CYBERSPACE: CASHLESS SOCIETY FINDS A HOME

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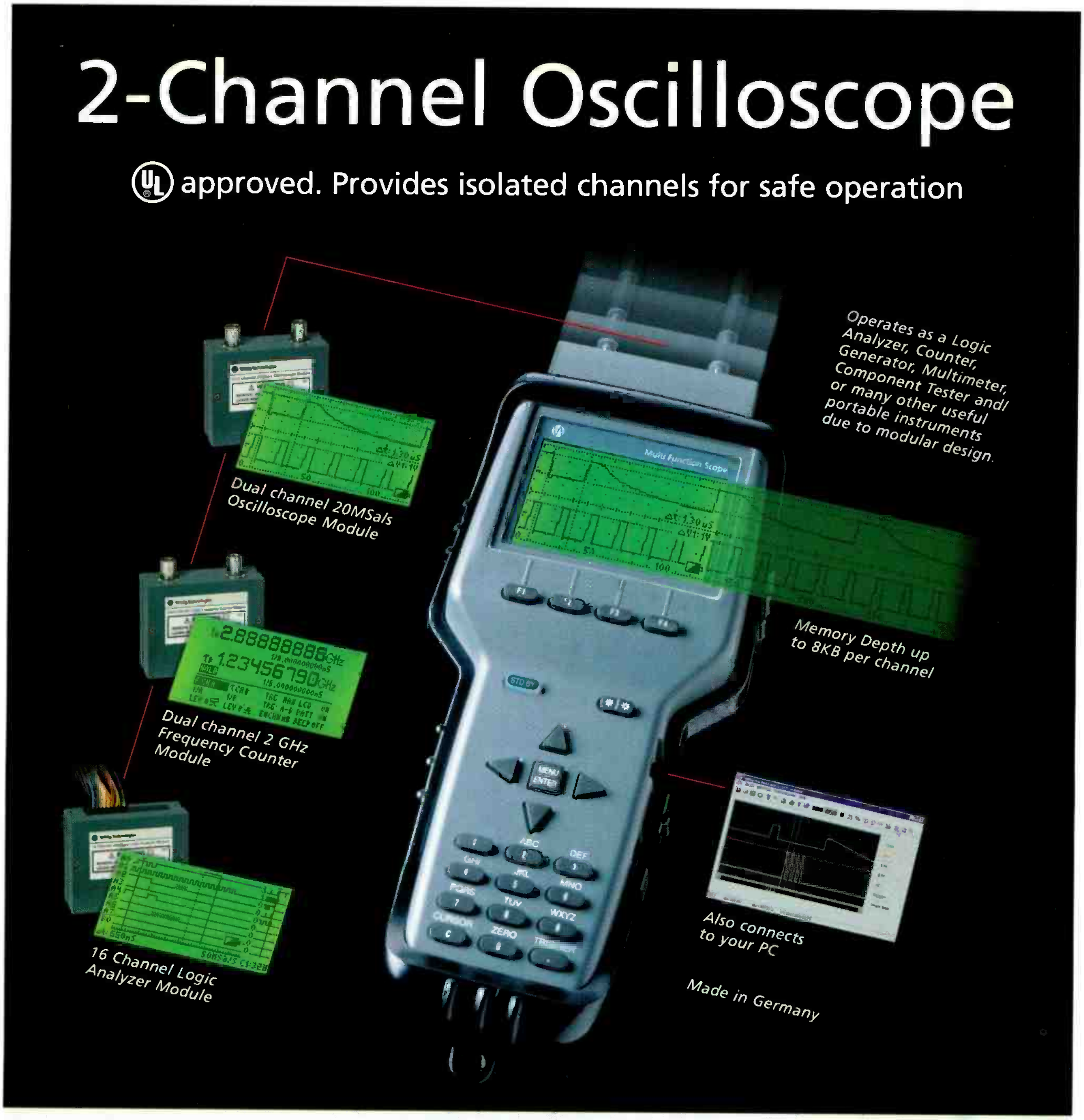

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Electronics Now

July 2001, Vol. 2, No. 7

Popular Electronics®

Poptronics®

THE MAGAZINE FOR THE HANDS-ON ELECTRONICS ACTIVIST!

FEATURES

PRODUCT REVIEWS

DEPARTMENTS

AND MORE

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Editorial

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Cybernetics!

Technology can be scary. Recently, there has been much debate over the ethics involved in genetic engineering and cybernetics—electronic implants—and whether their use should be strictly governed. Scientists proclaim that their research will give sight to the blind and cure paralysis, but CyberPunk fans are smiling to themselves. They all know that it is only a matter of time before cybernetics and genetic engineering will hit the consumer marketplace.

So, that same company that was trying to cure the sick can soon raise some research coinage by selling its latest multimedia brain-chip—complete with in-retina DVD play back and digital-to-neural encoding. Well, I polled fifty people and only two said they would even consider placing an entertainment device in their brain. I guarantee that somewhere in the world there are at least fifty people who would strap themselves into a complete cyber unit. I can see the future—**Poptronics** July 2015 features “Build Your Own Cartilage-Mounted Circuits” and “Troubleshooting Neuron-Transmitters.”

Anyway…this month we have two projects that are both practical and educational. Rudy Graf and William Sheets reveal the inner workings of the “MPX 2000.” This construction article is an excellent reference for radio enthusiasts. Marvin Smiths’ “In-Circuit Capacitor Tester” is a novice-level project that gives readers some great basic theory. These two features, combined with the regular supporting cast of contributing editors, all fit together to bring you the best in armchair electronics. So, what are you waiting for? Crack this issue open—or scan it into your brain-chip.

Enjoy!

Christopher La Morte
Managing Editor

LETTERS

mailto: letters@gernsback.com

Address Correction

It has come to our attention that the Pax World Web site mentioned