be mounted easily and evenly.

Mount the IR receiver module, piezoelectric speaker, and the power switch as shown. Note that it is not necessary to clean the residual solder flux off the bottom of the PC board after soldering is complete. If you desire to do so, do not let any solvent touch the speaker or power switch—these components can be damaged by the solvent.

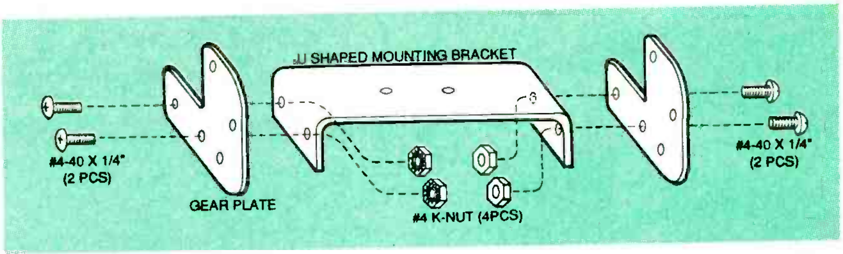



**FIG. 4—THE MAIN ASSEMBLY that holds the gears and wheels is composed of two side gear plates and one U-shaped bracket. Detailed mechanical drawings can be purchased from the source given in the Parts List.**

### Mechanical assembly

If you wish to make the Runabout from your own parts, you will need to do some sheet-metal work. As shown in Fig. 4, the main assembly that holds the gears and wheels is composed of two side gear plates and one U-shaped bracket. These were fabricated from 6061 aluminum sheet stock, 0.08-inch thick. It is not critical that you follow the original plans exactly, as long as you follow the general layout. Many of the mechanical parts including gears and motors can be purchased from the various manufacturers listed in Table 1.

Plastic gears were used for the Runabout, but metal gears will work just as well. Start by mounting the two gear plates to the mounting bracket. Mount the gears with No. 4-40 machine screws and nuts, as shown in Fig. 5. Threaded holes in the mounting bracket hold

**PARTS LIST**

**All resistors are 1/4-watt, 5%.**
R1–R3—270 ohms
R4—100 ohms
R5—51,000 ohms
R6—1000 ohms
R7—5.1 ohms
R8–R15—750 ohms
R16–R17—20,000 ohms

**Capacitors**
C1, C4—0.1 µF, 50 volts, ceramic
C2, C5, C9, C11—10 µF, 16 volts, radial electrolytic
C3—47 µF 16 volts, radial electrolytic
C6, C10, C12—0.68 µF, 50 volts, ceramic
C7, C8—15 pF, 50 volts, ceramic disk

**Semiconductors**
IC1—Pre-programmed PIC16C56-XT/P microcontroller (Microchip Technology)
IC2—MAX756CPA voltage converter (Maxim)
IC3—24LC16 serial EEPROM (Microchip Technology)
Q1, Q3, Q5, Q7—2N4403 PNP transistor
Q2, Q4, Q6, Q8—2N4401 NPN transistor
Q9—2N2907 PNP transistor
D1—1N5817 Schottky rectifier diode
D2—1N914 signal diode
LED1–LED3—green light emitting diode, right-angle PC-mount package

**Other components**
MOD1—Infrared receiver module, Everlight No. IRM-8410
XTAL1—4-MHz crystal, low-profile case
BZ1—piezo speaker, Murata-Erie No. PKM22EPP-40
M1, M2—hobby motor, Mabucci No. 020SA-09170
S1—SPST slide switch, PC-mount side actuated
B1—Two 1.5-volt AAA alkaline batteries
L1—15 µH molded inductor
**Miscellaneous:** Runabout PC board, battery holder for two AAA cells, one 18-pin and two 8-pin IC sockets, two 1-inch grommets (wheels), two 9/16- × 5/8-inch spacers (wheel hubs), gears and mounting hardware, six 3/8-inch No. 2 standoffs, one KF brand 7/8-inch "Domed-Glide" No. 6277 (front skid), acrylic plastic top cover, ABS black plastic bottom cover, screws and nuts, solder

**Note: The following parts are available from Silicon Sound, PO Box 371694, Reseda, CA 91337-1694, 818-996-5073:**
- **Complete Runabout robot kit with all parts including PC board, programmed PIC16C56, all gears, hardware, and top acrylic and bottom plastic covers—$99.00**
- **Assembled and tested Runabout robot—$139.00**
- **Pre-programmed PIC16C56 microcontroller—$17.00**
- **Complete set of eight plastic gears for Runabout—$15.00**
- **Full function universal remote control (can control your TV/VCR/Cable Box)—$15.00**

**Please add $4.50 for shipping and handling. California residents add 8.25% sales tax.**

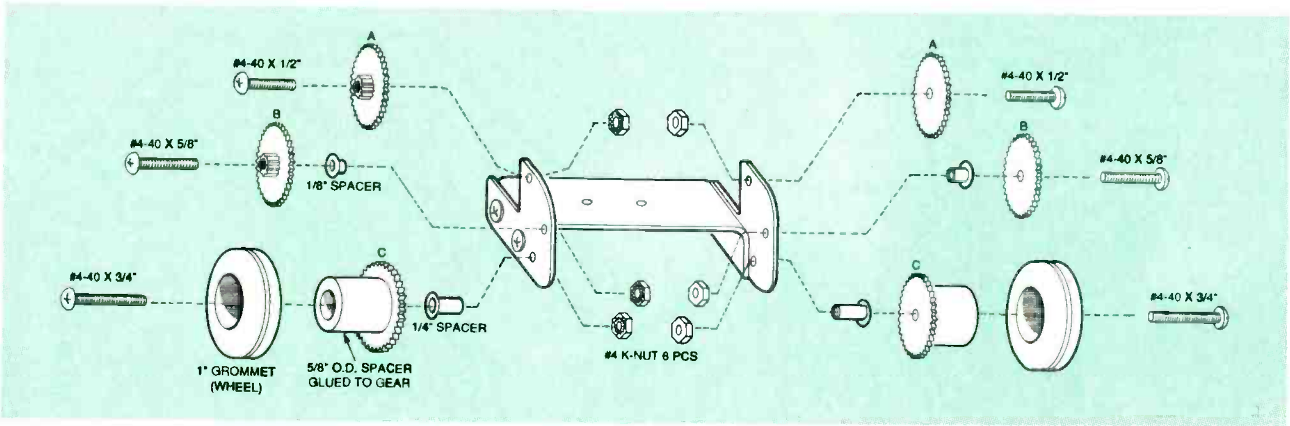



**FIG. 5—GEARS ARE MOUNTED** with No. 4-40 machine screws and nuts. Threaded holes in the mounting bracket hold the gear screws, with nuts locking the screws in place.

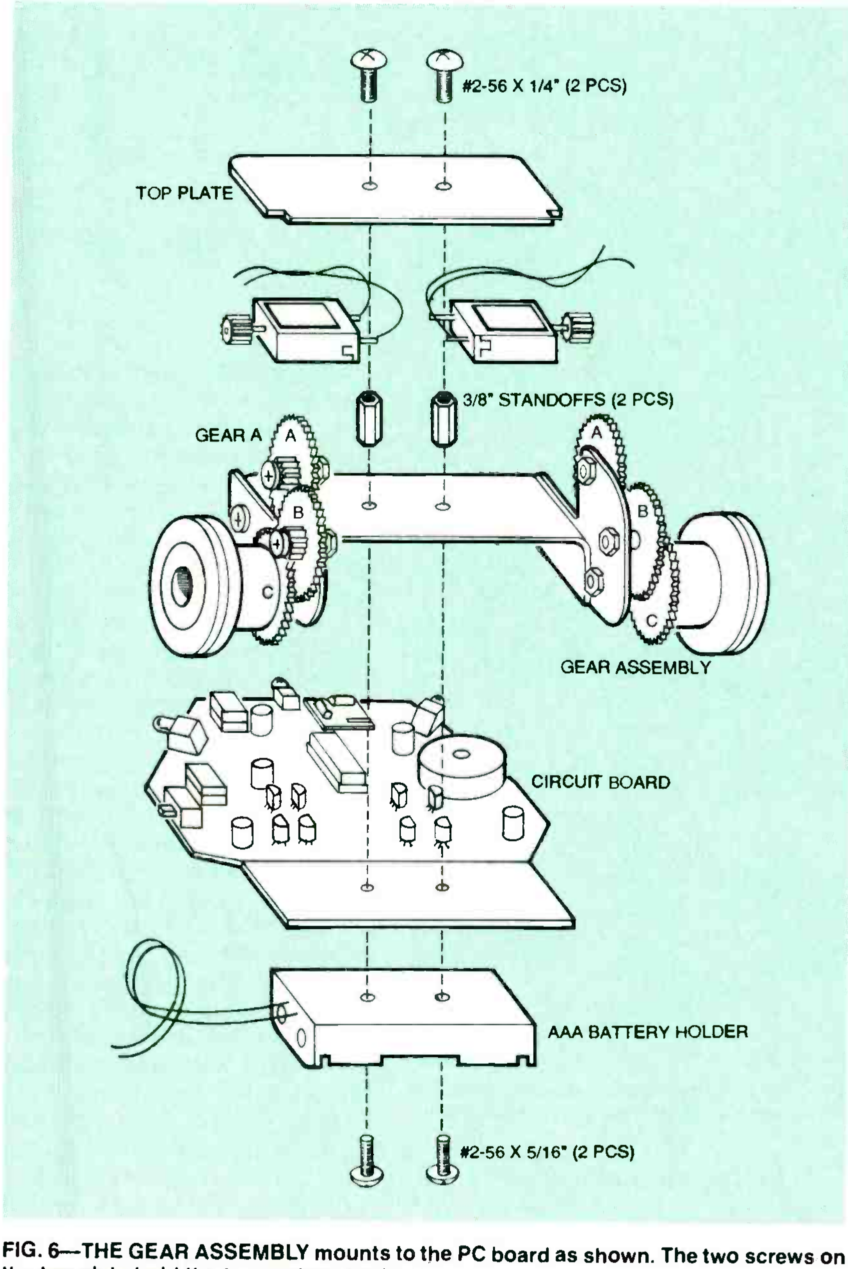



**FIG. 6—THE GEAR ASSEMBLY** mounts to the PC board as shown. The two screws on the top plate hold the two motors in place.

the gear screws; the nuts lock the screws in place. All gears must mesh smoothly.

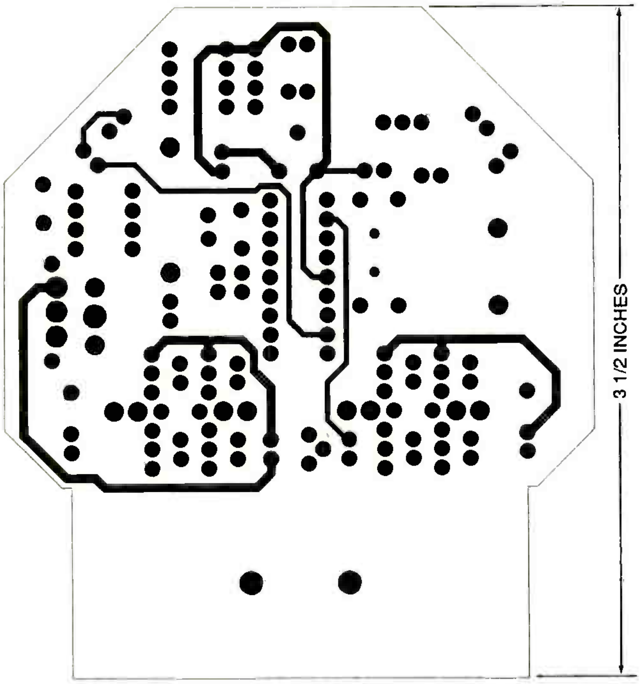
Figure 6 shows how the completed gear assembly mounts to the PC board, and how the two motors and battery holder are held in place. The two standoffs in the center are key to the assembly. The two screws on the top plate form a compression clamp for the two motors, holding them in place. To align the two motor gears to the other gears, loosen the top screws and adjust the position of the motors so they mesh with gear "A", as shown in Fig. 7.

If you use your own motors, you might need to make some adjustments in the overall dimensions as shown. As long as you end up with a two-wheel drive system, with motor current below approximately 300 milliamperes (the H-bridge transistor limit), you should be able to make a working robot.

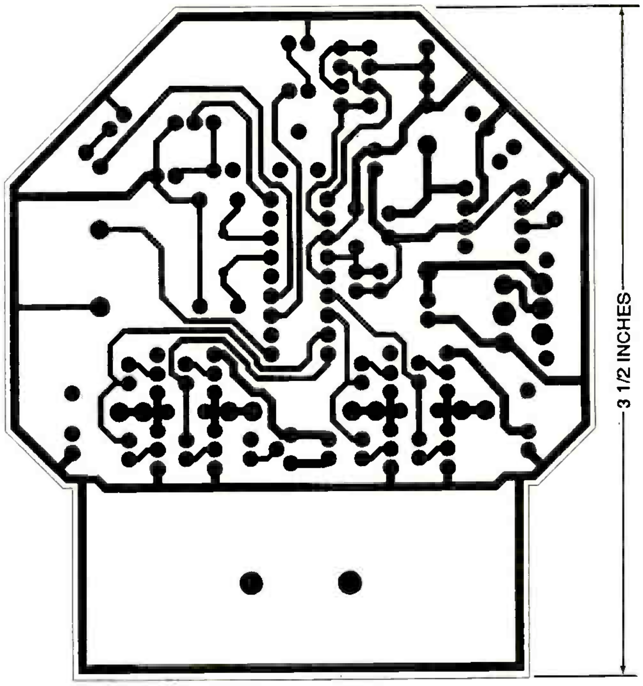
The Runabout's gear ratio is about 57:1, which means that the motors must turn 57 times for each revolution of the wheel. This gives the Runabout a slow and even motion. You do not have to stick to this ratio; you can eliminate a gear on each side plate if you desire a faster robot.

As shown in Fig. 5, the wheels are made from two large rubber grommets. These can be purchased in many different sizes from most electronics retailers. See Table 1 for sources.

The front "skid" is actually a nail-on-glide intended for use as a foot on the leg of a chair or table. Most hardware stores carry various types of these de-




RUNABOUT PC BOARD COMPONENT SIDE.




RUNABOUT PC BOARD SOLDER SIDE.

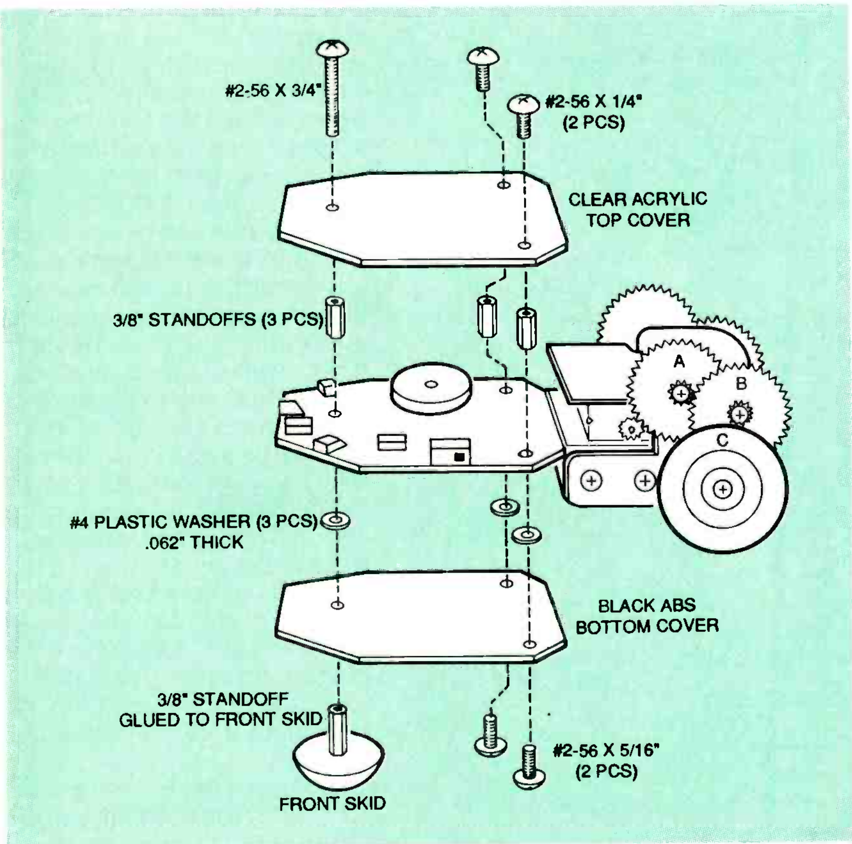



**FIG. 7—MOUNT THE TOP AND BOTTOM COVERS and front skid as shown here. To align the two motor gears, loosen the top screws and adjust the position of the motors.**

vices. Instead of a skid, you could fabricate some type of wheel for the front of Runabout.

Figure 7 shows how the top and bottom covers and the front skid are mounted. Before installing them, be sure to connect the motor wires to points W1 through W4, and connect the battery holder wires as shown in the schematic. Figure 8 shows the completed Runabout.

## Checkout

Inspect all solder joints and wire connections to ensure that everything is properly assembled. Rotate the two wheels by hand and observe that all the gears mesh and turn smoothly. If the gears are binding, you will have to reposition the motors and/or gears slightly.

If everything looks mechanically sound, install two AAA alkaline or Ni-Cd batteries and turn on the power switch. All three LEDs should turn on for about 0.2 seconds and you should hear a corresponding two-tone beeping from the piezoelectric speaker. At this point you can try controlling the Runabout with your universal remote. (Be sure the remote is set up to control a Sony brand TV.) Press the up-channel and down channel keys—these should move the Runabout forward and backward respectively. The up-volume and down-volume keys move Runabout right and left. One LED should turn on during any movement. Press and hold the "5" button and you should hear a beeping from the piezo element.

**TABLE 1—HARDWARE SUPPLIERS**

| Supplier | Products Available |
|---|---|
| Stock Drive products<br>2101 Jericho Pike<br>New Hyde Park, NY 11040<br>(516) 328-0200 | gears |
| Edmond Scientific<br>101 E. Gloucester Pike<br>Barringotn, NJ 08007<br>(609) 573-6250 | gears, motors |
| Digi-Key<br>701 Brooks Ave. South<br>Thief River Falls, MN 56701<br>(800) 344-4539 | infrared receivers |
| Radio Shack Stores<br>(nation wide, check<br>phone directory) | infrared receivers,<br>motors |
| RAF Electronics<br>95 Silvermine Rd.<br>Seymour, CT 06048<br>(203) 888-2133 | spacers, standoffs |
| H.H. Smith Inc.<br>632 Arch St.<br>Meadville, PA 16335<br>(814) 724-6440 | large grommets,<br>spacers, standoffs |
| Minor Rubber Inc.<br>49 Ackerman St.<br>Bloomfield, NJ 07003<br>(201) 338-6800 | large grommets |

• In addition, check hobby and surplus stores for gears and motors.

If nothing happens when power is applied, check to see that +5 volts is present at pin 6 of the DC-DC converter IC2. Also check for +5 volts at the power pins of IC1 and IC3, and make sure the grounded pins of each IC are at zero volts.

If you have an oscilloscope available, check the serial bit stream from the infrared receiver module. Pin 18 of the PIC16C56 should toggle rapidly between 0 to +5 volts whenever a button is pressed on the remote. (This is also a good way to see the code sequence of each key.)

The idling (no movement) voltage at pins 6 through 9 of the PIC16C56 (motor control pins) should be at approximately zero volts. Whenever a motion key is pressed on the remote control (up/down volume or up/down channel), the voltage at these pins should increase to about +5 volts depending on the direction of movement.

Check the voltage at the top of both motor H-bridge circuits (the emitters of Q1, Q3, Q5, and Q7). These points should be at the battery potential of approximately 3 volts. Be sure the emitters of Q2, Q4, Q6, and Q8 are at zero volts.

If the Runabout operates, but turns when it should go straight (and goes straight when it should turn), you must reverse both wires on one of the motors. If it moves in reverse when it should go forward, and turns left when it should turn right (and vice versa), reverse both wires on both motors.

A common mistake when controlling the Runabout is made by pressing the wrong keys on the universal remote. For example, if you press the "VCR" or "Cable" key, you will no longer be sending proper information to control the Runabout. Most universal remotes instantly change to a new mode and send out new codes if the VCR or Cable key is pressed. Any time you notice an immediate non-operation of Runabout, press the "TV" key on your remote and try again. (If that doesn't work try re-programming the remote for a Sony brand TV.)

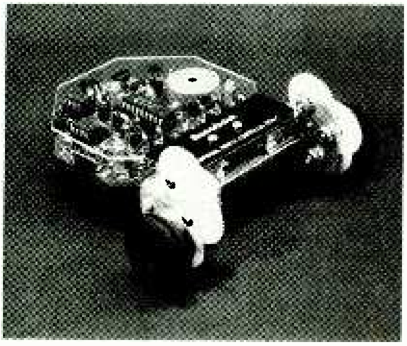


FIG. 8—THE COMPLETED RUNABOUT. The robot has a store-bought look to it, and is sure to entertain for hours.

## Operation

Table 2 lists all the functions programmed into the Runabout. For basic operation, the remote's channel and volume keys provide movement, while keys 0 through 9 produce sound effects and operate the LEDs. (Other keys not listed in Table 2 that you may have on your remote will not cause any action.) The Runabout responds only while the key is being pressed and stops when the key is let up (except in program-playback mode).

To enter the robot's program mode, press the "enter" key on your remote. Runabout will beep for approximately 1 second indicating that the program mode has been entered. Up to 127 movements, sound effects, and LED keypress commands will be recorded. After each action (key release), a short beep indicates that the action has been recorded. Press the enter key any time to exit (and save) your sequence, and then press the "power" key to play back a sequence. After the pre-programmed sequence ends, six short beeps will signal the end of the sequence. There is no way to interrupt a sequence during

**TABLE 2—RUNABOUT OPERATION**

| Universal Remote Key | Runabout Action |
|---|---|
| Up Channel | Move Forward |
| Down Channel | Move Reverse |
| Up Volume | Turn Right |
| Down Volume | Turn Left |
| Key 1 | Single LED On (Left) |
| Key 2 | Single LED On (Middle) |
| Key 3 | Single LED On (Right) |
| Key 4 | "Erratic Driver" Mode |
| Key 5 | Beep (Horn) |
| Key 6 | Dual Tones |
| Key 7 | Rising Tones |
| Key 8 | Change Speed |
| Key 9 | Falling Tones |
| Key 0 | Shift Key (Selects Memory 1-6) |
| Enter Key | Enter/Exit "Program" Mode |
| Power Key | Run Selected Program |
| Mute Key | Pause (In Program Mode Only) |

playback except to turn off Runabout or to remove the batteries.

To select a new memory location (one of six banks), press the "0" key on the remote. Two beeps signal that you can now press keys "1" through "6" (memory 1–6). Any other key will give an error signal. The Runabout always defaults to memory location 1 when power is first applied.

Runabout was designed for table-top use. The infrared receiver module will not function properly in direct sunlight, and you should therefore operate the device indoors only. The Runabout should work up to a distance of approximately 25 feet if the remote is aimed properly and contains fresh batteries.

Do not expect the Runabout to carry out long movement sequences with great precision. The gear assembly is not a precision mechanism, so there will be variations from one movement to another. Alkaline batteries have a sloping discharge curve.

As battery voltage declines, the overall speed of movement of the Runabout is reduced, and this reduction will effect positioning. Ni-Cd batteries have a more steady discharge rate, but their voltage is lower and the Runabout will move slower overall.

It's best to program short movement sequences if you want repeatability. Try to re-position the Runabout to its exact starting point. Also, a clean table top keeps small particles from getting trapped under the front skid and causing Runabout to turn slightly when it encounters them.

The Runabout might turn slightly due to other factors. The motors might not have identical torque and/or one gear assembly might not turn as smoothly as the other. You can solder in a low value resistor (typically 0.1 to 1 ohm or more) in series with the faster motor to try to slow it down. If desired, experiment with different resistor values in series with either motor wire. It might take several attempts to get the motors to turn at precisely equal speeds but patience will pay off and your robot will move in straight lines.

On some surfaces the front skid can resonate and cause a vibrating sound during movement. You can place a layer or two of masking tape directly on the bottom of the skid to solve this problem. The tape will dampen the contact between the table and the skid and reduce the noise.

Be careful when playing back pre-recorded sequences. You can easily lose track of where you started the sequence, and the Runabout can make an unexpected turn and fall off a table—and it *will* be damaged by a fall! Ω

## HARDWARE HACKER

*continued from page 53*

about making your own telephones, radios, batteries, and induction coils.

I particularly like all of the lucid instructions and the super clear technical illustrations. When compared with the glitzy schmaltz of the latest vapid computer magazines, effective technical communications sure seems to have gone downhill.

The second is *Strange Stories from Electrical Experimenter Magazine*, which is a thinner reprint having some original Tesla and Gernsback oddments in it. Any "lost" technology you'll find here is best left that way but it's great reading.

Lindsay has many more titles on old turn-of-the-century machine shop techniques, antique radio, and texts on how to make just about anything. Free catalogs are offered.

Industry insider publications this month include *Multimedia Producer*, *Inter@ctive Week*, *Emf-Emi Control*, and the *MFP Report*. The latter is crammed with information on all kinds of multifunction peripherals that can combine copying, printing, fax, and document scanning.

For many individuals most of the time, patents are virtually certain to end up a total loss of time, energy, money, and sanity. Find out why in my *Case Against Patents* package. Along with lots of tested and proven real-world alternatives. Also a big reminder that I recently bought an *entire* community college electronics department at auction and have a freebie surplus sale flyer for you. All kinds of bargains are hiding here.

As usual, please carefully read our *Names & Numbers* and our *Robotics Resources* sidebars before you dial our technical helpline. Immediate help, along with reprints and preprints of my columns appear on *GEnie PSRT*.

Ten free *Genie* hours per the *Need Help* box. I've also just added a lot more Basic Stamp support, lots more on Acrobat, more magic sinewaves, and a great new Internet launchpad. We also do now have several *Scott Edwards* columns plus the *Society of Amateur Scientists* forums. EN

## METROLOGY LAB

*continued from page 36*

It turns out that it is quite easy to measure resistor temperature coefficients. Since a bag of 200 good quality, metal-film resistors can be purchased for less than $10, there should be no problem selecting a suitable matched pair inexpensively. In fact, you are apt to find a suitable pair within the first dozen or so that you test.

On a scrap piece of perforated construction board, build the bridge circuit shown in Fig. 3. Be sure to use a multiturn potentiometer for R1, or the bridge will be impossible to zero. You will need a meter that can resolve 0.1 millivolt or better on its lowest DC scale (most DMMs). The bridge can be powered from three 9-volt batteries in series. Connect the resistor under test to the bridge with clip leads.

To determine the resistor tempco, you must heat the resistors in a bath of warm mineral oil, which is non-conductive and non-toxic. An ounce or two in a coffee cup, placed on a cup warmer works well. You want the temperature of the oil somewhere near 50°C (122°F), but the exact value isn't overly important. Don't make it so hot that it can burn you, and don't heat it in your microwave oven; the oil has little electrical loss and heats inefficiently. Keep it well stirred, so the temperature is even throughout.

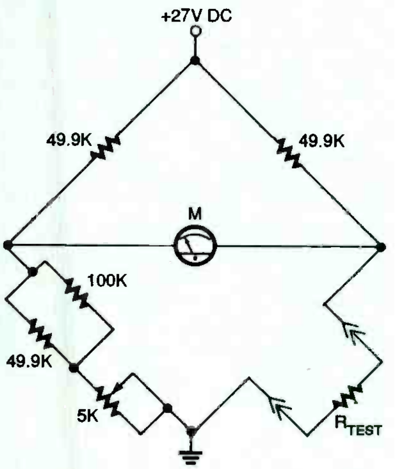



**FIG. 3—BUILD THIS BRIDGE CIRCUIT to select matched pairs of resistors for the voltage standard.**

**TABLE 1—CALCULATING RESISTOR TEMPCO**

| | |
|---|---|
| Meter reading at start: | –0.1 mV |
| Meter reading after immersion: | 1.2 mV |
| Room temperature: | 20°C |
| Oil temperature: | 48°C |
| The total bridge voltage change: | 1.2–(–0.1)=1.3 mV |
| The resistor change in PPM: | 1.3×148=192.4 PPM |
| The temperature difference: | 48 - 20=28°C |
| The resistor tempco | 1 92.4/28 = 6.87 PPM/°C |

You should be able to zero or nearly zero the meter with R1. With the meter zeroed, immerse the resistor in the hot oil. You should see a change in the reading of up to a few millivolts, and it should stabilize within a few seconds. Record the starting and finishing readings, the oil temperature, and the room temperature. Do this for at least twenty resistors.

Now you can calculate the actual tempcos. With 49.9-kilohm resistors, 27 volts DC, and the bridge nearly balanced, each millivolt of change indicates that the test resistor changed by 7.393 ohms, or 148 PPM. Dividing the resistance change by the temperature difference gives us the tempco. Table 1 shows an example.

The resistors used in the prototype were listed in the catalog as 100 PPM, but the parts were marked 50 PPM when they arrived. It was only necessary to test twenty resistors to find three acceptable pairs. Overall, the resistors proved to be quite good, with tempcos spread on both sides of zero.

Select two resistors from your batch that have tempcos less than 5 PPM/°C, and that match within 0.2 PPM/°C. They should also be within 75 ohms of each other (10 millivolts of each other in the bridge).

If you are including the optional trim circuitry, you will need one additional resistor. From the remaining resistors that were tested, select the resistor nearest to 0 PPM/°C, and preferably below ±5 PPM/°C. This will be used for R3 in the voltage standard.

Although the resistors that you select in this manner will serve quite nicely for the voltage standard, you should not be mislead into thinking that they are the equal of an expensive wirewound part. The wirewound resistor will probably have better long-term stability, a lower voltage coefficient, and a variety of other advantages. Still, the selection process re-

### PARTS LIST

**All fixed resistors are RN55D or better, 1%, metal film.**
R1—selected, see text
R2—2000 ohms, multiturn trimmer potentiometer
R3–R5—49,900 ohms (selected, see text)
R6—49.9 ohms
**Capacitors**
C1–C4—0.47 µF, 50 volts, metallized film
**Semiconductors**
IC1—LM340T15 voltage regulator, National or equiv.
IC2—LT1027BCH 5-volt reference, Linear Technology or equiv.
IC3—LTC1050CN8 amplifier, Linear Technology or equiv.
**Other components**
J1—2-terminal DC power connector
J2—5-way binding post, red (gold-flashed brass preferred)
J3—5-way binding post, black (gold-flashed brass preferred)
**Miscellaneous:** DC wall-mount adapter, 17–35 volts DC, PC board, case, solder, No. 18 AWG bus wire, resistors for resistor-selecting brige circuit.
**Note: The following items are available from Conrad Hoffman, 4391 County Road #1, Canandaigua, NY 14424-9611; E-mail, 73260.2255 @compuserve.com; checks and money orders accepted.**
- **Etched and drilled printed-circuit board—$15 plus $4 shipping and handling**
- **Calibration—$15 plus $4 shipping and handling**

## ADDITIONAL ERROR-SOURCE INFORMATION

Error sources that are invisible in most circuits can assume huge proportions at the PPM level. Here's a quick summary of just a few of them.

**Resistor temperature coefficient.** Popular at one time, carbon composition resistors are little used today. With a typical tolerance of ±5%, a tempco of 1000 PPM/°C or worse, and poor long-term stability, it's not hard to see why they've been supplanted. The most popular resistor today is the carbon-film type, which are commonly available in ±5% tolerance and have a tempco around ±350 PPM/°C, depending on value. Although they are fine in non-critical circuits, they have no place in precision instrumentation.

The best easily obtainable resistor is the metal-film type. They tend to be very stable, low in noise, and have a tempco of ±100 PPM/°C in the normal T1 or "D" grade.

For the ultimate in tolerance, stability, and tempco, there are special wire-wound and etched metal-foil resistors. Tolerances of less than .01% and tempcos better than 5 PPM/°C are available, but prices for such components start at several dollars apiece. Since they are mostly built to order, high minimum-order requirements and long lead times are the rule.

Wirewound resistors from the same wire lot tend to have well-matched tempcos. It would seem logical to expect metal film resistors from the same manufacturing lot to be well matched for tempco, but tests prove just the opposite. For metal-film resistors, expect both positive and negative tempcos of various magnitudes. If you need a close match, the parts must be tested.

You will also find that resistors typically undergo a small, permanent, value change when they are soldered. If you have spent several hours matching resistor values, be sure to use a heat sink between the body and the joint when soldering them, lest your work be wasted. Tempco is far less affected by soldering.

**Leakage currents.** Current leakage between traces and through poorly chosen capacitors can wreak havoc with precision circuits. Avoid these problems by keeping traces well separated, cleaning the board, and using only low leakage capacitors in critical locations. Polystyrene and most of the plastic-film capacitors are good choices. Sensitive IC pins and traces should be protected by guard rings where possible. Coating the board is beneficial, but only if it is clean and dry to begin with. If the coating traps moisture or contaminants, it will cause more trouble than it prevents.

When working with high excitation voltages, or attempting sub-PPM measurements, even wire insulation is important. Teflon or other low leakage insulation is recommended.

**Thermal EMF.** EMF is the abbreviation for electromotive force, the two dollar word for voltage. Thermal EMF refers to the small voltage generated where dissimilar metals touch, the Seebeck effect.

Imagine traveling through a typical circuit path. You first enter a copper wire and head towards the first dissimilar metallic junction (DMJ1), a solder joint. You leave the joint, but enter a copper trace of a different composition than the wire (DMJ2). You enter another solder joint (DMJ3), then a resistor lead (DMJ4). As you enter the resistor body, your compass jiggles, and you notice that the resistor end cap is made of steel (DMJ5). Back to the circuit board (DMJ6, 7, & 8), then through another solder joint, to an op amp with Kovar leads (DMJ9, 10). You haven't traveled far, but we have a plethora of dissimilar metallic junctions.

Now, think of every DMJ as a tiny temperature-controlled battery in series with your circuit.

Copper against Kovar will generate a thermal EMF of about 35μV/°C. One degree of difference between the reference leads times the gain of the following amplifier (2×) would result in a 70-μV error in the output of the voltage standard (7 PPM).

Fortunately, connections tend to come in pairs: two leads of a resistor soldered to a circuit board, two inputs of an op-amp, two 5-way binding posts, and so on. Kept at the same temperature, the small voltage produced at each junction will cancel out.

If the junction pair is not at the same temperature, a clever circuit designer will sometimes include an apparently unnecessary junction, just to cancel out the thermal EMF of a necessary junction.

Later in this series, you will see how bad these effects can get when you connect a sensitive null detector to a simple four-resistor bridge, then heat or cool one of the junctions. For now, be aware that plated banana plugs, plated alligator clips, and plug-in prototype boards are some of the worst offenders.

Very low thermal EMF connections can be made with brass or gold flashed brass banana jacks and ordinary copper magnet wire, plain copper "bell wire", or solid copper phone wire.

**Stress-induced errors.** Many components are sensitive to mechanical stress. The worst culprits seem to be epoxy DIP-packaged references. Manufacturers may publish great drift specifications, but check the fine print—they often apply only to the expensive metal or ceramic package.

Your technique is important. Never bend resistor leads while holding the resistor body. Grab the lead next to the body with long nose pliers, then bend the free end. The resistor should drop freely into the circuit board. Note that conformal coating the top of a board can increase the coupling of forces into the components, actually increasing drift problems.

Torsioning the circuit board can cause surprising stress in components, particularly ICs. It is often best to mount the board on three compliant supports to avoid warping it. Very little information is available on stress-induced errors, so experimentation is the order of the day.

**Learning more.** The techniques described here are quite specialized, and rarely mentioned in modern texts. Fortunately, older electrical engineering books went into great detail on various types of bridges and comparison methods. Many also had excellent sections on precision resistors, standards, meter design, and AC techniques. Check with used-book shops in your area. They often have early electrical engineering texts for just a few dollars. You will find that books written between 1900 and about 1950 are fascinating, and often better written than today's texts. In particular, look for any books relating to electrical measurement. Please remember to keep the information in the context of the year it was written, however. We are interested in adding to our knowledge, not regressing back to an earlier age!

For a fully up to date viewpoint, order Fluke's *Calibration: Philosophy in Practice*, shown in the references. It covers the history and current practice of calibration better than any other reference I've seen.

Another excellent book is Keithley's *Low Level Measurements*, also shown in the references. This is a very practical book, explaining all the low level error sources, and illustrating exactly how many types of difficult measurements should be made.

sults in a surprisingly good pair of resistors for the standard, and it takes some of the mystery out of passive component selection.

### Building the standard

Figure 3 is the parts-placement diagram for the voltage standard. Hand wiring this project is not recommended, but if you do, be sure to follow the component layout and wire routing exactly as it is on the printed-circuit board.

Install the components, being

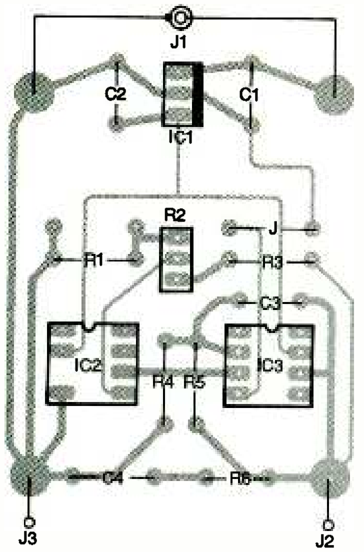
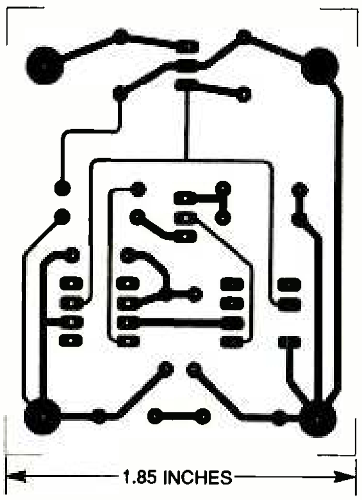



**FIG. 4—PARTS-PLACEMENT DIAGRAM for the voltage standard. Make the connections to jacks J2 and J3 with No. 18 AWG bus wire.**




**VOLTAGE STANDARD foil pattern, shown full size.**

sure to observe the normal precautions when handling the ICs that are sensitive to electrostatic discharge (ESD). The tab of the LT1027 indicates pin 8. Do not install R1, R2, or R3 unless you are including the optional trim circuit. Do not use sockets.

Install a 1½-inch length of No. 18 AWG bus wire in each of the four large pads near the corners of the board. Be sure you have enough solder to complete the board from one batch, as mixing different lots or types of solder might cause thermal EMF differences between the joints.

## Optional trim circuit

The trim circuit is optional because you will need access to a calibrated 4½ digit voltmeter to select the proper resistor. Install the 49.9-kilohm resistor that was selected earlier for R3, and install 2-kilohm trimmer potentiometer R2.

You will have to select R1 so the trim range passes through 10 volts DC. Be sure R2 is set to the center of its range. Temporarily attach a substitution box (or a trimmer potentiometer) in place of R1. Power the board and adjust the value of R1 until the output is exactly 10 volts DC, as measured on a calibrated 4½ digit DVM. The prototype required 18.82 kilohms, but yours may differ somewhat, depending on reference and resistor tolerances.

Install the closest standard 1% metal-film value for R1. The circuit board has pads to allow a parallel combination of resistors, if needed. Check that the trim range still passes through 10 volts DC, then recheck it after the unit has operated for a few days. The trim range is purposely narrow to allow an initial setting within 1 PPM.

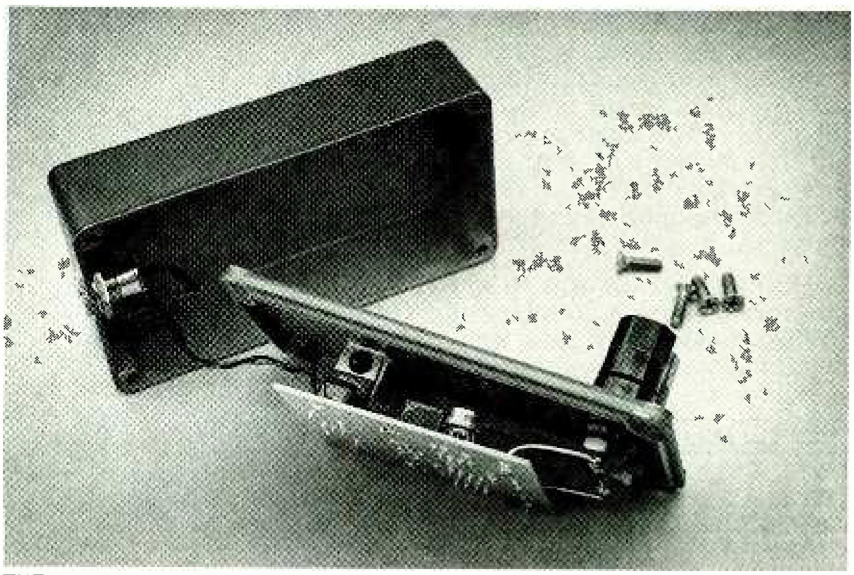
## Cleaning the PC-board

Remove all traces of flux with alcohol or other suitable flux remover. Next, wash the board with soap and warm water. Then scrub the solder side of the board—and accessible areas of the component side—with a nail brush or similar tool. Rinse the board thoroughly, and then dry it with warm air. There should be no visible streaking or contamination. If you can see any trace of flux or other deposits, repeat the cleaning process. Once the board is clean, handle it only by the edges to avoid depositing body oils on clean surfaces.

## Mounting the board

The prototype was mounted in a die cast metal case, but plastic cases are acceptable, too. To keep mechanical stress low, three-point support is used. The board is mounted only by the bus wire connecting the binding posts, and the voltage regulator. Ordinarily this wouldn't be good practice, but the voltage standard's board is small and light, so it doesn't cause any problem. Keep the board close to the binding posts and use No. 18 AWG bus wire for low output impedance.

Mount the voltage regulator to a small aluminum block or piece of aluminum angle. The regulator must be electrically isolated from the block, so use a mica washer and a plastic screw. Attach the aluminum block or angle to the case's lid.



**THE CIRCUIT BOARD is supported by the bus-wire connections to binding posts by the voltage regulator, which is attached to a small block of aluminum that is, in turn, fastened to the lid of the case.**

Splurge on good quality five-way binding posts. They should be copper, brass, or gold flashed brass. Do not use ring lugs, but solder directly to the rear of the posts. You may have to use a larger soldering iron to get a good solder joint.

The correct center-to-center distance for a dual banana plug is 0.75 inches. If the distance is even slightly wrong, insertion will be difficult, and the plugs will eventually be damaged.

Power to the standard is provided by a wall-mounted DC adapter, preferably with a detachable DC power connector. The circuit requires between 17 and 35 volts DC. Unregulated wall adapters typically produce higher voltages when used below their rated load. Thus many "12-volt" units will happily provide the necessary 17 volts. Be sure to check the actual voltage under load, because the standard will not be stable or accurate if supplied with less than 17 volts.

Do not mount a power supply inside the voltage standard's case. An external, wall-mounted adapter was specifically chosen to keep heat and magnetic fields out of the voltage standard, either of which is apt to cause errors.

## Calibration

The final step is to have the standard measured (adjusted, if you have included the optional trim components). Since this is your master link to the official standard volt, the measurement should be made on traceable equipment of very high quality. One of these three methods should yield a satisfactory result:

**1.** Have a local calibration lab measure the voltage standard. If the lab knows that it is for hobbyist use, and does not need a certificate of traceability, you might be charged less than for a commercial standard. Try to have the value read/set to ±10 μV (1 PPM) at 23°C. Be sure a firm price is agreed to before the work is started, and that it is understood what should be done if some problem prevents calibration—if the trim range is outside 10 volts DC, for instance.

**2.** Obtain access to a suitably accurate (and recently calibrated) meter and read/set the standard yourself. You or a friend may work for a company that has one of the new lower cost 6½ digit meters now available.

**3.** If you do not have a local source of calibration, you can send the standard to the author at the address given in the parts list. Calibration will take two to three weeks and costs $15..

For best stability, the voltage standard should be kept powered for at least a week or more prior to calibration. Ideally, the calibration temperature should be 23°C. The label shown in Fig. 5 can be copied onto adhesive label stock and affixed to the cover.

| The Mini Metrology Lab | |
|---|---|
| date of calibration | |
| date due for recalibration | |
| performed by | |
| test temperature | °C |
| E.M.F. | VDC |

**FIG. 5—CREATE A LABEL like this one and affix it to your standard.**

**THE COMPLETED VOLTAGE STANDARD ready to serve as the first part of the Mini Metrology Lab.**

## Performance

Standards at this level of precision generally need to stabilize for some time after assembly before they "settle down." The prototype was no exception, requiring several days to achieve a reasonable drift rate. It was then given its first calibration. After that, daily comparisons were made against a temperature-controlled standard cell bank. The prototype showed a temperature coefficient of about −3 PPM/°C, and a drift rate of about 2 PPM/month.

The overall performance is excellent for a non-ovenized reference, and your unit should perform in a similar fashion if you assemble it carefully.

The next part of this series will present a sensitive null detector that you can build. It will allow you to match resistors for use in a Kelvin-Varley divider, and it will facilitate comparisons between other voltages and this standard. Ω

**REFERENCES**


*Basic Electrical Measurements*, Melville B. Stout, Prentice-Hall, 1950
*Electrical Measurements*, Forest K. Harris, Ph.D., John Wiley & Sons, Inc., 1952
*Calibration: Philosophy in Practice*, Fluke Corp., 1994
*Low Level Measurements*, Keithley Instruments, Inc., 1992
*IC Op-Amp Cookbook*, Walter G. Jung, Howard W. Sams & Co., 1986
*1990 Linear Databook*, Linear Technology Corp.
*1992 Linear Databook Supplement*, Linear Technology Corp.
*1993 Linear Applications Handbook, Volume II*, Linear Technology Corp.

# THEREMIN

*continued from page 44*

If you don't have an oscilloscope, a pocket AM radio can be pressed into service to verify that the oscillators are working and set to appropriate frequencies. Start by setting the radio to some quiet point between 650 and 750 kHz, and placing it as close as possible to the modulator diodes D2 to D5. Set the radio to fairly high volume and adjust the tuning slug of L2 up and down. At some point, you should hear a click or chirp as the frequency of the oscillator passes through the frequency set on the radio dial. Tune the slug very slowly back toward where you heard the chirp and you will hear "whines"—faint whistles, feedthrough from adjacent stations and so on—as you get closer to the setting of the radio. As you turn further, you should reach a null where the previous whines are replaced by the hiss of white noise (there's no modulation so the only audible signal for the radio to detect is the noise of the transistors in the oscillators, which is fairly faint). When you have turned too far, you will begin to hear the same "whines" that you heard approaching the null. Leave the slug set as close to the null as possible; it doesn't have to be exact.

Now adjust the slug of L1. At some point you will hear a loud chirp as the oscillator you are adjusting passes through the common frequencies of the local oscillator and the radio. Slowly adjust back to the chirp and you should hear a very loud, pure tone descending in pitch as you approach the null. Leave the slug set for as close to null as possible and verify that the front-panel PITCH TRIM control can be used to set an exact null. Leave the control set so that a low-pitch tone can be heard.

To adjust the volume oscillator pair, set the radio dial to a quiet spot between 900 and 1000 kHz, and adjust L3 in the same way that you previously adjusted L2. When L3 has been set close to the frequency of the radio, adjust L4 for zero beat of the heterodyne signal as you did with L1. Verify that the VOL TRIM potentiometer provides a vernier control of the frequency.

At this point, you should be able to start listening to Theremax through an amplifier connected to the audio output. With the volume control of the amplifier advanced slightly, bring your right hand up to the volume antenna—you should hear a tone swell in the amplifier's speaker. If you don't hear a tone, check to make sure that there is still some audible signal being produced by the pitch oscillators. If that's not the problem, check the rest of the audio signal and control path. Read the volume control-voltage at the emitter of Q6 to make sure that it goes from about 0 to 6 volts as your hand approaches the volume antenna. If that's OK, check the differential pair, Q10 and Q11 and its control current source Q12. Finally, check the output stage IC2. If there's no volume CV, check the amp Q9 as described earlier, and the output of the Schmitt trigger,

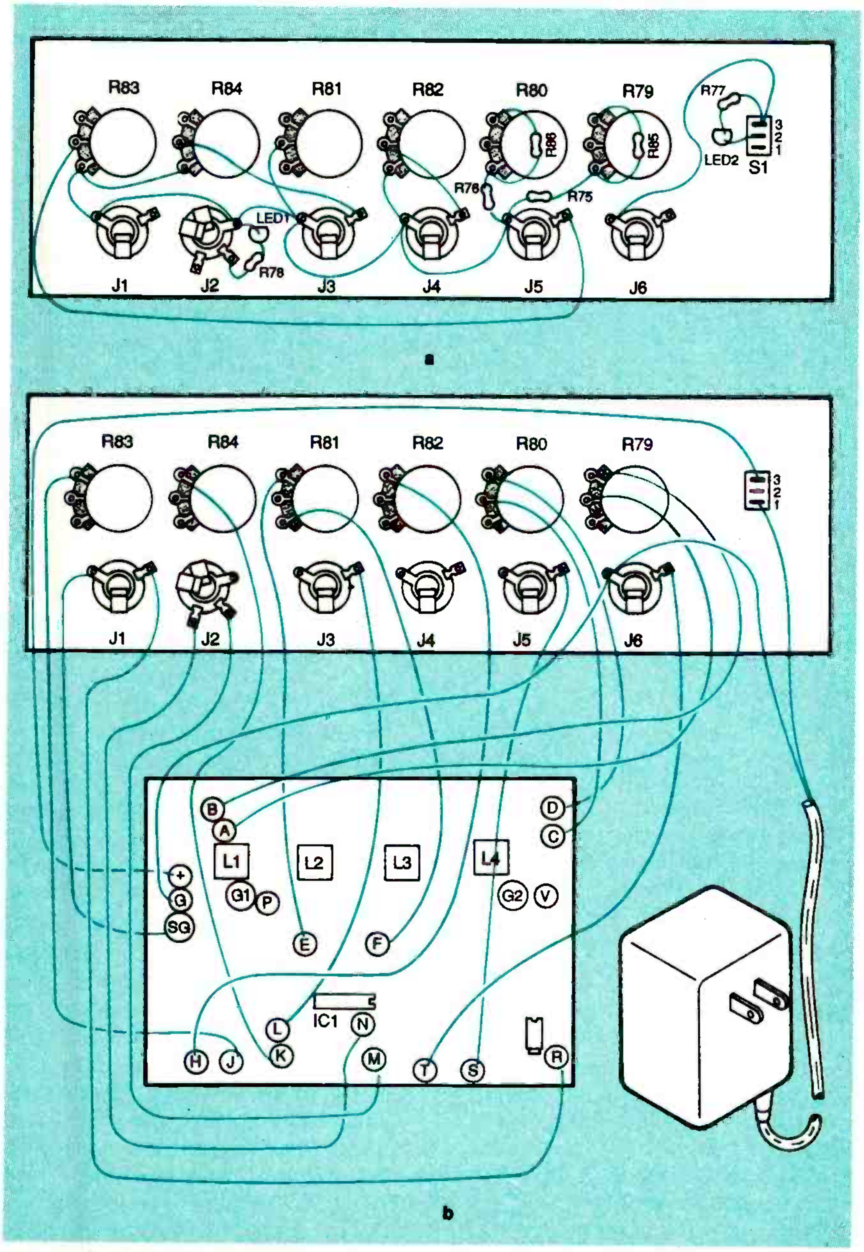



FIG. 4—OFF-BOARD WIRING for Theremax. Some fixed resistors and LEDs mount directly to the front-panel controls and jacks.

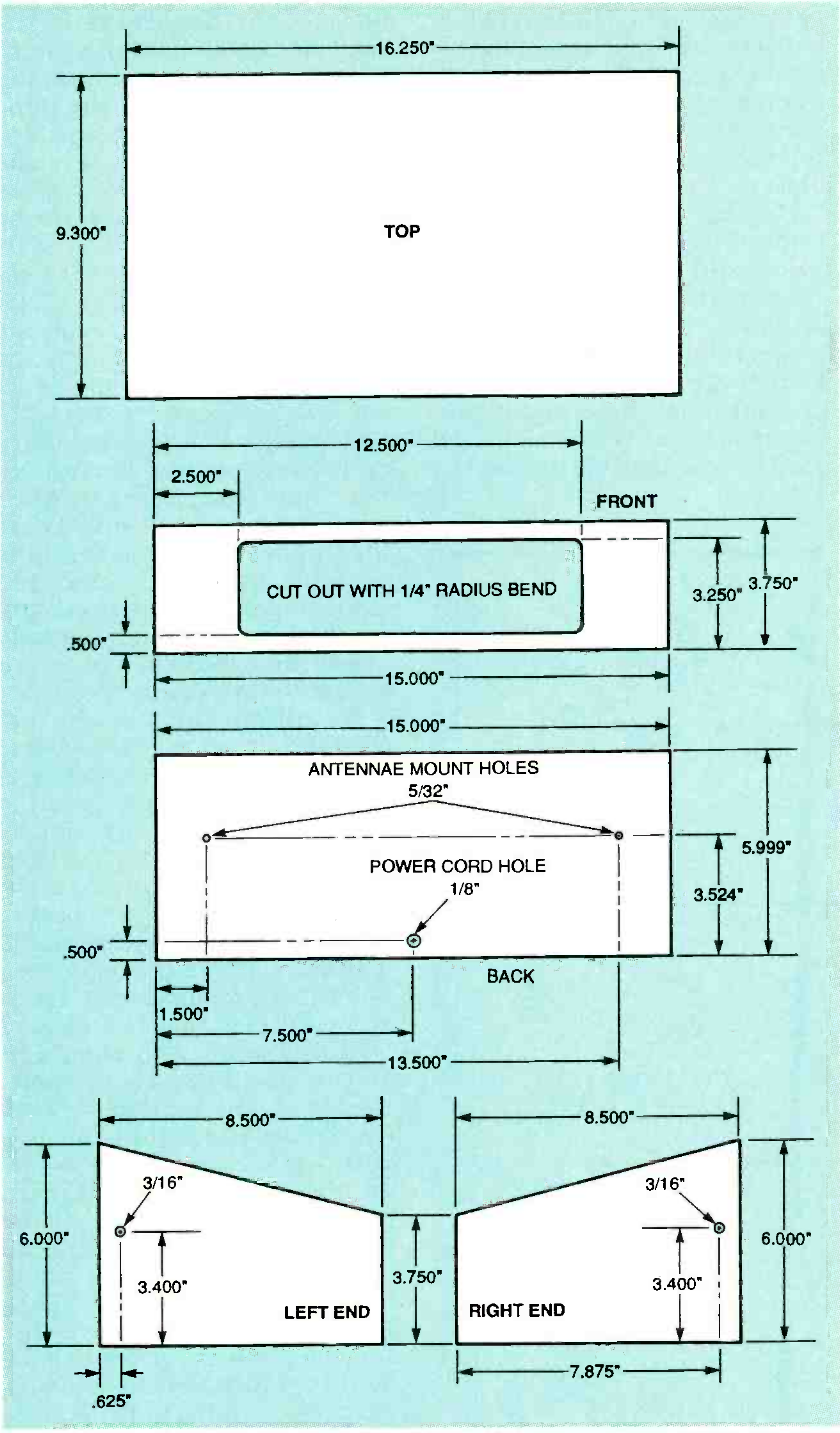



**FIG. 5—THEREMAX'S CASE IS EASY TO BUILD from ½-inch thick white pine.**

IC1-b at pin 1, where there should be a rail-to-rail square wave at the heterodyne frequency of the volume pair. If this signal is present, make sure the components of the differentiator/integrator (R25, C25, C31, D12 and D13) are in proper order.

With a tone audible, rotate the TIMBRE control clockwise and observe that the tone gets considerably more "sharp edged" as you fade from sine wave to square wave output. Turn the TIMBRE control fully counterclockwise. Advance the VELOCITY CONTROL fully clockwise and observe that as your hand rapidly approaches the volume antenna, the GATE/TRIG LED comes on. Also notice that the character of the sound now changes as your hand approaches the volume antenna, getting "fuller" when your hand approaches rapidly, and settling to a purer tone when you slow down, stop or withdraw.

## Playing Theremax

Playing the theremin is an art that can't be taught in a few paragraphs. Still much can be learned by observing the playing style of Clara Rockmore. Clara's background was as a concert violinist, but a palsy in her hands that developed at a young age appeared to have put an end to her career as a performing musician until she started playing the theremin.

In many pictures of Clara taken over more than a 30-year span she is seen in front of a huge free-standing loudspeaker. This was not just for the theatrical effect of the apparent glory behind her head, though in some of the photos this aspect is quite striking. She positioned the speaker directly behind her so that she could hear the note she was getting ready to play before it was loud enough for the audience to hear, performing pitch corrections in that last split second.

Reviews and other accounts of performances remark on her motionless, trance-like stance while playing, only her hands dancing back and forth over the antennae. That theatrical presence was rooted in necessity: A theremin doesn't respond to the motion of your hands only; it responds to body motion as well. If you're moving around while playing, you will find it more difficult to hit an exact pitch.

Clara had developed "aerial fingering" techniques that allowed her to play rapid passages with legato and even staccato articulation. A few years back when Bob Moog—the father of Moog synthesizers and manufacturer of theremins—was preparing an instrument for use in what was to be her last concert, he was quoted as remarking that he had to "hang it on the edge" to please Mrs. Rockmore. In the interest of

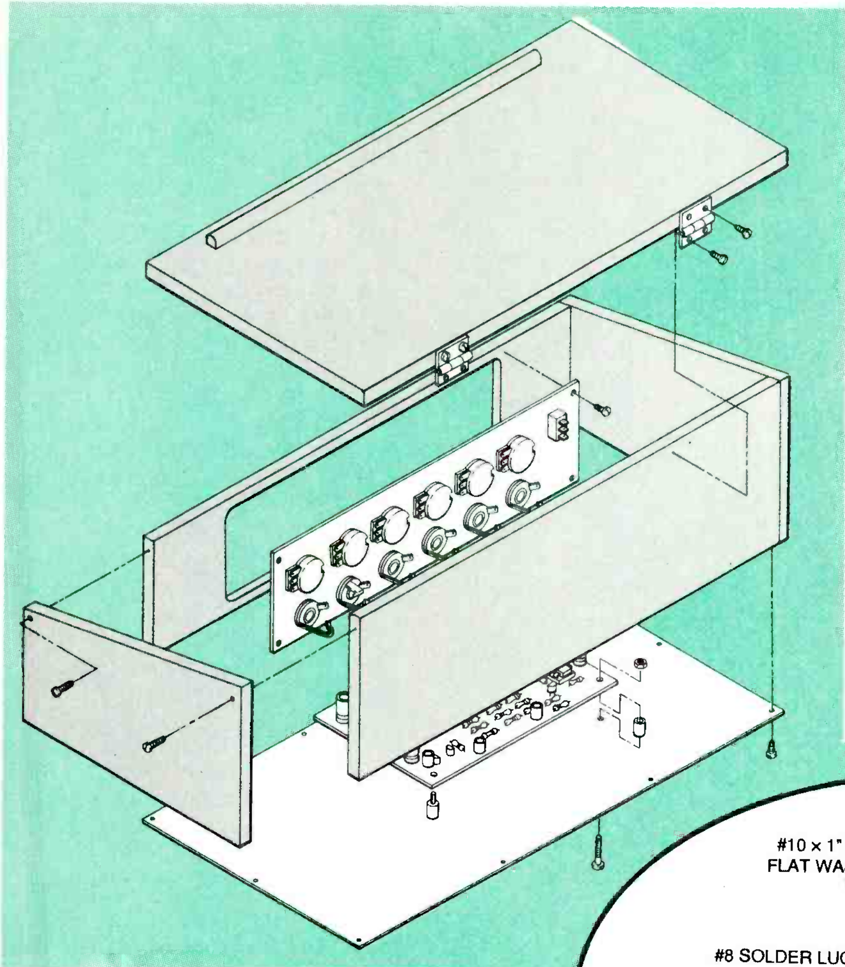


FIG. 6—ASSEMBLE THE CASE as shown here.

na. If you want to play Theremax this way, you should null the VOLUME TRIM control for minimum volume with your hand an inch or so from the antenna. Playing may seem more intuitive if you reverse this, so that volume increases as you move closer. To accomplish that, just null the volume trim with your hand removed. Either way, volume must be nulled completely for the velocity feature to work properly.

Closing the contacts of a SPST switch plugged into the MUTE jack turns the audio output off completely. You may find that a foot switch—either momentary or push-on, push-off—makes playing easier. This switch closure could also be an open collector transistor output from other equipment, such as the "S" triggers used in some

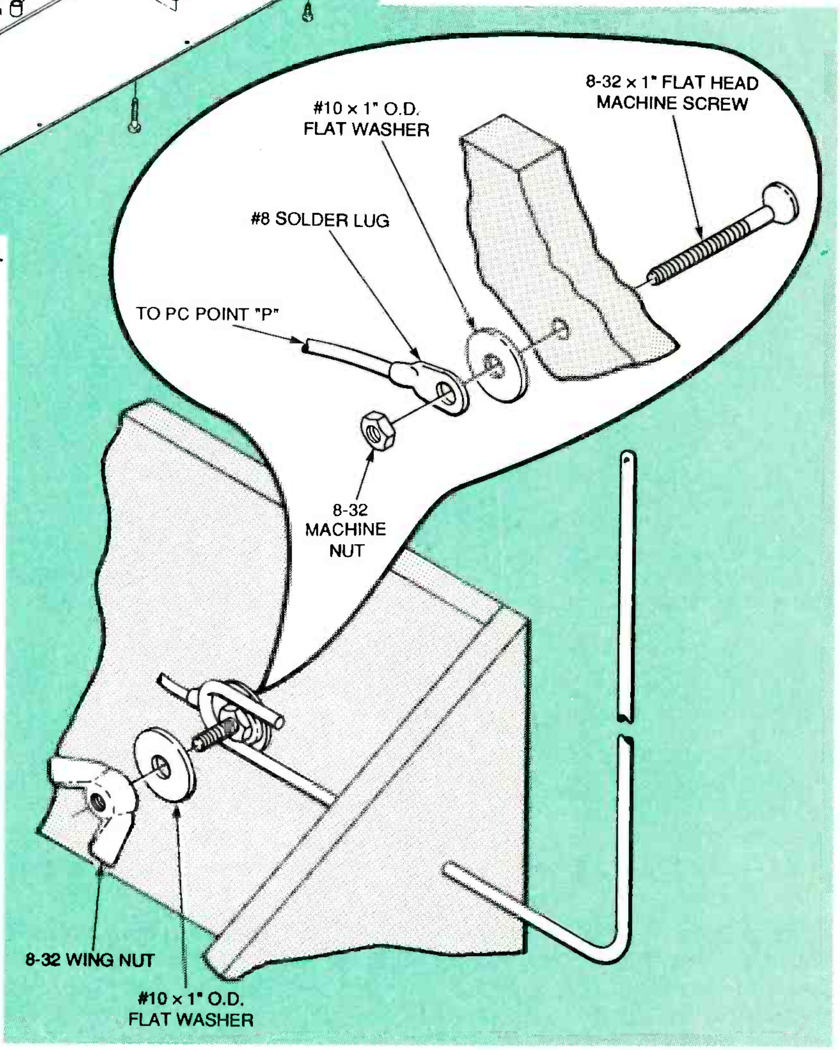



FIG. 7—FORM A LOOP at the ends of the antennas for mounting.

ease of playing, Theremax is designed to be somewhat less sensitive. However, substituting smaller capacitors in the tank of the oscillators will take its sensitivity up to this concert-level performance. But if you make these changes, be warned that you'll also need concert level skills to handle them.

For maximum sensitivity to hand gestures, the PITCH TRIM control should be clockwise from null so that the heterodyne frequency is two octaves below middle C (64 Hz or so). When tuned this way, the maximum range of about six octaves will correspond to an 18-24 inch range of hand motion. Only the rare performer will be able to use more than three or four octaves, because the last couple require that the hand be very close to the antenna.

Volume on the original theremins was increased by moving the hand away from the anten-

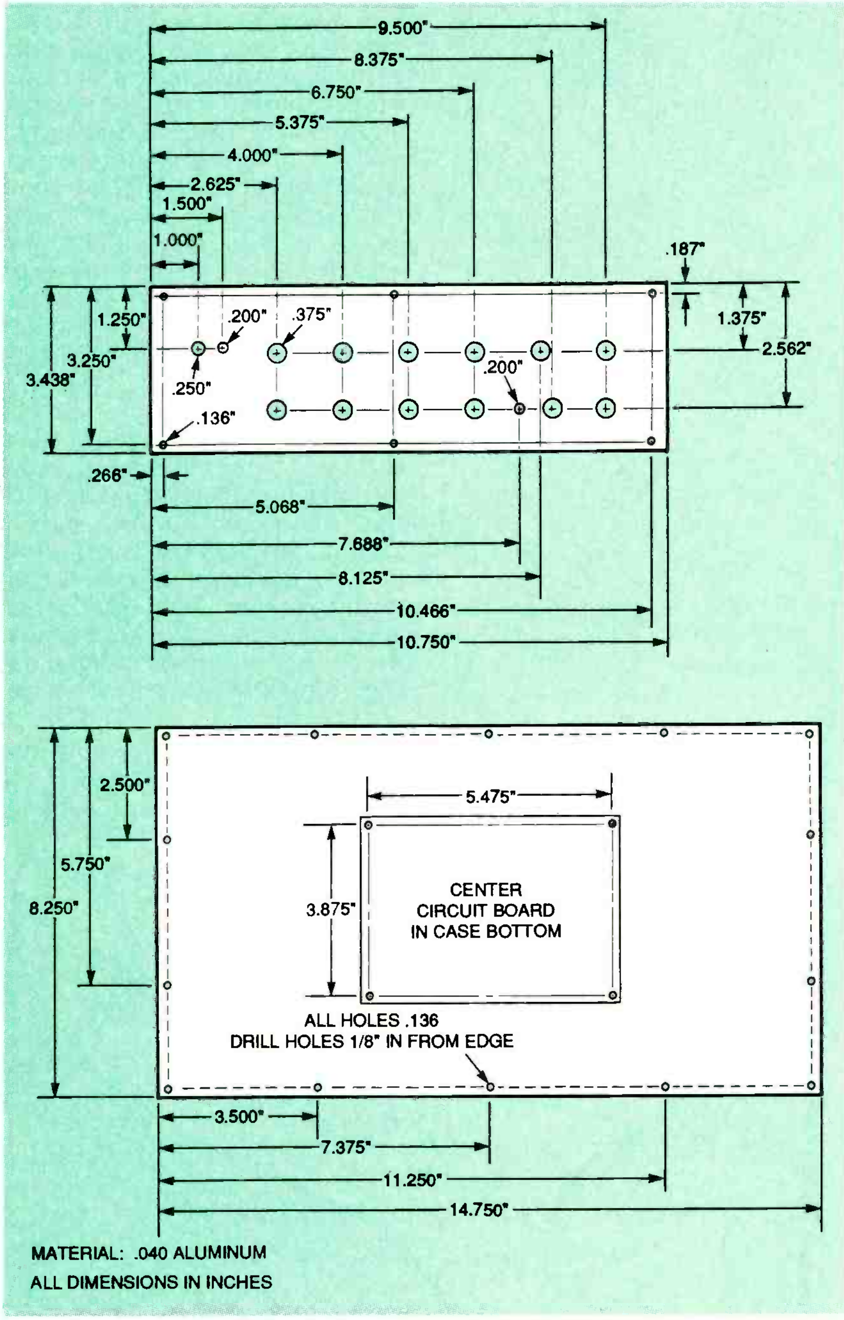



**FIG. 8—THE CASE BOTTOM AND THE FRONT PANEL should be made of metal.**

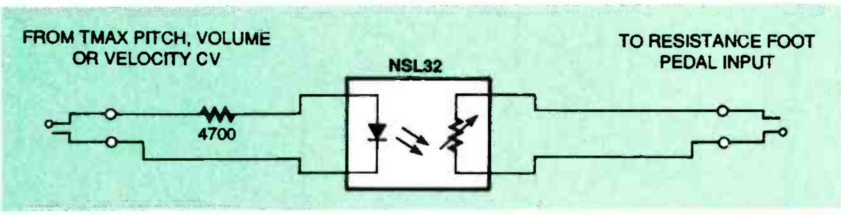



**FIG. 9—AN OPTOISOLATOR can convert Theremax's control voltages to a resistance.**

### PARTS LIST

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

R1—100 ohms
R2,R19—3300 ohms
R3,R8,R13,R17,R69—680 ohms
R4,R9,R14,R18,R48,R49,R61, R65,R66—56,000 ohms
R5,R6,R20,R21—47 ohms
R7,R12,R53—3900 ohms
R10,R15,R22,R23,R56—1000 ohms
R11,R16,R41,R50,R70—10,000 ohms
R24,R25,R54,R57—1 megohm
R26,R45,R59—4700 ohms
R27,R29,R60—470,000 ohms
R28,R67,R68—470 ohms
R30,R33,R34,R36,R37,R38—47,000 ohms
R31,R62—39,000 ohms
R32,R63—330 ohms
R35,R46—10 megohms
R39,R40,R55,R58,R64—22,000 ohms
R42—220,000 ohms
R43,R77,R78—2200 ohms
R44—4.7 megohms
R47—68,000 ohms
R51,R52—15,000 ohms
R71,R72,R73,R74—100,000 ohms
R75,R76—1500 ohms
R79,R80—1000 ohms, panel-mount potentiometer
R81,R82,R83,R84—10,000 ohms, panel-mount potentiometer
R85,R86—270 ohms

**Capacitors**

C1,C20,C42—100 µF, 10 volts, electrolytic
C2,C4,C8,C12,C16,C33,C43—0.01 µF, ceramic disc
C3—1000 µF, 10 volts, electrolytic
C5,C9,C13,C17,C39—100 pF, ceramic disc
C6,C10—100 pF, NPO, ceramic disc
C7,C11,C15,C19,C28,C31—470 pF, ceramic disc
C14,C18 —68 pF, NPO, ceramic disc

synthesizers. Muting the audio has no effect on the control-voltage outputs.

Many contemporary electronic musical instruments have provisions for external control of key parameters by means of control voltages, foot pedals, and so on. In many cases, Theremax's control voltages can be connected directly to these inputs. The availability of both gate and open-collector switching outputs on the GATE/TRIG output, J2 makes switch-style interfacing easy. In some cases, instruments expect a variable resistance at their external control jacks. In these cases, Theremax's control voltages can be converted to a resistance using an optocoupler, as shown in Fig. 9.

In some circles, voltage-con-

C21,C26,C32—10 µF, 10 volts, electrolytic
C22,C27,C34,C37—220 pF, ceramic disc
C23,C35,C36,C38—1 µF 10V, electrolytic
C24,C25,C30—0.1 µF, Mylar
C29—4.7 µF, 10 volts, electrolytic
C40,C41—0.001 µF, ceramic disc

**Semiconductors**

D1—8.2 volts, 400 milliwatts, Zener diode
D2–D9—1N34A germanium diode
D10–D14—1N914 silicon diode
D15,D16—red LED
IC1—LM339 quad comparator
IC2—748 op-amp
Q1–Q12—2N4124 NPN transistor

**Other components**

J1,J3,J4,J5,J6—¼-inch phone jack
J2—¼-inch stereo phone jack
S1—SPST switch
P1—DC wall-mount adapter, 9 volts, 100 mA.
L1,L2,L3,L4—796 kHz. (nom.) oscillator coil

**Miscellaneous:** knobs, circuit board, wire, solder, hardware, case, etc

**Note: The following are available from: PAiA Electronics, Inc., 3200 Teakwood Ln., Edmond, OK 73013; Tel: 405-340-6300; Fax 405-340-6378; Online: http://www.paia.com/paia:**

- **Complete kit of all electronic parts including power supply, circuit board and knobs less antennae and case (#9505K): $88.75**
- **Case kit with pieces cut from white pine and drilled for assembly. Includes hardware, formed antennae, bottom plate and punched, anodized and legended control panel (#9505C): $77.25**

**Please add $7.00 for shipping and handling with each order.**

trolled analog music synthesizers, antiques that they are, have great cachet. Theremax makes a useful supplemental controller to the keyboards typically used in these instruments. Figure 10 shows only one of an unlimited number of possible "patches." The PITCH CV output sets the frequency of the synthesizer's voltage-controlled oscillators (VCOs), so that the right hand still controls pitch. VCOs will typically provide a greater selection of waveforms than just sine or square, and multiple oscillators will produce a fuller sound.

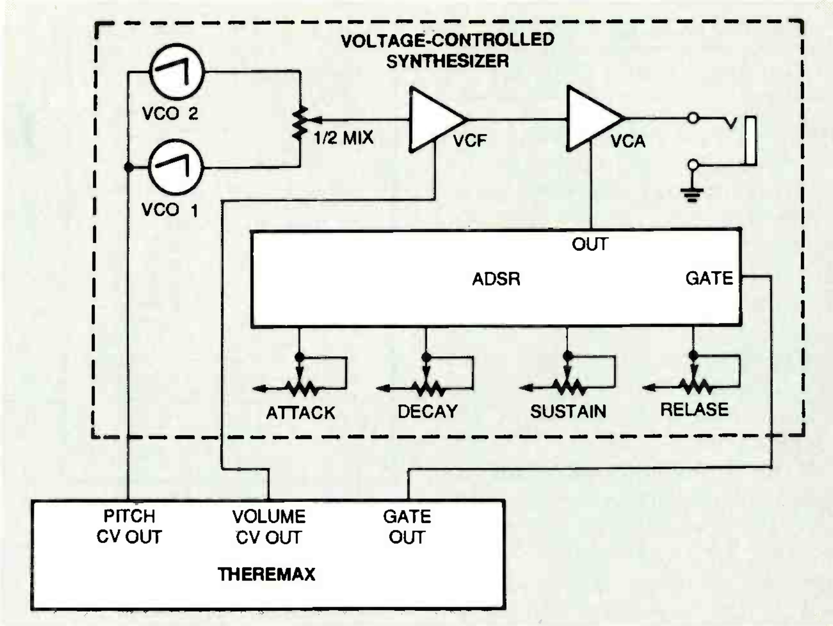
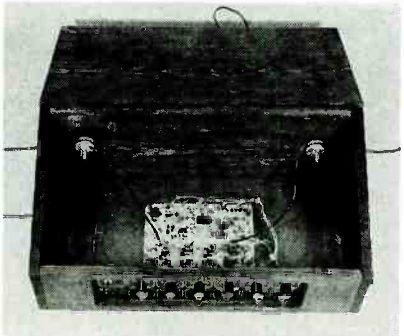



**FIG. 10—VOLTAGE-CONTROLLED SYNTHESIZERS can be controlled by Theremax.**

The volume CV isn't used to control volume; instead it's routed to the control-voltage input of the filter, so that the left hand now controls timbre instead.



**THE THEREMIN CIRCUIT BOARD mounted to the case bottom.**

So if volume is really timbre, how do you control volume? This is the cool part. As with most synthesizer patches, the dynamics of the sound—how fast it builds up and dies away—is controlled by an envelope generator, which here is triggered by Theremax's GATE output. The volume hand does still control volume, sort of, but now moving the hand quickly toward the antenna will trigger a sound with dynamics set by the envelope generator. And remember that the place where the hand ends the triggering move sets the timbre (VCF). You've got air drums!

Theremax's gate output and control voltages don't just respond to the gestures of a performer; they're actually general purpose people sensors and could be used to turn on or brighten lighting instruments arranged to accentuate different parts of a sculpture on the approach of an observer. Or produce kinetic art that responds to how quickly it's approached and how close a person stands. Music is just the beginning—there are a lot of possibilities. Ω

## RESOURCES

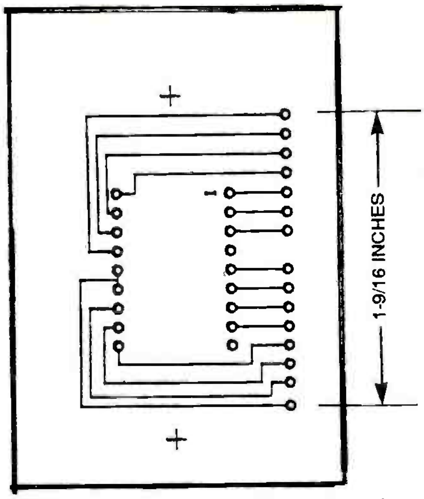
**Articles:** *Keyboard* magazine, February 1994. Much of the issue is devoted to Leon Theremin and Clara Rockmore.
**CD:** Clara Rockmore, *The Art of the Theremin* (Delos D/CD 1014), Delos International, Inc., 2210 Wilshire Blvd., Suite 664, Santa Monica, CA 90403.
**Internet:** The Theremin home page, http://www.vuse.vanderbilt.edu/jbbarile/theremin.html.
**Films:** *Theremin: An Electronic Odyssey*, a film by Steven M. Martin.
**Equipment:** Theremins are also manufactured by Bob Moog's company: Big Briar, Inc., Rt. 3, Box 115A, Leicester, NC 28748.

| ELECTROCHEMISTRY |
|---|
| *continued from page 48* |

stant-current function to loads less than $10/I_{SET}$.

While testing the constant-current source, check the accuracy of the output voltage of the differential amplifier IC5-b by comparing it with the measured output current ($V = I \times 10$). The circuit might not function correctly if resistors R4 and R6, and R5 and R7 are mismatched.

If the internal monitoring circuit is operating correctly, the LED display should present a reading for all variations in output voltage and current when one of the metering functions has been selected. Those values




**FOIL PATTERN for LED display board.**

should be within the general range of those that can be read from an external multimeter.

Turning the knob of potentiometer R34 should affect the reading, while switching S3 should hold the display constant at a specified. value. If this does not occur, trace the pulses through the circuit and check the latch load and memory reset lines at pins 1 and 5 of IC2 for small pulses. With a voltmeter, verify that there are output pulses from the 0.5 Hz reference clock at pin 15 of IC1. Test the coulomb counter by connecting a 1-watt load resistor with a value of about 1 ohm to its output. This should cause the digital display to increment slowly.

**Final adjustments**

First measure the reference voltage accurately. Then select the voltage reference option by closing switch S3. Now set trim-

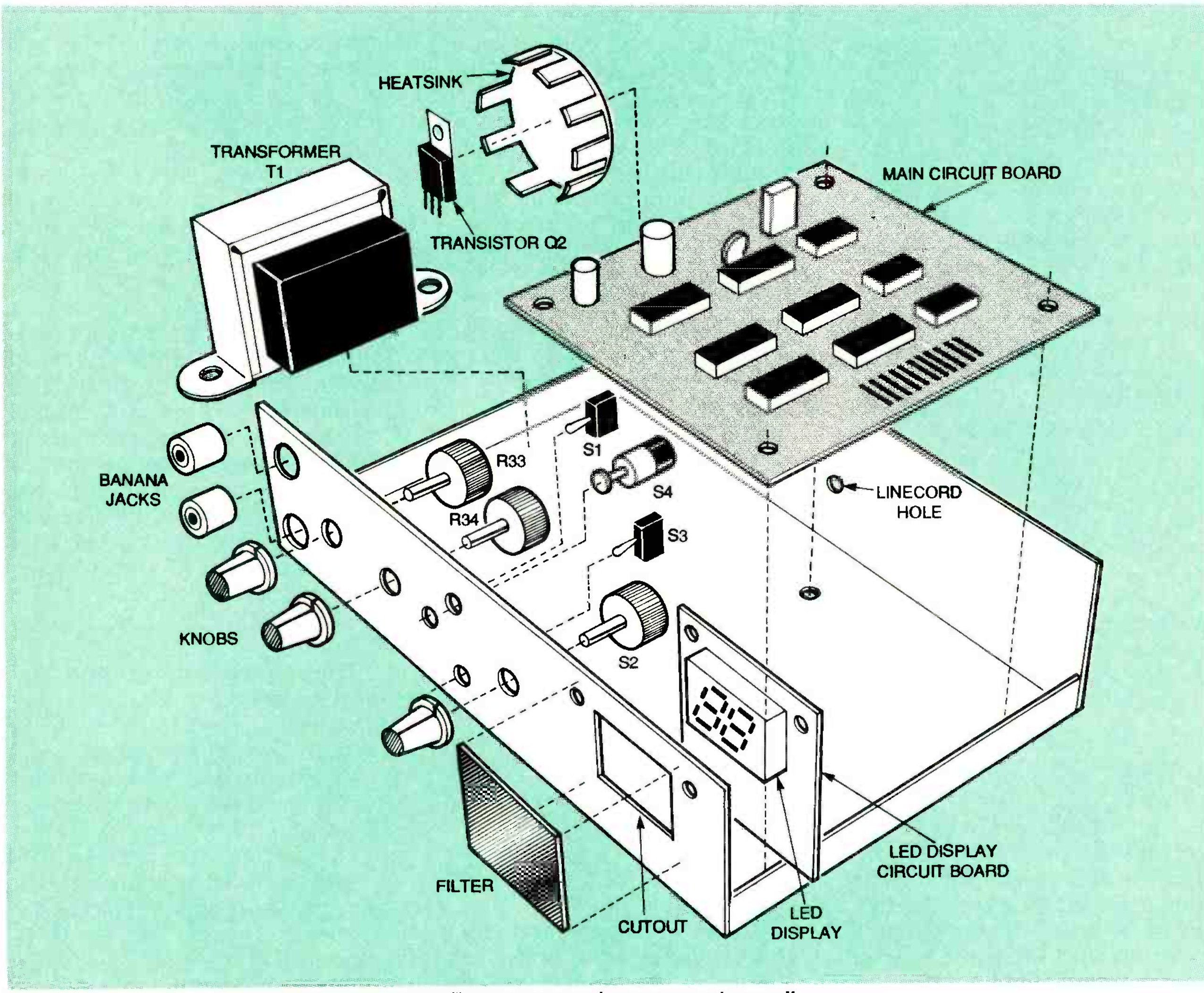



**FIG. 8—POWER SUPPLY ASSEMBLY DIAGRAM. The power supply components are all mounted in the lower half of a two-piece metal project case. The main circuit board is mounted on standoffs, and the transformer is fastened directly to the lower half of the case.**

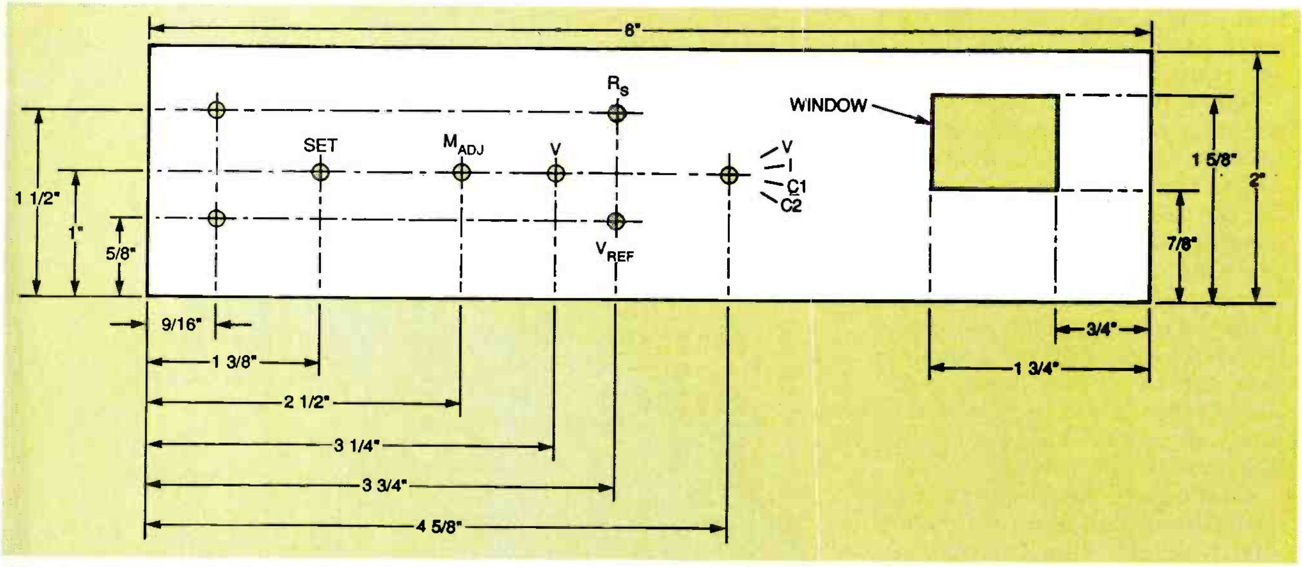



**FIG. 9—HOLE DRILLING TEMPLATE for front panel. Hole diameters will depend on components selected.**

mer potentiometer R35 so the supply's LED display is the same as the external meter display. When doing this, set the knob of panel potentiometer R34 at its midrange position. This will permit both positive and negative errors to be corrected. Record this voltage because it is the value that must be used to set the meter for normal use. Once this voltage scale has been set, all other scales will be set.

## Electroplating

Electroplating is now established industrial technology with its own specialized equipment and practices. You can learn a lot about commercial electroplating by plating small objects with this regulated power supply. However, remember that there are limitations on the size of the articles you can electroplate. They should be limited to objects such as rings, knobs, spoons, and perhaps small tools.

Refer again to Fig. 4. A typical small-scale electroplating setup will include a small laboratory-grade glass or plastic tank, an electrode, and the electrolyte for the metal you intend to plate. The metals you deposit exist in the electrolyte as positively charged ions. Because they will always be deposited on the cathode, attach the article you want to plate at the cathode connec-

**TABLE 1—PLATING SOLUTIONS**

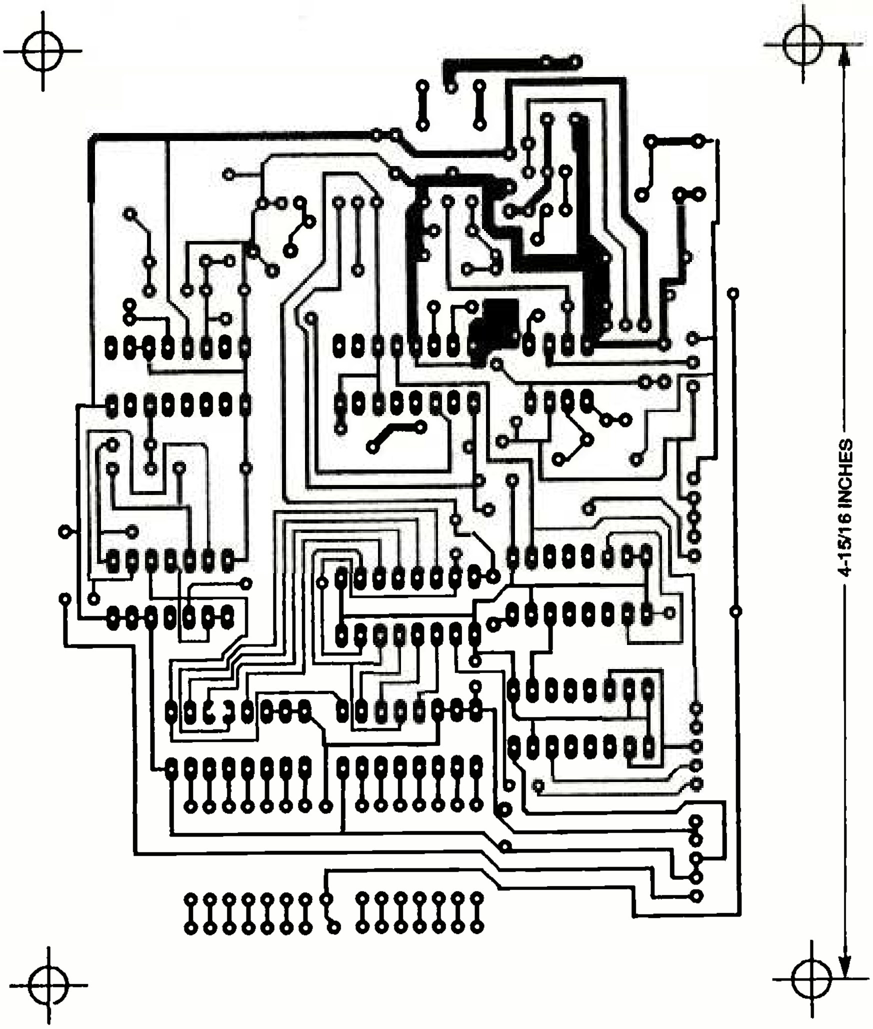
| | | |
|---|---|---|
| **Chromium** | | |
| Composition | $CrO_3$ | 450 grams/liter |
| | $H_2SO_4$ | 4.5 grams/liter |
| | Tartaric acid | 18 grams/liter |
| Temperature | 40-50° C | |
| Voltage | 4 volts | |
| Current | 0.85 amperes/square inch | |
| Efficiency | 15% | |
| Amount deposited | 0.3234 grams per ampere hour (3600 C) | |
| Anodes | Lead or inert. | |
| **Silver** | | |
| Composition | KCN | 37 grams/liter |
| | AgCN | 25 grams/liter |
| | $K_2CO_3$ | 25 grams/liter |
| Temperature | 20-27° C | |
| Voltage | <1 volt | |
| Current | 24 milliamperes/square inch | |
| Efficiency | 100% | |
| Amount deposited | 4.025 grams per ampere hour (3600 C) | |
| Anodes | Silver: (recommended plate first with nickel) | |
| **Nickel** | | |
| Composition | $NiCl_2.6H_2O$ | 300 grams/liter |
| | Boric Acid | 30 grams/liter |
| Temperature | 60° C | |
| Current | 0.17-0.7 amperes/square inch | |
| Efficiency | 97% | |
| Amount deposited | 1.095 grams per ampere hour (3600 C) | |
| Anodes | Nickel | |
| **Copper** | | |
| Composition | $CuSO_4.5H2O$ | 300 grams/liter |
| | $H_2SO_4$ | 50 grams/liter |
| Temperature | 16-50°C | |
| Voltage | 3 volts | |
| Current | 70 milliamperes to 1.3 amperes/square inch | |
| Efficiency | 98% | |
| Amount deposited | 1.186 grams/ampere hour (3600 C) | |
| Anodes | Copper | |

tion. The anode can either be inert or made from the metal you want to deposit.

Before plating an object, you will have to make some calculations to determine control settings. The principal setting is current density—the current passing through the electrolyte per unit area of the cathode—the object you want to plate. This will be in units of amperes per inch squared This calculation can be critical because if the current is too high, the deposited metal can blister, be flaky, brittle, or spongy.

Table 1 gives values of current densities for plating four different metals. After calculating the current requirements for the object you want to plate, set this value with a 1-watt load with a value of about 1 ohm. Some electrolytes also have specified operating voltages, so monitor those while plating.

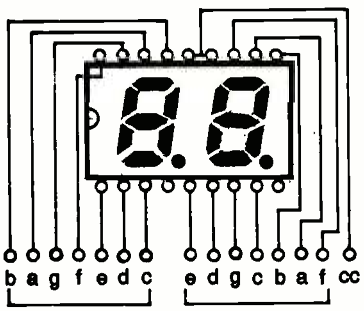
If the voltages are too high or low, the distance between the two electrodes can be altered to arrive at the correct voltage value. The larger the distance, the higher the effective resistance of the solution will be. Thus, the voltage will rise to maintain the same current. Remember that the area of the anode also affects the resistance of the solution, so try to match the surface areas of both anode and cathode.




FOIL PATTERN for main circuit board

**Electrolysis**

The relationship between coulombs passed and the robustness of the electrochemical reaction that occurs depends on the charge on the participating ions. For example, for the same value of coulombs, half as many copper atoms (Cu+2) will be deposited as silver (Ag+) atoms because copper ions need two electrons while silver ions need only one additional electron.




PARTS-PLACEMENT DIAGRAM for display board.

Remember that this discussion refers to the *number of atoms* and not the total weight deposited, because atoms have different weights. To make the controller easier to use, the scales have been normalized so that 96,500 coulombs displaces 1 mole of atoms, if they exist as individual charged ions.

The periodic table shows that silver has an atomic number of 47 and an atomic mass of 107.868, so 96,500 coulombs displaces 107.868 grams of silver. However, copper has an atomic number of 29 and an atomic mass of 63.546, so for copper with its double charged ion, the amount will be 63.5/2 or 31.7 grams.

Calculations for gas are more complex because gases do not always exist as atoms. They usually combine to form a molecule such as oxygen ($O_2-2$) or chlorine ($Cl-1$). The scale of the power supply has been normalized so that 1 mole of molecules has a volume of 24 liters (at 25°C and 760 mm pressure).The volume of a gas in the form of hydrogen ions ($H+$) released is calculated here for a known passage of charge:

96500 coulombs yields 1 mole of hydrogen atoms.

1 mole of hydrogen atoms = 1/2 mole of hydrogen molecules ($H_2$)

This represents 24/2,or 12 liters of gas.

**Precautions required.**

*Caution:* Exercise care when doing even the simplest experiments in electroplating and

*Continued on page 82*

**WAVEFORM GENERATOR**

*continued from page 46*

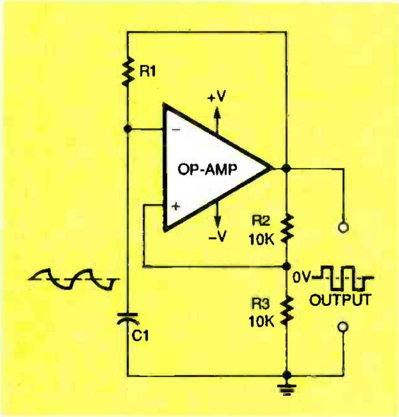



**FIG. 5—AN RELAXATION oscillator based on an op-amp.**

mined by the time constants of resistor-capacitor pairs R4-C1 and R3-C2.

These time constants will be equal if the values of C1 and C2 are equal and the values of R3 and R4 are equal. The circuit then generates symmetrical squarewaves at a frequency determined by $1/(1.4 \times R3 \times C2)$. Because of this inverse relationship, frequency can be decreased by increasing the R or C values and increased by reducing the R or C values. The multivibrator can be made variable by replacing resistors R3 and R4 with twin-ganged potentiometers in series with 10-kilohm limiting resistors.

Squarewaves can be obtained from this multivibrator at the collectors of both transistors Q1 or Q2, but these waveforms will be 180° out-of-phase. Because the leading edges of this multivibrator's output waveforms are rounded and have relatively long rise times, they are not suitable as clock pulses. Many variations of this basic multivibrator have been devised to improve its voltage range and the shape of its output waveforms.

## Op-amp generators

The operational amplifier IC will produce better squarewaves than the multivibrator. Figure 5 shows how to configure an operational amplifier as a relaxation

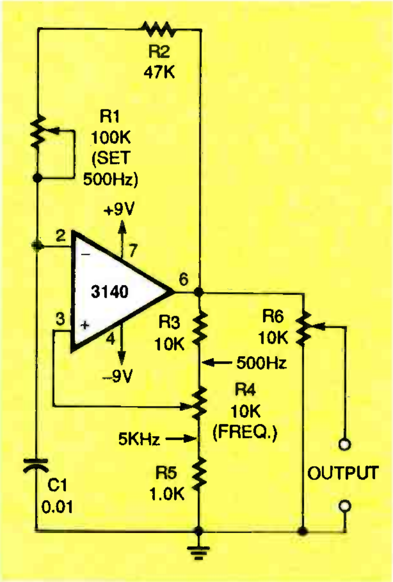



**FIG. 6—A 500-Hz TO 5-kHz OP-AMP squarewave generator.**

oscillator. This circuit's output switches alternately between the op-amp's positive and negative saturation levels. The voltage divider, formed by the junction between resistors R2 and R3, feeds back a fraction of this voltage to the op-amp's noninverting input pin, a requirement for oscillation.

Resistor R1 and capacitor C1 form a time-constant network. When the output of the op-amp is high, capacitor C1 charges through resistor R1 until its voltage reaches the positive value set by the R2-R3 voltage divider. Then comparator action occurs, and the op-amp's output is switched negative regeneratively. This causes C1 to discharge through R1 until its voltage falls to the negative value set by the R2-R3 divider.

The op-amp's output switches positive again, and the sequence repeats, generating a symmetrical squarewave at the output of the op-amp and a triangle waveform across capacitor C1. This response will continue as long as power is applied to the circuit. The Harris Semiconductor CA3140 operational amplifier IC is a ±15-volt, BiMOS, 4-MHz device.

It has fast rise and fall times and produces a more sharply defined waveform than commodity op amps. Its operating frequency can be varied by changing the values of either R2 or C1, or by altering the ratio of R2 with respect to R3.

Figure 6 is the schematic of a squarewave generator based on the CA3140. Its external components were selected to generate squarewaves from 500 Hz to 5 kHz. These frequency changes

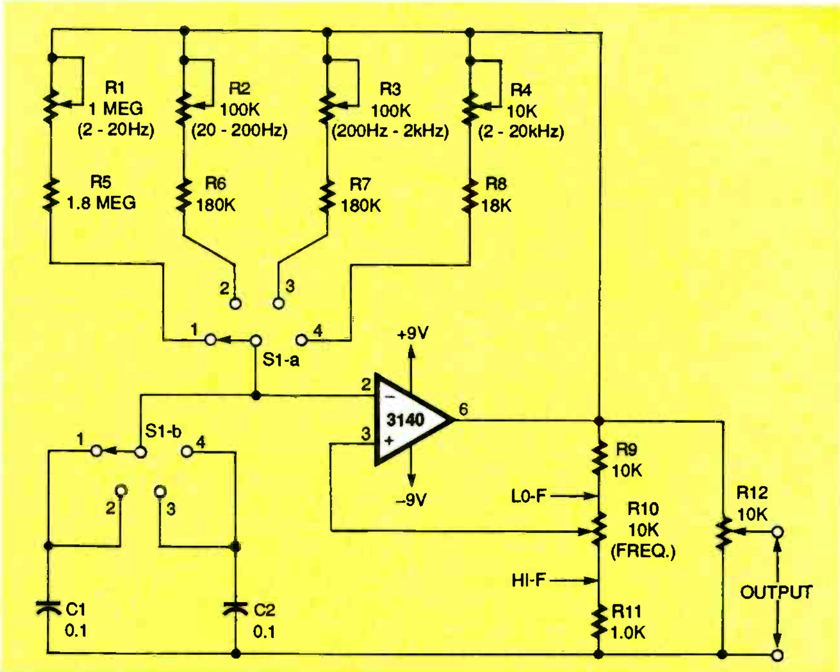



**FIG. 7—A GENERAL-PURPOSE FOUR-decade 2 Hz to 20 kHz op-amp squarewave generator.**

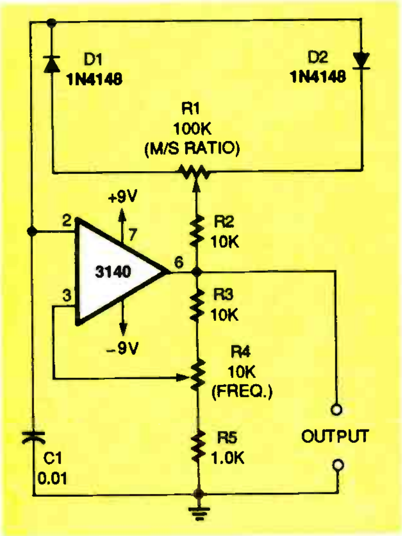



**FIG. 8—THIS SQUAREWAVE GENERATOR offers a variable duty cycle and frequency.**

can be made by altering the attenuation ratio set by resistor R3, potentiometer R1, and resistor R5. Adjusting potentiometer R1 will preset the range of FREQUENCY control potentiometer R4, while potentiometer R6 provides for output amplitude control.

Figure 7 is a modification of the Fig. 6 circuit that converts it to a general-purpose squarewave generator which spans 2 Hz to 20 kHz in four ranges. Potentiometers R1 to R4 permit the precise setting of each of the four channels within overall frequency range when preset. The four ranges are 2 Hz to 20 Hz, 20 Hz to 200 Hz, 200 Hz to 2 kHz, and 2 kHz to 20 kHz.

In the relaxation oscillator circuit of Fig. 5, capacitor C1 alternately charges and discharges through resistor R1, and the circuit generates symmetrical squarewaves. However, the same circuit can produce a variable asymmetrical waveform by modifying it, as shown in Fig. 8. Capacitor C1 now has alternate charge and discharge paths through diodes D1 and D2.

The output waveform of the Fig. 8 circuit has a variable duty cycle, and its frequency can be varied from 650 Hz to 6.5 kHz by adjusting *frequency* potentiometer R4. Capacitor C1 alternately charges through R2, the left end of potentiometer R1, and diode D1, and it discharges through R2, the right end of R1, and diode D2. This produces a waveform whose output symmetry is variable. However, adjustments of potentiometer R1 will have a negligible effect on the waveform's frequency.

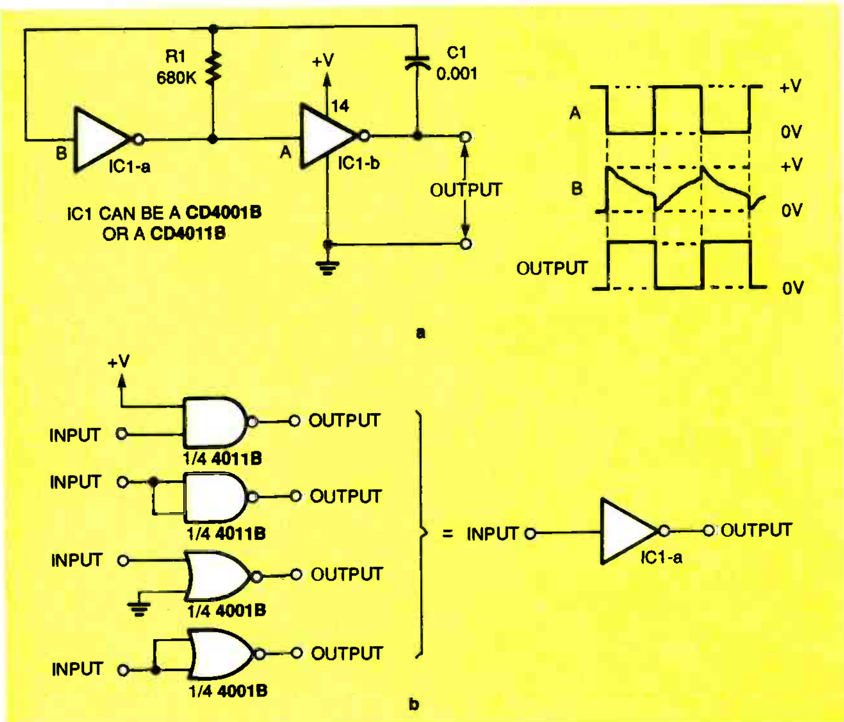



**FIG. 9—A TWO-STAGE, 1-kHz CMOS astable multivibrator and its waveforms (a), and the alternative two-input NAND and NOR gates that can function as stages (b).**

## CMOS astable generators

Squarewaves can also be produced with CMOS NOR and NAND gates. These are available ready-made in CMOS CD4001B quad 2-input NOR gate or CD4011UB quad 2-input NAND gate ICs. Figure 9-a shows an astable multivibrator circuit consisting of two gates connected to function as inverters.

Quality squarewaves can be obtained from IC1-b, and lower quality squarewaves, 180° out-of-phase, can be obtained from IC1-a. This circuit runs at about 1 kHz with the component values shown, and its output squarewaves are suitable for some clock applications. The circuit operates as follows:

The two inverters are in series, and the time-constant network R1-C1 is positioned so that the signal at the junction of R1-C1 is fed back to the input of IC1-a, and R1-C1 forms a closed loop around IC1-b. If C1 is initially fully discharged and the output of IC1-b has just switched high, the R1-C1 junction is positive. This condition drives the output of IC1-a low, but the voltage decays exponentially as C1 charges through R1.

Eventually the voltage falls into the linear transfer voltage

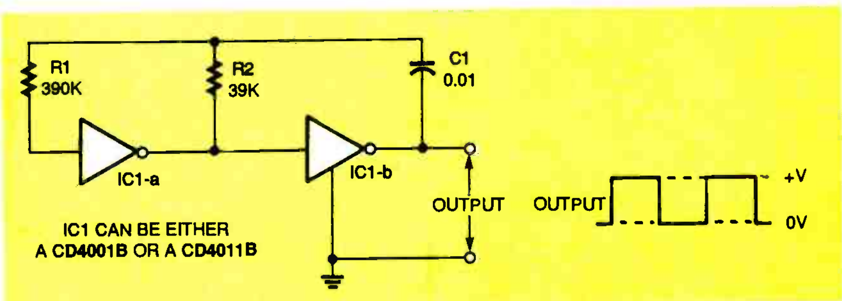



**FIG. 10—A COMPENSATED VERSION of the 1-kHz astable multivibrator (Fig. 9-a) offers improved frequency stability.**

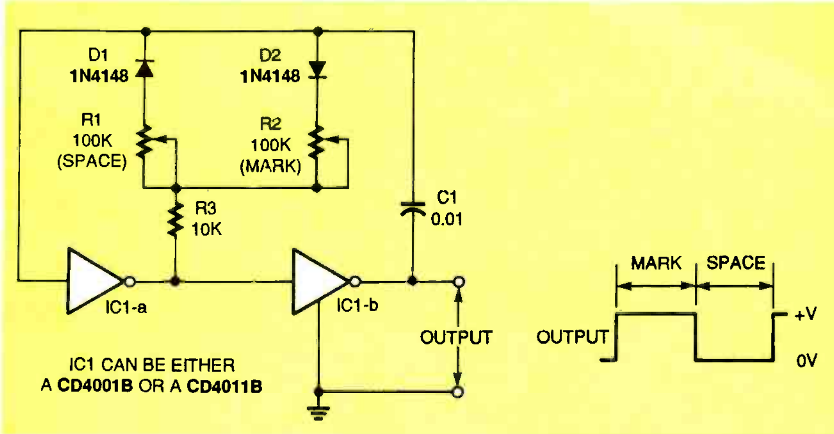



**FIG. 11—THIS CMOS ASTABLE MULTIVIBRATOR offers variable pulse width and period times.**

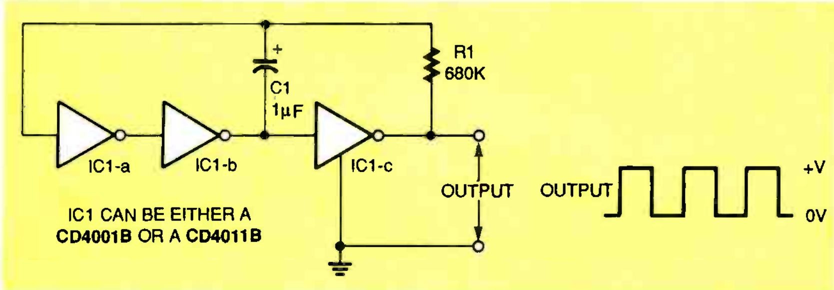



**FIG 12—THIS RING-OF-THREE astable multivibrator can generate precise clock pulses.**

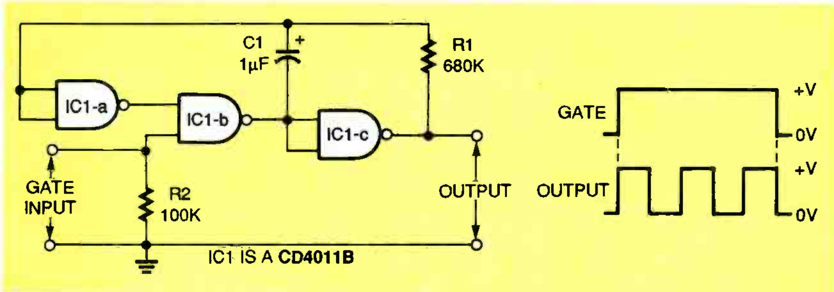



**FIG. 13—THIS GATED RING OF THREE astable multivibrator is gated by a logic1 input, and it has a normally-low output.**

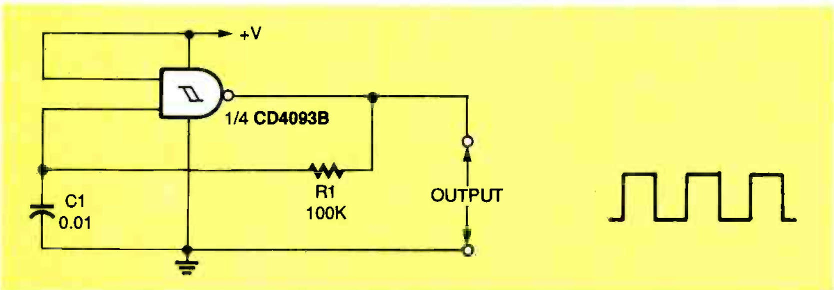



**FIG. 14—AN ASTABLE MULTIVIBRATOR based on a CMOS Schmitt trigger gate.**

range of IC1-a, causing its output to swing high. Regenerative feedback causes the output of IC1-b to switch abruptly to a low state. Simultaneously, the output of IC1-a switches high. This response causes the charge on C1 to apply a negative voltage to the input of IC1-a. However, IC1-a's built-in input protection diodes prevent this, and they discharge C1 instead.

Consequently, at the start of the second cycle, C1 is again fully discharged, so the R1-C1 junction is initially at zero volts. This drives the output of IC1-a high. The voltage then rises exponentially as C1 charges up through R1. Eventually it reaches the linear transfer voltage range of IC1-a, triggering another regenerative switching response in which the output of IC1-b again switches high, and the output of IC1-a switches low. Capacitor C1 is again discharged through the input protection diodes of IC1-a. This sequence will continue as long as power is applied to the ICs.

This circuit's operating frequency is inversely proportional to the R-C time constant. The period can be determined approximately by multiplying the time constant by 1.4. Increasing or decreasing the values of either C1 or R1 will vary the output frequency. Capacitor C1 must be nonpolarized, and its value can vary from a few tens of picofarads to several microfarads. Moreover, resistor R1 can vary from 4.7 kilohms to 22 megohms. The astable oscillation frequency can vary from a fraction of 1 Hz to about 1 Mhz. To obtain variable-frequency operation, substitute a fixed and a variable resistor in series for R1.

The inverting circuits in Fig. 9-a circuit can be either single NOR gates (from a CD4001B) or single NAND gates (from a CD4011UB). The possibilities are shown in Fig. 9-b. The inputs of all unused gates in these ICs must be tied to either the power supply or ground pins. The CMOS circuits can be powered from any 3- to 15-volt DC source. Connect the zero-volt wire to the $V_{ss}$ pin 7 of either the CD4001B or CD4011UB, and connect +V pin to the $V_{DD}$ pin 14, common to both devices.

Connect the output of the astable multivibrator in Fig. 9-a between the zero and positive supply values. The R1-C1 junction voltage will not swing below zero or above the positive supply value because of the built-in clamping diodes at the input of

IC1-a. The presence of these diodes makes the operating frequency dependent on the supply voltage.

An approximate 10% rise in supply voltage causes about a 0.8 % decrease in frequency. The waveform's frequency and symmetry are also influenced by the transfer voltage value of the individual IC1-a inverter/gate. (The actual frequency can vary by as much as 10% between the different brands of those ICs.)

## Circuit modifications

Some of the limitations of the Fig. 9 circuit can be minimized by compensating the NOR or NAND gates as shown in Fig. 10. Place resistor R2 in series with the input of IC1-a. The value of R2 should be about ten times that of R1.

The principal function of R2 is to allow the R1-C1 junction to swing freely below the zero and above the positive supply voltage to improve the circuit's frequency stability and waveform symmetery. If R2 has a value ten times that of R1, frequency will change only about 0.5% when the supply voltage changes from 5 to 15 volts.

Several other interesting modifications can be made to the basic and compensated astable multivibrator circuits of Figs. 9-a and 10. Figure 11 shows the basic circuit modified to give a variable-symmetry output. In this circuit, capacitor C1 charges through diode D2, potentiometer R2, and resistor R3 to generate the pulse width or mark of the waveform. However, C1 discharges through diode D1, potentiometer R1 and resistor R3 to set the space period or period minus the pulse width.

Although the two-stage astable circuit is a satisfactory general-purpose squarewave generator, its output does not make a suitable clock generator for fast counting and dividing circuits. The circuit has a tendency to pick up and amplify supply-line noise during the switching stages of its operating cycle. This makes the leading and trailing edges of the squarewaves ragged.

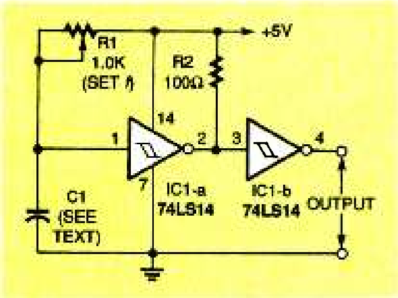



FIG. 15—A VARIABLE-FREQUENCY astable multivibrator based on TTL Schmitt trigger gates.

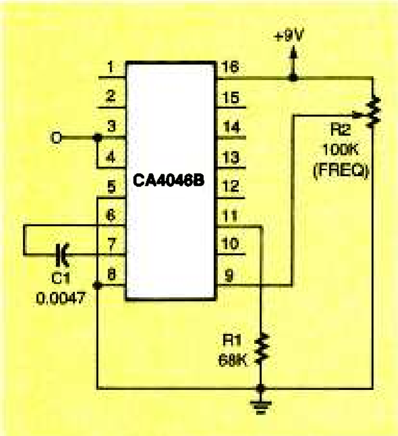



FIG. 16—THIS SQUAREWAVE GENERATOR, based on a VCO, produces 5-kHz squarewaves.

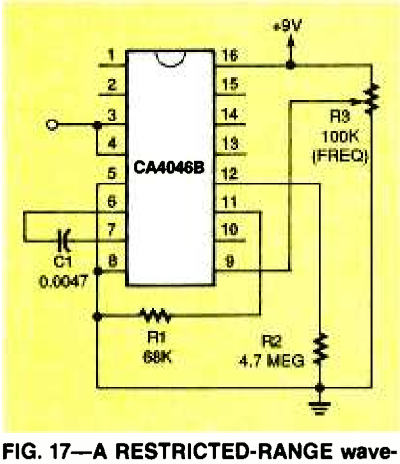



FIG. 17—A RESTRICTED-RANGE waveform generator whose waveform frequency can be varied from 72 Hz to 5 kHz.

## Ring-of-three astable

The ring-of-three astable multivibrator circuit in Fig. 12 is superior to the basic two-stage circuit in Fig. 9-a, although it is similar. The differences are that its input stage (IC1-a and IC1-b) acts as an ultra-high-gain, non-inverting amplifier, and the positions of its principal timing components R1 and C1 have been switched. Because of the very high overall gain of this circuit, it produces an excellent and glitch-free squarewave output which is ideal for clock-pulse generation.

The basic ring-of-three astable circuit can be modified in ways that are similar to the modifications of Fig. 9-a previously described. For example, the Fig. 12 circuit will work in either basic or compensated form, and it can produce either a symmetrical or nonsymmetrical output.

The most interesting variations occur, however, when the circuit is gated. This can be done with either the IC1-b or IC1-c stages. Figure 13 shows how the oscillator is gated on by a logic-1 input signal, and the circuit has a normally low vol output.

## CMOS Schmitt generators

An excellent astable clock generator can also be made from a single CMOS Schmitt inverter stage. Suitable ICs for this application include the CD40106B hex Schmitt trigger and the CD4093B quad 2-input NAND Schmitt trigger. Each Schmitt trigger NAND gate of the CD4093B becomes an inverter by disabling one of its input pins, as shown in Fig. 14.

This circuit produces a squarewave output whose edges are unaffected by supply line ripple and other electrical interference. Its operating frequency is determined by the R1-C1 values, and it can be varied from less than 1 Hz to more than 1 MHz.

The Fig. 14 circuit can be gated by an external signal if the spare pin from the positive power source is disconnected and used as the gate input pin. The astable circuit is gated on by a high (logic-1) input to this pin, but it gives a high output when it is gated off.

## TTL astable circuits

Astable squarewave generators can also be made from inexpensive TTL ICs. This can be done with the circuitry within the 74LS14 hex Schmitt trigger.

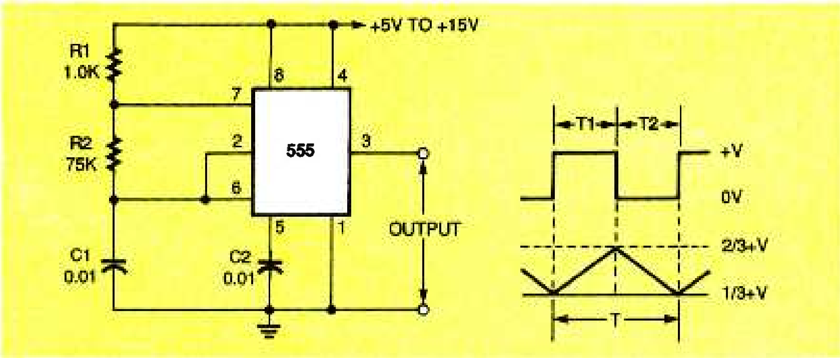



**FIG. 18—A 1-kHz ASTABLE MULTIVIBRATOR based on a 555 IC.**

Figure 15 is the schematic for a circuit that generates a clean squarewave output with a pulse width that is half of the period. A second Schmitt trigger stage provides a buffered output.

This circuit should be powered from a fixed 5-volt supply, and its timing resistance (R1 + R2) must be within the 100-ohm to 1.2- kilohm range. The circuit's frequency can be changed by R1 from about 8.2 kHz to 89 kHz, when C1 is 0.1 μF.

### VCO clock oscillators

Clock generator circuits can be made with the CD4046B CMOS micropower phase-locked loop (PLL) IC, as shown in Fig. 16. This device contains a voltage-controlled oscillator (VCO) that can produce excellent symmetrical waveforms. The VCO's upper frequency limit exceeds 1 MHz, and it offers a voltage-to-frequency linearity of about 1%. The VCO can be scanned through a million to one range if an external voltage is fed to its VCO IN pin 9.

The VCO's frequency depends on capacitor C1 (minimum value of 50 pF). It is connected between pin 6 and pin 7. Then fixed resistor R1 (minimum value of 10 kilohms) is connected between pin 11 and ground. The wiper of potentiometer R2 is connected to pin 9, and the supply voltage is applied to pin 16.

In Fig. 16, the CD4046B is organized as a VCO squarewave generator. The time constant of R1-C1 determines the circuit's maximum frequency, obtained when the voltage on pin 9 is at its maximum value, about 1 volt less than the supply voltage. Potentiometer R2 controls waveform frequency by applying a control voltage to pin 9. That frequency falls to less than 1 Hz when the control voltage is zero volts.

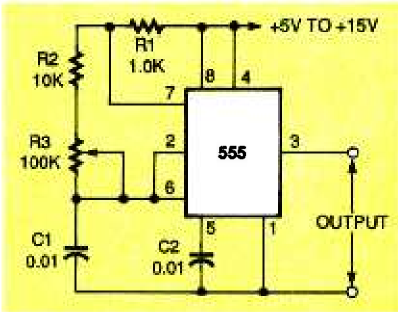



**FIG. 19—WAVEFORM FREQUENCY of this astable multivibrator can be varied from 650 Hz to 7.2 kHz.**

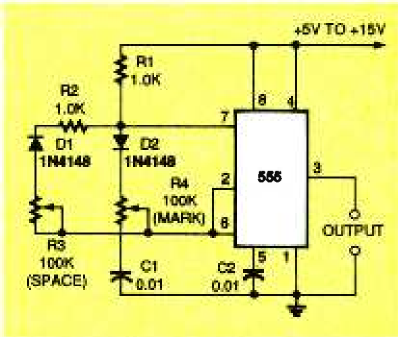



**FIG. 20—PULSE WIDTH of this astable multivibrator can be set from 7 to 750 microseconds.**

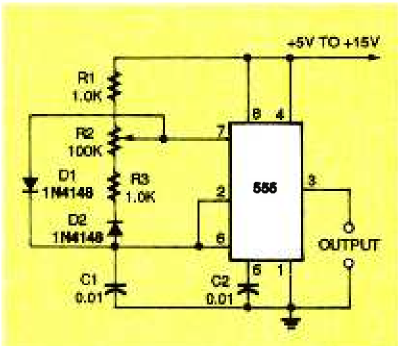



**FIG. 21—THE DUTY CYCLE of this 1.2 kHz astable multivibrator can be varied from 1% to 99%.**

The effective voltage-control range at pin-9 varies from 1 volt below the supply voltage to about 1 volt above zero. This voltage swing provides the one million to one frequency span. The supply voltage should be regulated to obtain the most accurate waveforms.

Figure 17 is a modification of the Fig. 16 to restrict the range of the VCO. Resistor R2 is connected between pin 12 and ground to set the VCO's minimum frequency, which is determined by the R2-C1 time constant. Maximum frequency is determined by C1 and the parallel resistance of R1 and R2. The frequency of the waveform can be varied from about 72 Hz to 5 kHz by setting the wiper of potentiometer R3.

### 555 astable circuits

The 555 timer IC becomes a free-running or astable multivibrator and it generates squarewaves if it is configured as shown in Fig.18. The TRIGGER pin 2 is short-circuited to THRESHOLD pin 6, and timing resistor R2 is connected between pin 6 and DISCHARGE pin 7. When power is applied to this circuit, C1 charges exponentially through the series-connected resistors R1 and R2.

When the voltage on C1 reaches two-thirds of the supply voltage, DISCHARGE pin 7 is switched low, discharging C1 exponentially through R2. When the voltage on C1 voltage falls to one-third of the supply voltage, a new timing sequence is initiated. Capacitor C1 recharges to two-thirds of the supply voltage through R1 and R2, and the sequence repeats as long as power is applied.

If resistor R2 has a significantly larger value than R1, oscillating frequency is determined principally by the R2-C1 time constant. A nearly symmetrical squarewave is developed on pin 3, and a nearly linear triangle wave appears across C1. The values of R1 and R2 can be varied from 1 kilohm to tens of megohms. The circuit's power drain is influenced by the value of R1 because pin 7 is effectively grounded during each half cycle.

With the values of the components shown in Fig. 18, the pulse widths of T1 and T2 are approximately equal to $0.7 \times R2 \times C1$. Thus the period is about $1.4 \times R2 \times C1$. The output frequency (the reciprocal of the period) is equal to $0.72/(R2 \times C1)$.

Figure 19 modifies the circuit to permit the frequency to be varied by replacing resistor R2 with a 10-kilohm resistor (R2) and a 100-kilohm potentiometer (R3) in series. With the component values shown, the frequency can be varied from about 650 Hz to 7.2 kHz with R3. The circuit's range can be increased by selecting alternative values for C1.

**Duty cycle control**

In each operating cycle of the Fig. 18 circuit, capacitor C1 alternately charges through R1 and R2, but discharges only through R2. Thus, the circuit can generate nonsymmetrical waves with duty cycles determined by the resistor values.

Figure 20 is the schematic for an astable multivibrator whose duty cycle can be controlled. Capacitor C1 alternately charges through resistor R1, diode D1 and potentiometer R4, and it discharges through potentiometer R3, diode D2, and resistor R2. Resistor R2 protects the 555 against damage if the resistance of R3 is reduced to zero.

Figure 21 illustrates a way to alter the duty cycle of the astable multivibrator without changing its frequency. Capacitor C1 alternately charges through resistor R1, diode D1 and the upper half of potentiometer R2, and it discharges through diode D2, resistor R2 and the lower half of potentiometer R2. Pulse width can be increased or decreased, but each cycle period is constant. The circuit oscillates at about 1.2 kHz with the value of C1 as shown. The most important feature of this circuit is that its duty cycle can be varied from 1% to 99% by adjusting potentiometer R2. Ω

## ELECTROCHEMISTRY

*continued from page 76*

electrolysis because their byproducts can be toxic, injurious to the skin and eyes, or flammable. Perform all experiments in a well ventilated room, and wear rubber gloves and laboratory safety goggles.

The electrolysis of water releases hydrogen gas that can explode in the presence of a spark, if allowed to accumulate. Similarly, the electrolysis of sodium chloride (NaCl) releases chlorine, a poison gas.

Handle all plating solutions with care to prevent spillage or contact with the skin. Do not work with any of the solutions containing silver or chromium ions unless you have had laboratory experience in handling them. The silver solution is extremely toxic because it contains cyanide.

This electrolyte should never be allowed to come in contact with an acid because hydrogen cyanide will be formed. The chromium solution is not only corrosive, but it is also a powerful oxidizing agent that can cause ignition if it contacts flammable materials.

After completing all electrolysis experiments or electroplating, return all chemicals to appropriate glass or plastic containers that can be closed securely for storage. Most of the electrolytes mentioned in Table 1 must be purchased from chemical supply houses. However, you might be able to purchase copper sulfate and boric acid at your local drug store, and sulfuric acid can be obtained from hardware or automotive supply stores.

Chemical suppliers who sell their products to schools and colleges might let you buy some of these chemicals in small quantities, but many are restricted by law for valid reasons. The metal anodes can be made from relatively pure scrap metal. For example, strips of copper roofing material and silver wire can be used. But avoid any metal alloys that you suspect might contain metal contaminants. Ω

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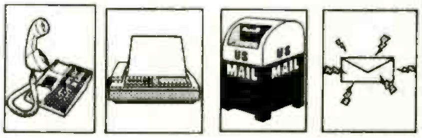


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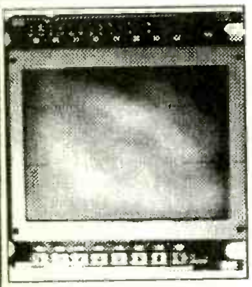

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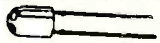

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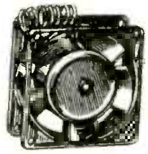

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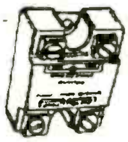

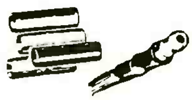

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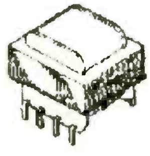
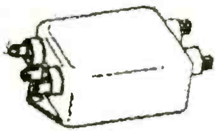
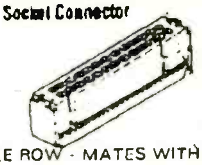


**CURTIS INDUSTRIES #F1200AA20**
10 AMP 250VAC - 20AMP 115VAC
50/60HZ - SIZE: 2"W X 2 ½"L X 1 ½"H
.250" QUICK Connect terminals for line & LOAD. Brand new factory Boxed
**BRIGAR SALE PRICE ...... $3.50**



**.100" IDC SOCKET CONNECTORS**
Socket Connector



DOUBLE ROW - MATES WITH 2 ROWS .025" HEADERS SQ. PIN S OF .100" CENTER MALE

| PART# | CONTACTS | PRICE |
|---|---|---|
| 812-7022-101 | 10 PIN | 25¢ |
| CW 220-16-003 | 16 PIN | 28¢ |
| 812-2022-101 | 20 PIN | 30¢ |

**5 - 9W DC/DC CONVERTERS**
- PC-MOUNTABLE
- 500 V Isolation
- PI INPUT FILTER
- Unregulated

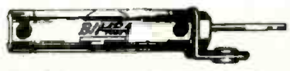
SHORT CIRCUIT PROTECTED
HIGH EFFICIENCY - 75%
OUTPUT: ±12V ±375 MA
REGULATED LINE: 1.2% LOAD 8%
REFLECTED RIPPLE: 75MA P-P
***PRICE... $6.25 EA.***


**3 COND 14 AWG**
- LENGTH: 4 FEET
- COLOR: GREY
- O.D. .375"
- TYPE: SJT
- CSA APPROVED
- strip and untinned ends.

Electronic Cords

PRICE ........ $1.25 EA
Standard 3 prong molded plug.
100 Pcs. For $1.00 EA

**BINBA #D-35849-A-1.5**
**BORE 7/16" STROKE 1/12"**
OVERALL CYLINDER LENGTH: 4 1/2"
ROD DIA: 3/16" THREADED END 10-32
RETRACTED LENGTH: 3/4" SINGLE ACTING. NOSE END MOUNTED
250 PSI - SPRING RETURN
PRICE............ **$ 8.95**

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# Quality Reconditioned Test Equipment

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Synthesizer/ Function Generator, 1 μHz to 21 MHz, wideband sweeper, programmable, 11 digit resolution. Has opt 002, high voltage output.
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## Hewlett-Packard 334A
Distortion Analyzer, 5 Hz to 600 kHz range, measures total harmonic distortion down to 0.1 % full-scale. Residual noise below 25 μV. Voltage measurement over a range 300 μV to 300 V rms full scale.
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Makes carrier measurements to 32.5 MHz, voice channel measurements from 50 Hz to 100 kHz, can use the 3336B Level Generator as an automatic tracking generator. Opt 004. Like new condition.
**$850.00**

## Hewlett-Packard 3336B Synthesizer/ Level Generator
Frequency coverage is from 10 Hz to 21 MHz, making the 3336B useful for telephone circuit loop testing on most FDM systems. Includes opt 005. Like new.
**$850.00**

## Hewlett-Packard 54100D
Digitizing Oscilloscope, 1 GHz bw, 350 ps risetime, 100 ps/div time base, 40 ms/sec max digitizing rate, pre-trigger viewing, logic triggering, includes (3) HP 54002A 50Ω BNC input pods.
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## Hewlett-Packard 5335A
Universal Counter, 200 MHz, automatic rise time, duty cycle, pulse width, slew rate and phase measurements, automatic triggering.
**Special $1250.00**

## Hewlett-Packard 1725A
275 MHz portable Oscilloscope, 10 mV/ div to 5V/div vertical deflection factor, 10 nS max sweep rate, expandable to 1 nS/ div. Includes 2 probes.
**$625.00**

## Hewlett-Packard 1725A/034
As above, opt 034 adds DMM which measures voltage, current and resistance. Includes 2 probes.
**$675.00**

## Tektronix 475A DM44 Oscilloscope
250 MHz bw, dual channel, 5 mV/ div sensitivity, 1nS/ div sweep rate. With differential-time/ DMM option. Includes 2 probes.
**$975.00**

## HP 5345A/ 5355A/ 5356B
Frequency Counter, 500 MHz direct counting, 20 mV sensitivity dc to 500 MHz,. Has frequency converter plug-in and frequency converter head.
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## Hewlett-Packard 8012B
Pulse Generator, 50 MHz, variable transition times down to 5 ns, ± 10V amplitude; selectable source impedance, ideal for testing TTL.
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## Tektronix 492 Spectrum Analyzer
50 kHz to 21 GHz, 80 dB dynamic range, amplitude comparison in 0.25 dB steps. Options 01, 02.
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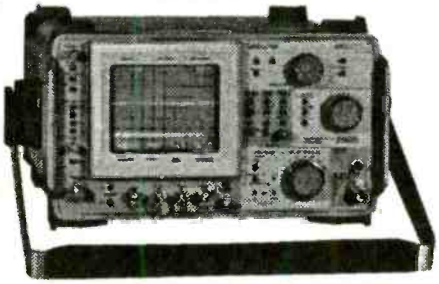

## Tektronix 492 Opt 01, 02, 03
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## Hewlett-Packard 11667A
Power Splitter, dc to 18 GHz. Opt 001, New boxed.
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## Wavetek 3520
Signal Generator, 1 to 2080 MHz frequency range,GPIB programmability, 32 complete front-panel stored settings, non-volatile memory, programmable internal modulation source.
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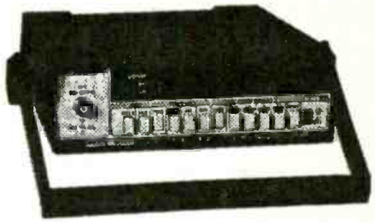
## Fluke 1900A
Multifunction Counter, 5 Hz to 80 MHz, provides frequency, period, period averaging and totalize measurements, 6 digit display, 1 MHz low-pass filter.



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## Anritsu ML422B
Selective Level Meter, 50 Hz to 30 MHz, providing highly accurate measurements of signal levels, with the stability of frequency needed to manufacture, install and maintain FDM systems.. Functions as a wideband level meter, psophometer or voice band analyzer.
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## Tektronix 454 Oscilloscope
DC to 150 MHz, 5 mV/ div sensitivity, dual trace, .05 μs to 5s/ div timebase plus sweep delay circuit.
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## Tektronix 2336 Oscilloscope
100 MHz field service oscilloscope, 5 mV/ div to 5 V/ div, 5 ns/ div sweep rate, delta time on the flip top cover.
**$1250.00**

## Tektronix 7834 Oscilloscope
Storage Oscilloscope mainframe, 2500 c/μs stored writing speed, dc to 400 MHz bw, multimode storage. Includes (1) 7A19 amplifier, (1) 7A26 dual trace amplifier, (1) 7B85 delaying time base, & (1) 7B80 time base.
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| 6BJ7 JAN | 2.00 | 1.60 | 1.40 | 1.20 | 1.00 | .90 | .80 |
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| 6EA8 JAN PHILIPS | 2.00 | 1.60 | 1.35 | 1.15 | .95 | .80 | .70 |
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| 6L6GC JAN PHILIPS | 21.50 | 16.90 | 16.20 | 15.40 | 14.90 | | |
| 6L6WGB JAN PHILIPS | 13.90 | 13.30 | 12.80 | 12.30 | 11.80 | 11.50 | 10.90 |
| 6SJ7 JAN GE METAL | 1.40 | 1.15 | .95 | .85 | .75 | .70 | .65 |
| 6SL7WGT JAN PHILIPS | 5.90 | 5.50 | 4.90 | 4.40 | 3.90 | 3.60 | 3.30 |
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| 6X5WGT JAN PHILIPS | 1.90 | 1.50 | 1.35 | 1.20 | 1.05 | 1.00 | .95 |
| 12AT7WC JAN GE | 6.15 | 4.90 | 4.40 | 3.90 | 3.50 | | |
| 12AU6 JAN PHILIPS | 1.90 | 1.50 | 1.25 | 1.00 | .90 | .80 | .70 |
| 12AX7WA JAN GE | 9.65 | 7.70 | 6.50 | 5.90 | 5.40 | 4.90 | 4.50 |
| 12AX7WA JAN PHILIPS | 9.65 | 7.70 | 6.50 | 5.90 | 5.40 | 4.90 | 4.50 |
| 12SG7 JAN RCA | 1.00 | .80 | .70 | .60 | .50 | .40 | .35 |
| 12SH7 JAN GE | 1.00 | .80 | .70 | .60 | .50 | .40 | .35 |
| 12SJ7 JAN | 1.25 | 1.00 | .90 | .80 | .70 | .60 | .55 |
| 12SL7JAN GE | 1.25 | 1.00 | .90 | .80 | .70 | | |
| 83 JAN GTE | 8.75 | 7.00 | 6.40 | 5.80 | 5.50 | | |
| 829B JAN CETRON | 8.55 | 6.85 | 6.25 | 5.65 | 5.35 | 4.75 | 4.50 |
| 5656 JAN RAYTHEON | 7.50 | 6.00 | 5.00 | 4.20 | 3.30 | 2.50 | 2.20 |
| 5751 JAN GE | 4.50 | 4.30 | 4.10 | 3.80 | 3.50 | | |
| 5814a JAN PHILIPS | 3.75 | 3.00 | 2.75 | 2.50 | 2.20 | 2.00 | 1.90 |
| 6072a JanGE - MIL 12AY7 | 8.90 | 7.70 | 6.50 | 5.90 | 5.40 | 4.90 | 4.50 |
| 6080WC JAN GE | 6.15 | 4.90 | 4.40 | 3.90 | 3.40 | 2.90 | 2.60 |
| 6188 JAN PHIL = MIL 6SL7 | 11.15 | 8.90 | 7.90 | 6.40 | 5.90 | 5.60 | 5.30 |
| 6189W JAN PHILIPS | 3.75 | 3.00 | 2.75 | 2.50 | 2.20 | 2.00 | 1.90 |
| 6922 JAN PHILIPS | 4.25 | 3.40 | 2.80 | 2.10 | 1.90 | 1.65 | 1.45 |
| 7581a JAN PHILIPS | 19.50 | 18.00 | 17.25 | 16.50 | 15.75 | | |

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## The Complete, Low Cost, Circuit Design System

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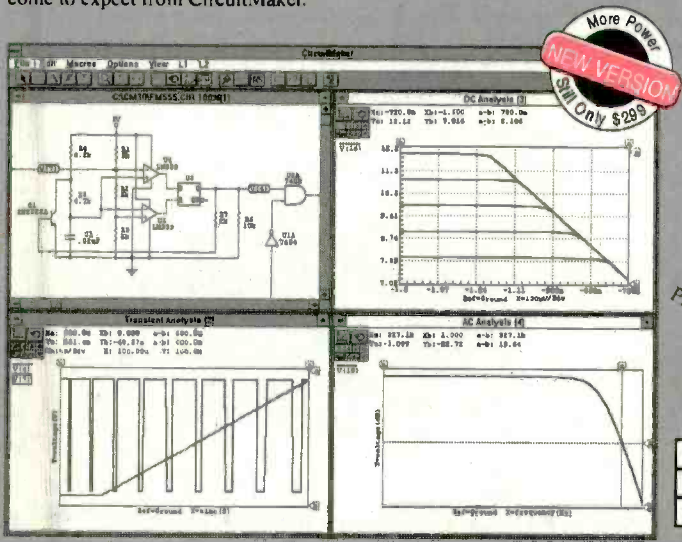


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| | Schematic Capture | Professional Schematic Features | Digital, Analog, and Mixed-Mode Simulation | 1000+ Devices/Models | SPICE Export/Import | PCB Export | Retail Price |
|---|---|---|---|---|---|---|---|
| CircuitMaker | YES | YES | YES | YES | YES | YES | $299 |
| Electronics Workbench version 4 | YES | NO | YES | NO | NO | NO | $299 |
| Electronics Workbench Engineer's Pack | YES | NO | YES | YES | YES | YES | $599 |

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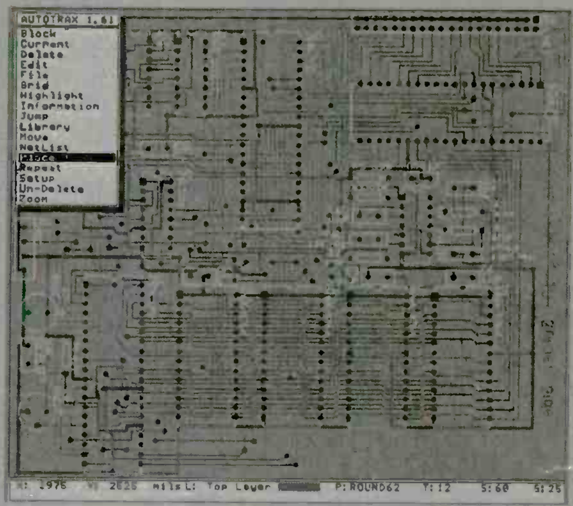


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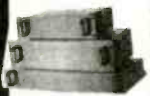

| | | |
|---|---|---|
| LG-1273 | 3x12x7" | $ 26.50 |
| LG-1684 | 4x16x8" | 32.50 |
| LG-1924 | 4x19x11½" | 38.25 |
| LG-1925 | 5x19x11½" | 42.00 |
| LG-1983 | 2¼x19x8" | 35.25 |
| LG-1923 | 3x19x11½" | 36.50 |
| LG-1927 | 7x19x11½" | 50.50 |

LG- Black anodized rack cabinet

New

| | | |
|---|---|---|
| *LL-1923B | 2¾x19x12" | 69.50 |
| *LL-1925A | 5x19x12" | 79.50 |

*LL- High quality full Aluminum Cabinet
*LL- Front panel .157" & other panels .078"

- Dimensions in inches ±.05
- Custom-made for other dimensions if over 100 pcs for single model !

### Modular Desktop Consoles

| | L x W x H | |
|---|---|---|
| LE-453 | 4x4¾x3" | $ 7.50 |
| LE-653 | 6x4¾x3" | 9.75 |
| LE-853 | 8x4¾x3" | 11.75 |

LE- Black finished aluminum panel 1mm thick.

### Camera Housing

| | | |
|---|---|---|
| *LD-1244 | 2¾x10¾x4" | $55.00 |
| **LD-1516 | 3¾x13¾x4" | 29.50 |
| **LD-1565 | 4x13¾x5¼" | 31.75 |

*LD- Stainless Steel 0.7mm
**LD- Sheet Metal 1mm

### Alarm Box with Lock

Mejor Compra !

| | | |
|---|---|---|
| LB-1085 | 8¼x10¼x5" | $18.75 |
| LB-1395 | 9¼x13¼x5" | 25.50 |
| LB-1525 | 12¼x15¼x5" | 35.25 |
| *LB-1494 | 9¼x14¼x4¼" | 21.50 |
| LB-1383A | 8½x13¼x4" | 23.25 |

*No lock & LB- Sheet Metal 0.8mm

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| | | | |
|---|---|---|---|
| 001 | 28/30V x 2 | 6A | $ 30.00 |
| 002 | 36V x 2 | 3A | 25.00 |
| 003 | 40V x 2 | 6A | 32.00 |
| **008 | 28/30V x 2 | 6A | 40.00 |
| **009 | 48/53V x 2 | 8A | 66.00 |
| **012 | 33/40/42Vx2 | 6A | 48.00 |

### TA-800MK2 ▲▲ 120+120W Pre & Main Stereo Amp. (4 lbs.)

Kit:$ 67.92
Asmb.$ 86.95

Power Output:120W into 4 ohms RMS. 72W into 8 ohms RMS. Frequency Response:10-20KHZ. THD: <0.01%. Tone Control: Bass ±12dB, Mid & Treble ±8dB. Sensitivity: Phono Input, 3mV into 47K. Line, 0.3V into 47K. Signal to Noise Ratio: 86dB. Power Requirement: 40VDC @ 6A. Suggested Mark V model 001 or 008 transformer. Recommended Metal Cabinet LG-1924.

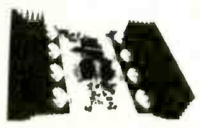
### TY-13 ▲ 20 Color LED Level Meter

Clearance Sale

Kit:$ ~~20.15~~ $ 9.90

Use this dual LED display indicating meter with your stereo power amplifier to indicate instantaneous speaker power. Operating range is -30dB to +5dB and can be calibrated to operate with 1 to 200 watt amplifiers. Not consume any amplifier power. A peak LED illuminates on overload!

### AF-3 ▲▲▲ 300W MOSFET High Power Mono Amp. (7 lbs.)



Kit:$ 165.00 Asmb.$ 195.00

Power Output: 300W into 4 ohms RMS. 200W into 8 ohms RMS. Frequency Response: 10HZ-20KHZ. THD: <0.03%. Signal to noise ratio: 91dB. Input Sensitivity & Impedance at 1KHZ, 1V 47K. Load Impedance 4-16 ohms. Power Requirement: ±55 to ±65VDC 8A. Suggested Mark V model 009 Transformer. Capacitor 10,000uf 80-100V model 016 or 019. Recommended Metal Cabinet LG-1925 for each channel.

### TR-503▲ Regulated DC Power Supply

Kit:$ 18.75 Asmb.$ 27.65

It is short circuit proof and has overload protection. Output voltage is variable over a range of 0-50V. Current limit trip is adjustable up to max of 3A. Suggested Mark V 002 transformer. (1 lb.)

### TA-388 ▲▲▲ Class A FET Dynamic Buffer Stereo Pre-Amp (1 lb.)

Best Pre-Amp

Kit:$64.00 Asmb.$ 80.00

Frequency Response (at rated output): Overall 10HZ-100KHZ +0.5dB-1dB. THD: Overall <0.007% at or below rated output level. Channel Separation (at rated output 1KHZ): Overall better than 70dB. Hum & Noise: Overall better than 90dB. Input Sensitivity (1KHZ for rated output): 300-600mV. Maximum Output Level: Pre-Amp output 1.8V (0.1% THD). Power Requirement: 30V X 2 AC 500mA.

### SM-302▲▲ 60+60W Stereo Power Amp

Kit:$ 75.00
Asmb.$ 94.00

It provides 3 input jack pairs. One pair accept a high impedance microphone. The two remaining pairs are for high & low level input sources. Power Output: 60W per channel into 4 ohms RMS. 20HZ-20KHZ. THD:<0.1%. Input Sensitivity: Mic/Guitar 10mV,Hi 380mV,Lo 640mV. Ready to plug in when assembled. (11 lbs.)

### SM-100 ▲▲▲ 150 MHZ 8 Digit Frequency Counter (2 lbs.)

Sale

Kit:$ ~~79.00~~ $ 65.00
Asmb.$ 99.00

Frequency Range: 10HZ-150MHZ. Gate Time: 0.01s, 0.1s, 1s, 10s. Input Sensitivity: KHZ range 10HZ-10MHZ 20mV(min.). MHZ range 1MHZ-120MHZ 20mV(min.), 120MHZ-150MHZ 35mV (min.), 150MHZ-200MHZ 40mV(typical). Time Base: 10MHZ crystal, ±10 ppm. Input Impedance: 1M ohm. Response Time: 0.2s. Resolution: 0.1 HZ: 10s gate time, 1HZ: 1s gate time, 10HZ: 0.1s gate time, 100 HZ: 0.01s gate time. Hold the last input signal. Reset counter to 0. DC 9V power adapter or 1.5VX4"D"size batteries.(Adapter not included)

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| | | |
|---|---|---|
| SM-36 | Dynamic Noise Reduction ▲ | $ 26.00 |
| TA-006 | 6W Mini-Amplifier ▲ | 9.50 |
| TA-28 | Digital Voice Memo ▲▲ | 25.00 |
| TA-120 | 36W Class A Power Amp. ▲▲ | 32.50 |
| TA-201 | Mircophone Mixer Mono Amp.▲ | 20.79 |
| TY-45 | 20 Bar/Dot Level Display ▲▲ | 38.25 |
| TY-2 | Flourescent Light Driver ▲ | 14.75 |

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CIRCLE 301 ON FREE INFORMATION CARD

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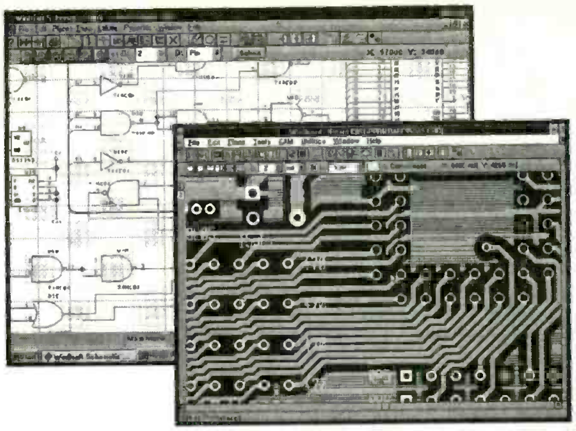

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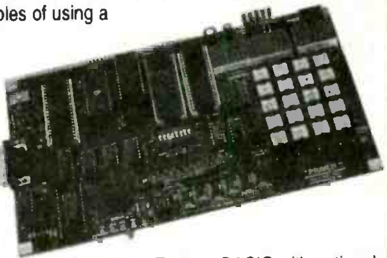

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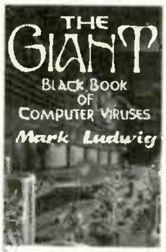


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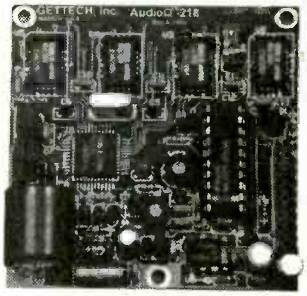

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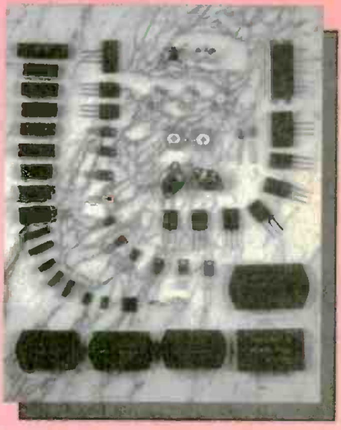

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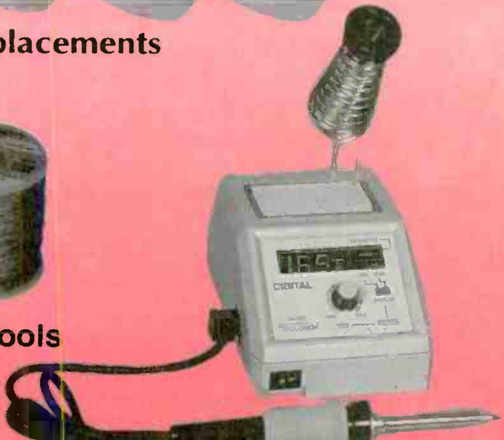

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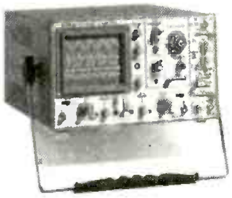

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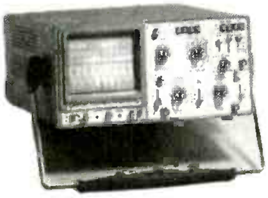

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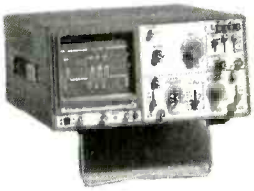

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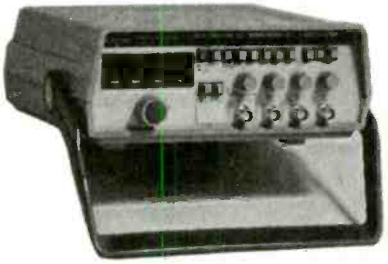

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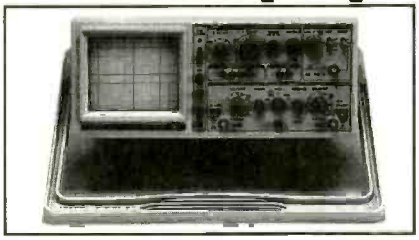

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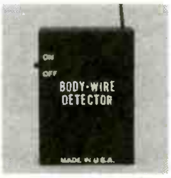


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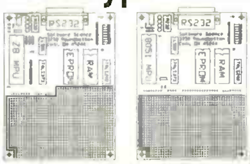


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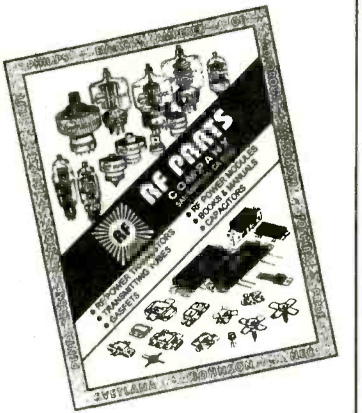


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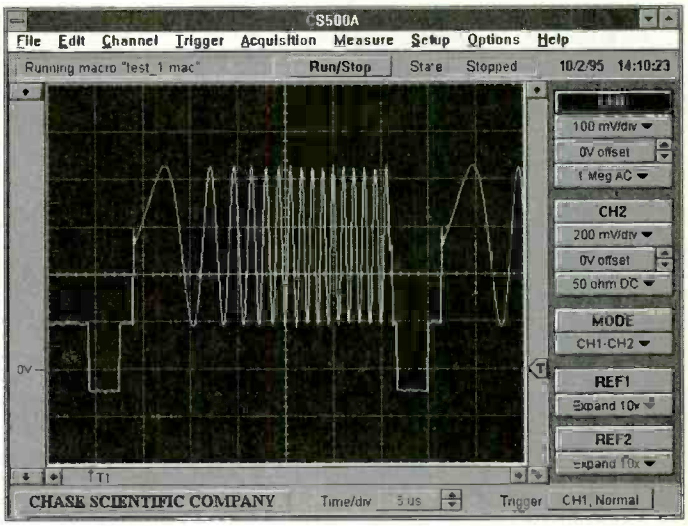


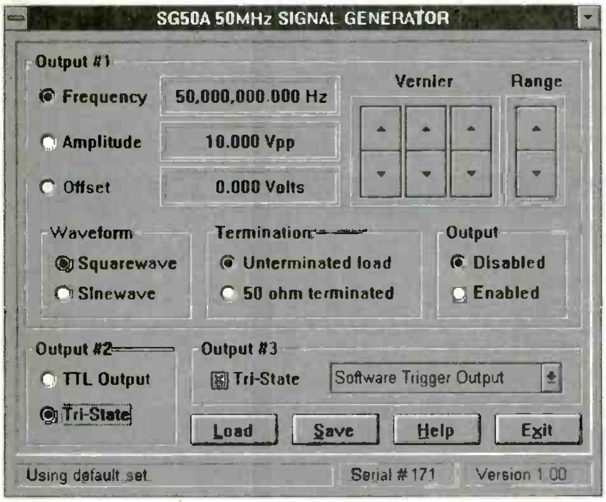


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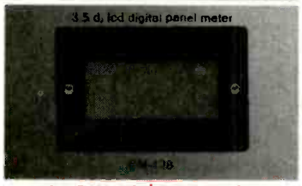


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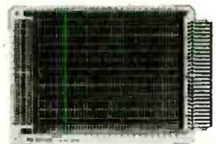

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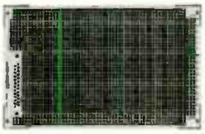

- Board Length: 6-5/16" (160mm)
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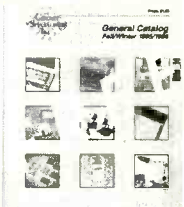


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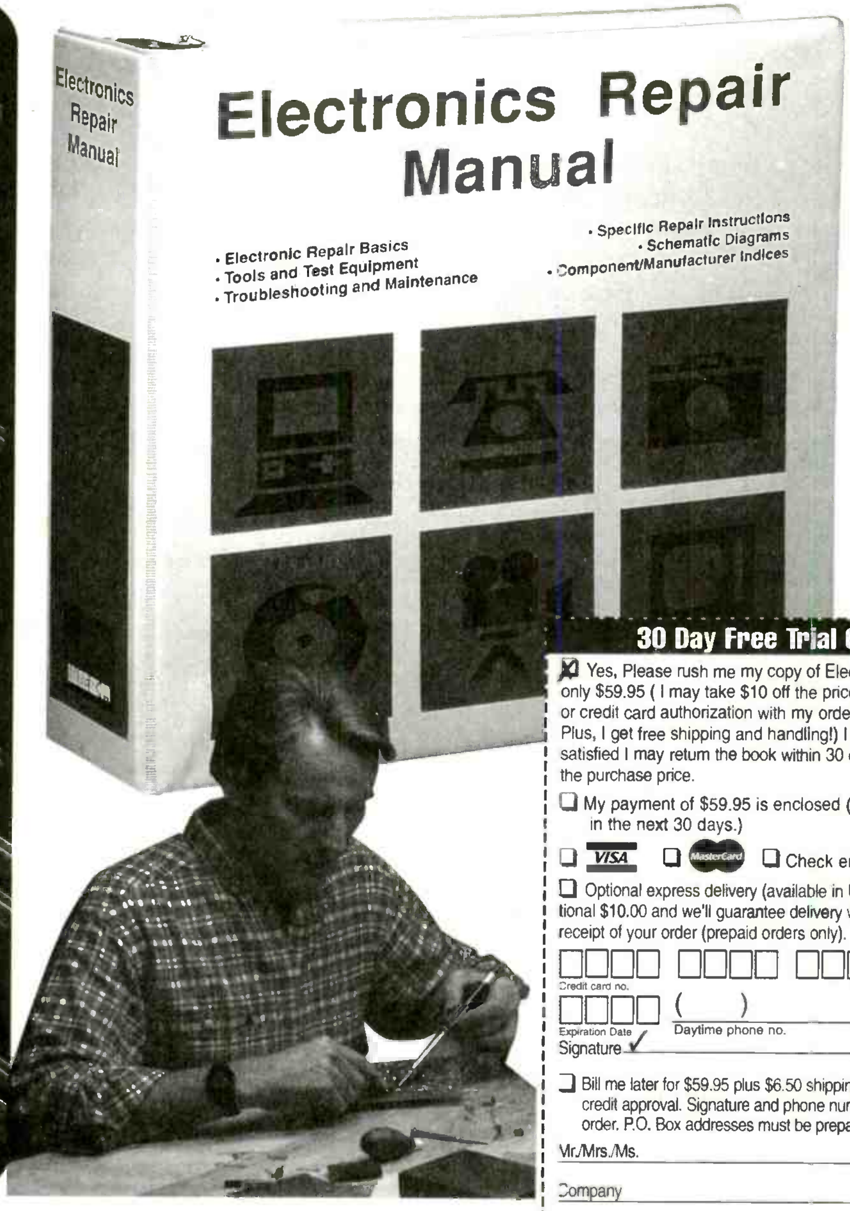


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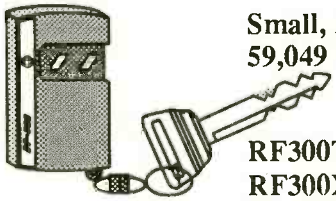

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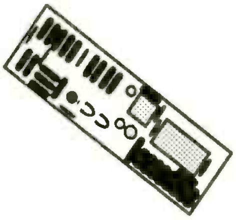

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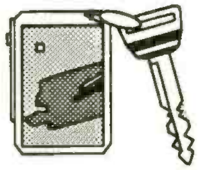

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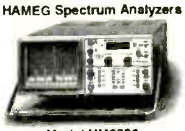

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HP 8406A Comb Gen.,1/10/100 MHz increment .......... $450.00
HP 8444A-opt059 Tracking Generator, 0.5-1500 MHz .......... $1,500.00
HP 8552B IF Section .......... $750.00
HP 8553B RF Section, 1 kHz-110 MHz .......... $500.00
HP 8554B RF Section, 0.1-1250 MHz .......... $800.00
HP 8555A RF Section, 0.01-18 GHz .......... $950.00
HP 8555A System, with 8552B & 141T .......... $2,375.00
TEK TR503 Tracking Generator, 0.1-1800 MHz .......... $1,750.00
HP 11665B Modulator, 0.15-18.0 GHz .......... $375.00
HP 8405A Vector Voltmeter, 1-1000 MHz .......... $700.00
HP 85021A Directional Bridge, 0.01-18 GHz .......... $1,200.00
NARDA 7000A Microwave Multimeter, 0.1-18 GHz .......... $1,950.00
BOONTON 1020 Synth. Sig. Gen., 0.15-540 MHz .......... $1,850.00
BOONTON 102C Signal Generator, Sig. Gen., 0.15-540 MHz .......... $850.00
FLUKE 6060A/AN Synthesizer, 10 kHz-520 MHz .......... $2,000.00
FLUKE 6060B-488 Signal Gen., 10 kHz-1050 MHz .......... $3,750.00
GIGATRONICS 875/86 Levelled Multiplier, Ka & V band .......... $8,000.00
HP 85100V Freq. Multiplier, 50-75 GHz out .......... $4,250.00

HP 8654A Signal Gen., 10-520 MHz .......... $625.00
HP 8660C Synthesizer, with 86603A &86633B .......... $4,500.00
WILTRON 6742A-opt.01 Synth. Sig./Swp. Gen., 18-40 GHz .......... $9,000.00
HP 8620C Sweep Oscillator Frame .......... $550.00
HP 8620C-opt011 Sweep Oscillator Frame, HPIB .......... $675.00
HP 86222B-opt.2 RF Plug-in, 10-2400 MHz, atten. .......... $1,950.00
HP 86290B RF Plug-in, 2.0-18.6 GHz, +10dBm .......... $2,000.00
WAVETEK 1067 Sweep Gen., 1-400 MHz, 75 Ohms .......... $500.00
WAVETEK 962 Sweep Generator, 1-4 GHz .......... $2,000.00
BOONTON 42B/41-4B Power Meter, 1 MHz-12.4 GHz .......... $475.00
BOONTON 42B/41-4E Power Meter, 1 MHz-18 GHz .......... $650.00
BOONTON 42B/42-S/3 Power Meter, 1 MHz-8 GHz .......... $375.00
HP 432A/478A Power Meter, 0.01-10 GHz .......... $375.00
HP 435A/8481A Power Meter, 10 MHz-18 GHz,100mW .......... $1,000.00
HP 435A/8482A Power Meter, 0.1-4200 MHz, 100mW .......... $1,000.00
HP 435A/8482H Power Meter, 0.1-4200 MHz, 3 W .......... $1,150.00
HP 435A/8484A Power Meter, 10 MHz-18 GHz, 10uW .......... $1,000.00
HP K486A WR42 Thermistor Mount, 18-26.5 G .......... $400.00
HP Q8486A WR22 Power Sensor, 33.0-50.0 GHz .......... $1,500.00
HP R486A WR28 Thermistor Mount, 26.5-40 G .......... $400.00
WAVETEK 1034A Portable Power Meter,0.001-18GHz .......... $375.00
AILTECH 7618E Noise Source, 15 dB, 0.01-18 GHz .......... $500.00
BOONTON 82AD Modulation Meter, 10-1300 MHz .......... $1,000.00
HP 8447A-001 Dual Amplifier, 0.1-400 MHz .......... $500.00
M.S.C. MC5112 Noise Source, 25.5 dB, 1-12 GHz .......... $325.00

## COAXIAL & WAVEGUIDE

BIRD 8325-30 30 dB Atten., 500 W, DC-500 MHz .......... $325.00
HP 11691D Dir. Coupler, 22 dB, 2-18 GHz .......... $500.00
HP 11692D Dual Dir. Coupler,22 dB,2-18 GHz .......... $900.00
HP 33330D Detector, 10 MHz-33 GHz, APC3.5 .......... $275.00
HP 764D Dual Dir. Coupler, 215-450 MHz .......... $150.00
HP 778D-opt.011 Dual Dir. Coupler,20 dB,0.1-2GHz .......... $400.00
HP 779D Dir. Coupler,20 dB, 1.7-12.4 GHz .......... $375.00
HP 8472A Crystal Detector, 10 MHz-18 GHz .......... $150.00
HP R532A Frequency Meter, 26.5-40.0 GHz .......... $500.00
KRYTAR 202020016 Directional Detector, 2-20 GHz .......... $200.00
NARDA 26298 20 dB Atten., 150 W, DC-1 GHz .......... $175.00
NARDA 3000-SERIES Directional Couplers .......... $150.00
NARDA 3090-SERIES Precision Hi Directivity Coupler .......... $225.00
NARDA 4000-SERIES SMA Mini Directional Couplers .......... $75.00
NARDA 4203-6 Dir. Coupler, 6 dB, 2-18 GHz,SMA .......... $225.00
NARDA 5070-SERIES Precision Reflectometer Couplers .......... $300.00
NUCLEONICS AM-432 Spiral Antenna, 2-18 GHz "NEW" .......... $95.00
SPACEK LABS DQ-1 WR22 Flat Broadband Detector .......... $550.00
WEINSCHEL 3200-1 Prog. Atten., 20-127 dB, DC-2 GH .......... $200.00
WILTRON 97SF50-1 Directional Bridge, 0.01-18 GHz .......... $1,500.00

## MISCELLANEOUS

HP 28687A LAN Wire Test Instrument .......... $750.00
HP 3551A Transmission Test Set .......... $750.00
HP 4935A Transmission Test Set .......... $1,650.00
HP 59401A HPIB Bus Analyzer .......... $700.00
TEK 1411R-opt.04 PAL Test Signal Generator .......... $2,750.00
TEK 144 NTSC Test Signal Generator .......... $700.00
TEK 147A NTSC Test Signal Generator .......... $950.00
TEK 1485R Waveform Monitor, NTSC & PAL .......... $1,850.00
TEK 521A PAL Vectorscope .......... $1,500.00
HP 59307A HPIB VHF Switch .......... $200.00
P.A.R. 5206 Lock-In Amplifier, 2 Hz-200 kHz .......... $3,000.00

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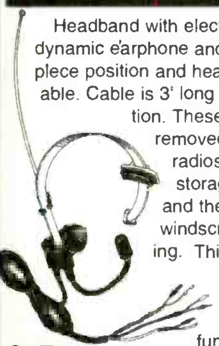
## COMMUNICATION HEADSET w/ ANTENNA



Headband with electret microphone, dynamic earphone and antenna. Mouthpiece position and headband are adjustable. Cable is 3' long with 6 wire termination. These are new units removed from walkie-talkie radios. They have been in storage for a long time, and the foam microphone windscreens are deteriorating. This may detract from the appearance of the units, but they are unused and functional.

**CAT# PHN-8**

10 for $45.00

**$5.00 each**

## ULTRASONIC TRANSDUCER SET

Murata-Erie # MA40A3R & MA40A3S 40 Khz transmitter and receiver, matched pair. Band width: 4K hz.+. Ideal for remote control systems, burglar alarms, flow rate detectors, etc. 0.64" diameter X 0.47" high.

**CAT# UST-40**

**$2.50 per pair**

## MINI 12 VDC SOLENOID

12vdc, 54 ohm miniature solenoid. Coil mounted on U bracket. Bracket size: 0.36" x 0.43" x 0.81" long. 1.65" long plunger extends from both sides of coil. Spring return. Can be used for both push and pull action.

**$1.25 each**

10 for $10.00

**CAT # SOL-23**

## *Special Pricing* 2 CONDUCTOR LINE CORDS

**6' 18/2 WHITE**

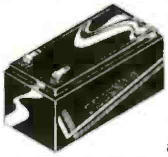
SPT-2 insulation. Polarized 2 prong plug.

**CAT # LCAC-18**

**3 for $1.20**

100 for $35.00

## *RECHARGEABLE GEL CELL* 12 VOLTS 3 A/H



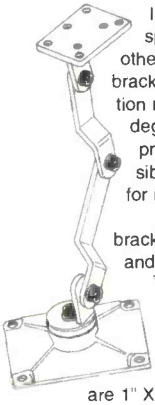
Maintenance free, rechargeable gel cell battery. An excellent back-up power source for alarms, communications equipment, lighting or computers. Can be used in any position and can be trickle charged for long periods of time. 5.3" X 2.63" X 2.39"

**CAT# S12-3**

**$15.00 each**

case of 10 - $120.00

## TILT/SWIVEL MOUNTING BRACKET



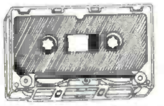
Ideal for video cameras, small speakers, video monitors and other equipment, these aluminum brackets feature locking multi-position ratchet joints and a 360 degree swivel ratchet base to provide endless mounting possibilities. Originally designed for mounting cellular phones on automobile consoles, these brackets could be used for ham and CB applications as well. The base plate is 3.55" X 1.97". The end plate is 2.08" X 1.77" and has an assortment of pre-drilled holes for various applications. Arms are 1" X 0.20" die-cast aluminum. 10" reach fully extended. Flat black.

**CAT # SMB-1**

10 for $65.00

**$7.00 each**

## C-30 AUDIO CASSETTE



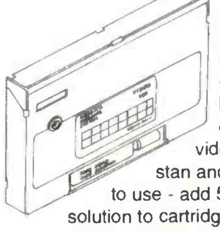
Brand-new, good-quality 30 minute (15 min. per side) audio cassettes. Excellent for demos or instruction tapes. Manufactured without record-prevent knockout tabs, so the indentations must be taped over before use.

**CAT # C-30**

**3 for $1.00**

100 for $30.00 • 500 for $125.00

## *GREAT DEAL!* VHS VIDEO HEAD CLEANER



To keep your VCR in optimum condition, use cleaning system every 20-30 hours of operation. Prevents build-up of lubricants, oxides and dirt on video/audio heads, capstan and pinch roller. Easy to use - add 5 drops of cleaning solution to cartridge, load and play as you would any video cassette. Due to a special purchase, we are offering an unusually low price on this item.

**CAT# VHS-500**

**$3.00 each**

12 for $2.75 each
48 for $2.50 each
96 for $2.25 each

LARGE QUANTITY AVAILABLE!

## 9 FOOT DUAL AUDIO CABLE

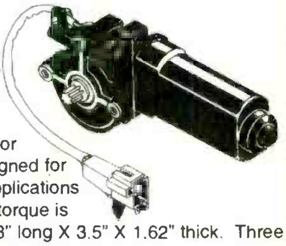
9' shielded dual audio cable with color coded (red and yellow) RCA style pin plugs either end. Black cable.

**CAT# DCB-108**

**$1.00 each**

10 for $8.50 • 100 for $75.00
1000 for $500.00

## 12 Vdc GEAR MOTOR



Denso Brand 40 RPM @ 12.6 Vdc @ 600 ma. (no load). Right-angle drive gearhead motor originally designed for automotive applications where lots of torque is required. 6.68" long X 3.5" X 1.62" thick. Three mounting holes on 1.9" and 2.6" centers.

**CAT# DCM-64**

**$17.50 each**

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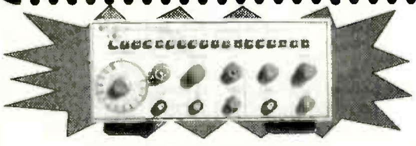
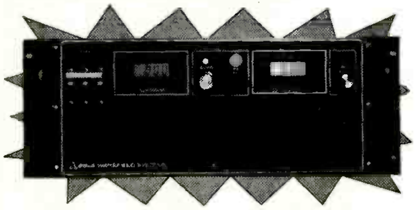


**HEWLETT PACKARD**
**HP 3312**
**SWEEP/FUNCTION GENERATOR**

Well designed and easy to use, this function generator combines economy and quality into one compact unit. Freq range is 0.1Hz-13MHz, output into 50 ohms is 10.0VP-P. Sweep-AM,FM, or tone burst. This unit features-sync. out, trig. phase, symmetry, offset and more. **Price: $935.00 ea. Fully checked.**



**"*SERIOUS*" POWER SUPPLY**
**TCR 20S135**

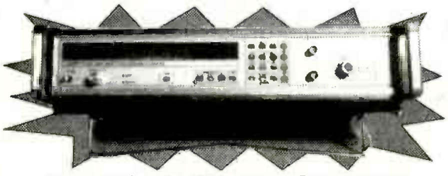
Output voltage is adjustable from 0-20V With a current limited maximum output of 135 clean DC amps. Digital LCD meters present both voltage and current along with LEDs for CC or CV operation. These units are currently wired for 220v operation but can be reconfigured for 110v operation. They're good & heavy but lightly priced **at: $895.00 Good condition.**

**ROHDE&SCHWARZ**
**SMDA 41314**
**AM/FM SIG GENERATOR**

This high performance generator operates from 0.4Mhz-484Mhz. Modes of operation are AM, FM with 12 standard mod freq's of .3-6KHz. S/N ratio typ 130 dB at 20 KHz from carrier. This unit is supplied with the BN413115 Freq-control unit (phase lock) and VOR/ILS test generator. Very nice stuff for connoisseurs of fine German made test equipment.
**Price: $995.00**

## "CLUSTER SURPLUS"

-Do you have that warm funny feeling inside? This brand new in the box Eimac 2-240 power tube does when you energize the filament with 3-4v. Classic bulb shape. **Price: $16.00**
-Canon C-mount TV zoom lens 15-150mm V10x15 F 1:2.8 **Price: $68.00**
-P.M motor designed originally to operate copiers. Voltage input is 110v ac or dc this unit runs very well at lower voltages. Great for the hobbist, they're" new" and provide lots of torque (1/4"shaft. output). **Price: $19.95**
-Switching supply 3.0"X 5.0" footprint. input is 115vac with outputs of +5vdc@4A, +12vdc@1A, -12vdc@.75A. Unused as removed from new equipment. **Price: $24.95**



## MICROWAVE FREQUENCY COUNTER
## EIP MODEL 545A

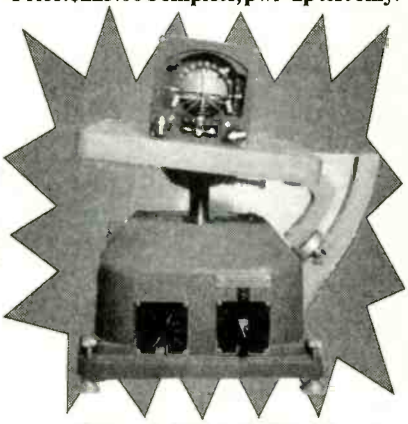
The 545A easily covers 10 Hz-18GHz frequency range with -30dbm relative sensitivity and 10 watt (+40dB) input damage protection. In addition, the 545A also measures RF power to 0.1 dB with an overall acurracy of 0.5dB.The unit comes with internal ovenized oscillator. Like-new conditon. **Price: $2295.00**

**All Prices in U.S. Dollars**
**Please include telephone/fax number with mail-in orders.**
**Orders must be prepaid by guaranteed instrument.**

***Manuals available at extra cost***

**CANADIAN MILITARY**
**"GPS" SYSTEM**

"Its a dream come true," You need NEAT STUFF cheap! This box of technology is based on the 68020 micro and packs lots of fine military technology into a green enclosure. Lots of RF & Digital circuits, plus the nicest DC-DC converter makes this a "parts bonanza" if you can't find a use for the GPS. Comes complete with 2 antennas & backlit LCD remote keypad. They light-up and do stuff.....that's all we can say!
**Price:$225.00Complete, pwr-up test only.**



**IDEAL AEROSMITH INC.**
**GYRO SCORSBY TABLE**

Model 1411BVS-30 scorsby **table** with digital speed and direction control. Features include auto reverse in the oscillate mode and nice quiet operation. The **flight director** (sitting on the table) is mfg'd by Litton Systems or Astronautics. These are great for simulators or just foolin' around. What's so great is that both axis are driven by D.C. servo motors that allows operation from a computer with slight modification for feedback.They're certainly the neatest precision instrument.
**Tilt Table Price: $1595.00**
**Flight Director Price: $ 195.00**

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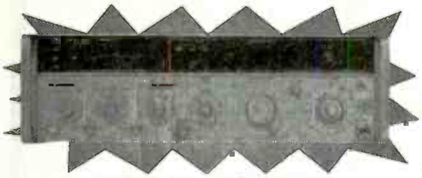
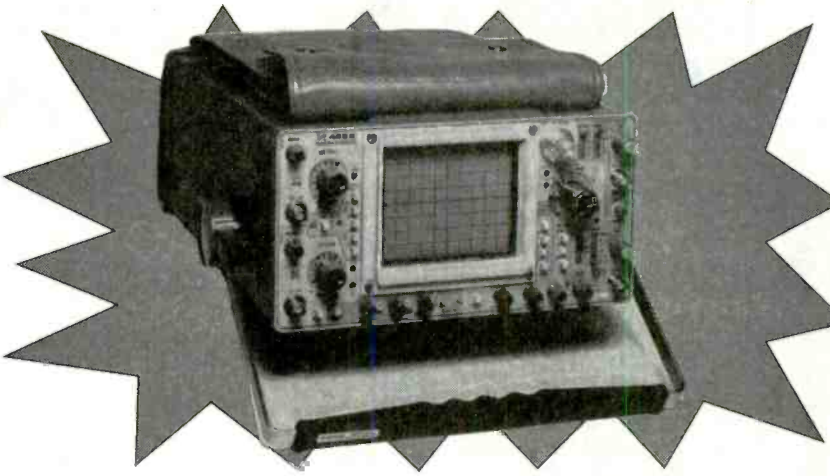


## HEWLETT PACKARD 8640B SIGNAL GENERATOR

Industry Standard sig-gen 500Khz-512Mhz features internal phase lock/synchronizer and digital freq readout. +19to -145 dBm output. AM,FM,Ext and Pulse modulation.

**Price: $2295.00 OPT 001 add $100.00**
**OPT 003 add $150.00**

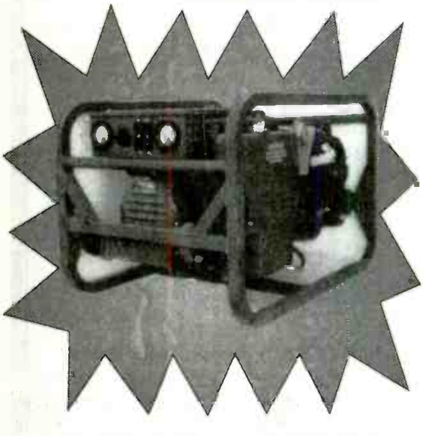


# *TEKTRONIX 465B*

Proof is in the pudding when it comes to this instrument"s track record. There's no doubt, that popularity speaks many languages when speaking of the "465B" or 465M. This excellent instrument continues the tradition of the standard 465 oscilloscope by adding useful features such as CH-1, CH-2 sum or difference, trigger view in any combination, alternate sweep and trace selection versatility. Many technicians dream of owning a quality 100-MHz oscilloscope, but funding rarely permits. Fortunately, we were recently able to acquire a limited supply of 465B-s in nearly *new* condition. Our *LOW PRICES* will likely permit "you" to own one of the best scopes anywhere in the country. If your need js current and action *swift* you too will be a member of a growing club!!!

**SELECTED EXCELLENT COND......$849.00**
**TEKTRONIX 465-M. 100MHz............$695.00**

These instruments are fully checked out. They are supplied with an original front panel cover and complete service manual. Original TEK Probes are $75.00 each with each purchase.



## MILITARY STANDARD D.C. GENERATOR

Superior QUALITY plus rugged design are features of this deluxe 2 cylinder 4 stroke gasoline generator. The control panel contains meters for voltage & current indication, main circuit breaker and voltage adjustment. Shielded wires and plugs comprise the RFI suppression ignition system eliminating most radio noise. These units are "new" in the original carton complete with operators manual and only require fuel and oil for operation; output voltage is adjustable approx. 10-32v (28v nom) @ 53.3A (1.5Kw) continuous duty load.

**Price: $345.00 New in Orig. Carton.**
**You will be impressed!!!**

## ESI MODEL 250 DA IMPEDENCE BRIDGE

Resistance range- 0.1 milliohms - 11megohms, capacitance 0.1pf-1100mf, inductance 0.1 μH to 1100 Hy. Dissipation factor (R/X or D) 0.001 to 1000. Internal oscillator 1 KHz.

**Used, not functionally checked...............$95.00**
**Functionally checked...........................$165.00**

## WAYNE KERR PRECISION INDUCTANCE BRIDGE

Microprocessor based, Crt display and programmability make this sophisticated bridge easy to use. RLC measurements can be made with a very high degree of accuracy (typ 0.1%). Call/Info.

**Price: $2750.00**

## COLLECTOR ALERT - $39.00
## 8-DAY AIRCRAFT CLOCK
## 1-7/8" dial

**Great collectors item for the ham shack, fifties vintage funct/chkd.**

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| -HP 3551A TRANSMISSION TEST SET | $ 950.00 |
| -HP 3581A WAVE ANALYZER | $1,295.00 |
| -HP 4260A LCR BRIDGE | $ 385.00 |
| -HP 4948A IN-SERVICE TIMS (brand new) | $3,995.00 |
| -HP 5006A SIGNATURE ANALYZER | $ 450.00 |
| -HP 5315AUNIVERSAL COUNTER (1 GHz) | $ 675.00 |
| -HP 54111D COLOR DIGITAL STORAGE SCOPE | $8,500.00 |
| -HP 8160A OPT-20 PROG PULSE GEN | $3,995.00 |
| -HP 8505 NETWORK ANALYZER SYSTEM | $6,000.00 |
| -HP 8558A SPECTRUM ANALYZER .01-1.5GHz | $2,750.00 |
| -HP 8559A SPEC-ANALYZER .01-22GHz | $4,995.00 |
| -HP 8640A SIGNAL GENERATOR (512MHz) | $ 995.00 |
| -TEK FG504 FUNCTION GENERATOR (40MHz) | $ 875.00 |
| -TEK 520 VECTORSCOPE | $1,200.00 |
| -TEK 1502 TDR w/CHART REC | $2,200.00 |
| -TEK 2465 300 MHz OSCILLOSCOPE | $2,750.00 |
| -ANRITSU MS420K NETWK SPEC- AN.10Hz-30MHz | $1,800.00 |
| -CROWN MODEL 7560 1KW PWR AMP. DC - 40KHz | $1,800.00 |
| -DATRON 4000A DC & OHMS CALIBRATOR | $ 4,500.00 |
| -EIP 351D 18 GHz FREQ COUNTER | $ 950.00 |
| -ENI MOD 310L 250KHz-110MHz @ 50db GAIN | $ 765.00 |
| -ENI MOD 406L 150 KHz-250MHz @ 40db GAIN | $ 850.00 |
| -GOULD 220 CHART RECORDER | $ 950.00 |
| -GOULD RS 3800 PROGRAMABLE CHART RECORDER/w MOD 5900 SIG CONDITIONER &DC AMPS (NEW) | $6,500.00 |
| -MARCONI 2018 SYNTHESIZED SIGNAL GENERATOR 80KHz - 520MHz | $1,750.00 |
| -ROHDE & SCHWARZ SIG GENERATOR .4-484MHz | $ 750.00 |
| -SCHENCK DYNAMIC BALANCING MACHINE MOD CAB570 WITH- BED , SENSORS & MANUAL | $4,500.00 |
| - EATON NM-17/27A EMI FIELD INT. METER | $1,500.00 |
| - FLUKE 5100A CALIBRATOR | $3,800.00 |
| - FLUKE 6039A FREQUENCY SYNTHESIZER | $ 500.00 |
| - BOONTON 82AD AM/FM MOD-METER | $1,275.00 |
| - BOONTON 102F SIG. GEN. 1040MHz | $1,295.00 |
| - COLLINS 651S-1 RECEIVER | $1,250.00 |
| - GRT-22 UHF POWER AMPLIFER | $ 200.00 |
| - HARRIS RF280 HF/TACTICAL TRANSCEIVER | $1,500.00 |
| - LEXEL MOD 75 HIGH POWER ARGON LASER | $1,500.00 |
| - R392 RECEIVER .5-30MHz | $ 165.00 |
| - T195 100w COMPANION XMTR TO 392 | $ 85.00 |
| - WAVETEK 3002 RF SIG. GENERATOR | $ 795.00 |
| *****ATTENTION DIVERS-GAS DRIVEN COMPRESSORS***** | |
| - BAUER 11CFM 3500 PSI COMPRESSOR SYSTEM | $3,500.00 |
| - BAUER K14 3500 PSI COMPRESSOR SYSTEM | $2,750.00 |

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## NIGHT VIEWERS

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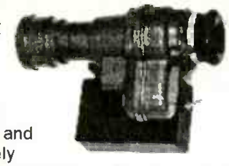

Supplied with new and completely assembled USSR made scope. The EHT power supply is supplied in kit form. Will work in extremely low light levels! Best value small night vision scope available: **$220**
Tube only from the above and EHT supply kit: **$90**

**FIBER OPTIC TUBES** Used 1st gen. 25 or 40mm (input/output window dia). With a suitable 'fast' lens give a good image in half moon light. Can be IR assisted to see in total darkness. Each tube is supplied with an 9V - EHT power supply kit:
25mm tube **$90**, 40mm tube **$120**
We also have blemished versions of these tubes (not in central viewing area). Satisfaction guaranteed! Both sizes (please specify) & EHT kit **$35**

**INTENSIFIED NIGHT VIEWER KIT** See in the dark! Make your own night scope with good vision in sub-starlight illumination! We supply a 3-stage fiber optically coupled image intensifier tube *and* an EHT power supply kit, lens and eyepiece. 25mm **$270**, 40mm **$360**

**IR TUBE AND SUPPLY** A tube and supply combination that can be used as the basis of making a very sensitive IR responsive viewer. Typical sensitivity 0.01 lux. Tube and supply kit **$80**

## GEIGER COUNTER

Ready made Geiger counter detects dangerous Beta and Gamma rays. Plug-in probe, can be extended with cable, computer interface (serial), visual and audible indication of detected particles. **$52**

## KITS and BITS

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**LASER BEAM COMMUNICATOR KIT:** Tx, Rx, plus IR laser: **$39**
**PLASMA BALL KIT:** PCB and components, needs a light bulb: **$18**
**SLAVE FLASH TRIGGER:** Triggers a second flash unit by picking up light from camera mounted flash: **$5.50**
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**PC DRIVEN ELECTROCARDIOGRAM:** Silk screened/solder masked PCB only and 3.5" disk with instructions. Uses common components: **$8**

**HIGH POWER IR LEDs** 880nm 12º 30mW @ 100mA **10 for $6**
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## CCD CAMERA-VCR SECURITY SYSTEM

Ready made PIR detector module and learning IR remote control combination sets any IR remote controlled VCR to *RECORD* activity within a 6m range and 180º view. Starts recording at first movement and stops a few minutes after the last movement. Just like commercial systems costing $1000's!! No connection needed to your VCR. PIR detector, control kit, IR learning remote control and instructions **$70**

**TINY PCB CCD CAMERA** Mono, with auto iris lens, 0.1 lux, IR responsive, can be used in total darkness. 1.8 x 3.75 x 1 inch, weight 1.4 oz. Can be connected to video-in of a standard monitor or VCR. **$99**

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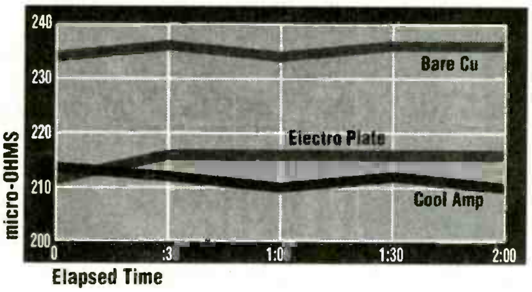
## Cool-Amp

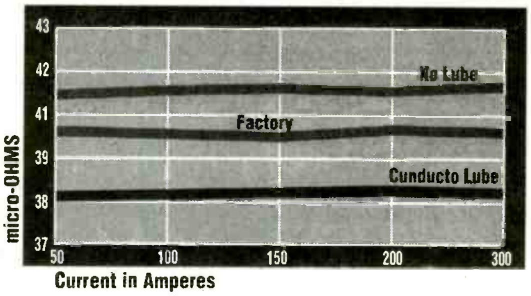



### From the report:

"...compare the conducting properties of Cool-Amp silver plating compound with factory silver elctro-plated bus and bare copper bus.

"The test results indicated that the contact resistance of the Cool-Amp plated bus connection was slightly lower than that of the electro-plated bus connection and much lower than that of the bare copper bus connection. The final temperature at temperature equilibrium of the bus connection employing Cool-Amp was slightly lower than that of the electro-plated bus connection and the bare copper bus connection..."

## Conducto-Lube




### From the report:

"...compare the conducting properties of Conducto-Lube lubricant with factory lubrication and non-lubricated connections on an air switch. Identical test setups and procedures were used for each test so that comparative data could be collected and the relative performance of each type of connection could be quantified.

"The test results indicated that the contact resistance of the switch employing Conducto-Lube was generally lower than that of the factory lubricated switch and the switch that used no lubricant."

### Cool-Amp How it works:

- Applies *on the job.* Application is simple. Yet Cool-Amp adheres permanently. As tests show, it is better than electroplating.
- Minimizes overheating and power loss by silver plating high amperage connections.
- Saves time, reduces maintenance. Cool-Amp is so simple to apply on the job. It assures maximum conductivity for copper, brass, or bronze contacts and prevents losses due to oxidation.

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Conductivity is demonstrated by inserting test prongs into a container of Conducto-Lube and establishing a circuit. Photo shows low voltage (115 VAC) continuity through container.

### Conducto-Lube How it works:

- This is *the* conductive lubricant; highly conductive because it contains pure silver.
- Originally developed to lubricate switches, to the point tension can be adjusted to factory specs allowing full rated capacity of the switch to be maintained at all times.
- Uses have continued to expland–from switches and breakers–to any application where a conductive lubricant is needed.

*Various tests were performed on both products in the Electro-Test, Inc. facilities in Portland, Oregon during January-March, 1994. Evaluation of plating thickness of Cool-Amp was performed by Surface Science Laboratories of Mountain View, California.

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**Mike Murphy - Service Center Co - Van Nuys CA**
The single best investment of repair equipment we've made. It outperforms all other desoldering tools we've used. Easier to use and least expensive.

**Bob Monroe - M.A.R.C. Electronics - Virginia Beach VA**
Best investment we've made. Saves time, especially with multi-sided PCB's. Extremely pleased with warranty. Failed within 6 months and replaced by DEN-ON overnight.

**Dick Manning - Dicks Electronics - Hartland WI**
The ease & speed of component removal greatly increases productive time. The SMD kit makes SMD removal a breeze, even for inexperienced Techs.

**Dave Hayes - E-H Engineering Ltd - Lincoln NE**
Has been a durable & reliable desoldering unit. Our use has been both lab & field application over the last 2 yrs. with positive results.

**Bob Sorrels CET/CSM Polytronics Microcomputer - Shreveport LA**
We've used our SC7000 almost every day for about three years with virtually no problems. Just clean it before you turn it off for the day.

**George Hefner - Hefner Electronics - Coleridge NE**
Being a one-men service center, I hesitated to spend the money on a desoldering tool, however all that changed when I nearly ruined a $400 computer logic board. I use the SC7000 daily. It has cut my desoldering time by 50 to 75%.

**Steven Gray - Electronic Wizards - Wichita KS**
By far the best desoldering tool we've ever used. Much more suction than other similar types we've tried. No trouble with postage stamp IC's or anything else.

**Dennis McMannis - Thorn Services International - Mabelton GA**
The SC7000 has decreased my use of wick by 75% and at $25 a roll, it pays for itself within months. My total bench time is reduced by approx. 20%.

**Don Cressin - Certified Electronics Serv ice - Ellicott City MD**
We have obtained excellent results with the SC7000 including repairing high density U/V tuners. It is one of the best purchases we have made.

**Doug Pettit - LuRay Electronics - LuRay VA**
We found that the SC7000 not only saves money vs. wick, but saves valuable time in troubleshooting. It allows you to be more accurate in removing SMD's.

**Paul Horvat - Service Excellence Inc. - Dumont NJ**
It has made a almost impossible job (desoldering a 64 pin CPU) a piece of cake. Glad I found you.

**Harold Smedberg - Smedberg Electronics - Custer MI**
The SC7000 has reduced my damage to PC boards by 90%. It has also decreased my desoldering time by 50%. The best priced tool on the market.

**Tom Mullett - JC Penny TD&S - Wausatose WI**
The SC7000 is a very easy to use, self-contained desoldering tool. We had a 70% increase in production after the purchase of the SC7000. I highly recommend it.

**Paul Reindorf CET - Osage Comm. - Santa Fe NM**
This tool has paid for itself over & over again. I don't know how we ever did without it.

**Randy Whitehead - Service West - Salt Lake City UT**
My techs thought it would be a waste. I bought one anyway after a demo. My techs then fought over it. Now we have three. It is the Best desoldering tool we have ever used.

**Timothy Kraft - Monikraft, Inc. - Cherry Hill NJ**
We replaced all our existing desoldering stations with the SC7000. Our technicians are very pleased with the improved performance, portability, and reliability over our previous higher priced equipment.

**Mike Metsikas - RGB Services - Philadelphia PA**
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**Bill Warren CET/CSM - Warrens Audio & Video - Knoxville TN**
We have been extremely satisfied with the quality and durability of the DEN-ON SC7000 as well as with after the sale support.

**David Dumber - Video Tech Center, Inc. - Belair MD**
The compact design of the SC7000 boast optimum efficiency. I wouldn't trade it's performance for any system at even twice the price.

**Keith Sahs - J & M Electronics - Omaha NE** It's a must tool for my bench. I can desolder multiple pin IC's quickly and clean. It will even take up large solder amounts on tuner and case grounds.

**Ray Wurmnest - Ray's Electronics, Inc. - Bloomington IL**
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**Don Multerer CET - Sencore - Sioux Falls SD**
Good Techs love good tools - light weight, fast, easy to use. I use it to build electronic trainers where parts are removed and circuits modified.

**Gale Halloway - Gale T.V., Inc. - Virgina Beach VA**
Desoldering has never been easier. We use the SC7000 Desoldering Tool daily. We are fully satisfied with this product.

**A.L. Hurdle CET - Corapeake NC** The first time I used the SC7000 was on a 64 pin DIP. After removing the solder from the last pin of the IC, it just fell off the board. Highly recommended.

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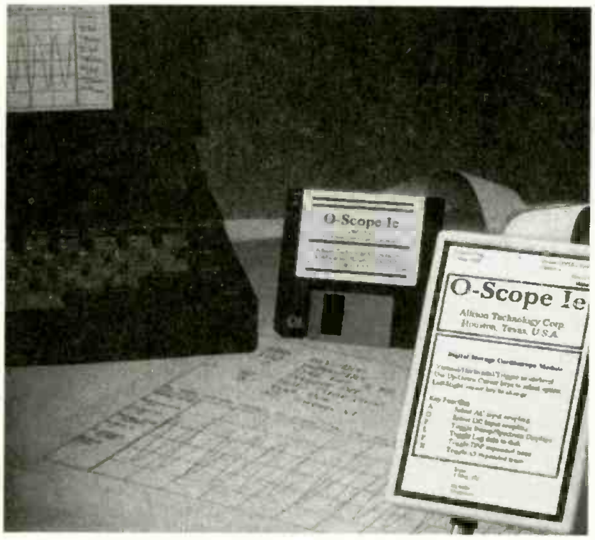


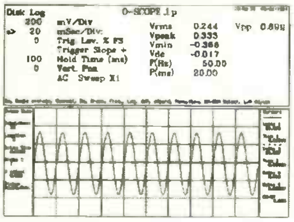


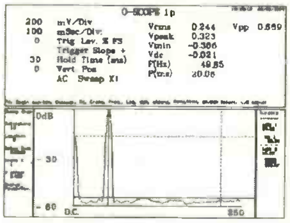


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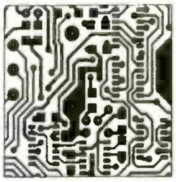

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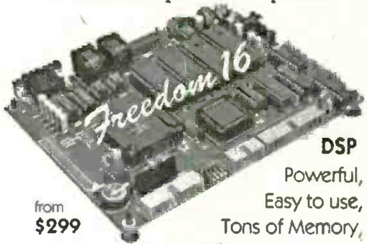


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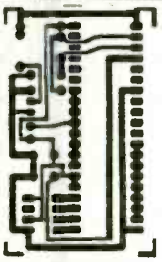

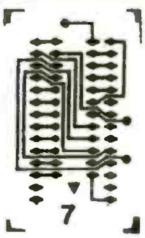


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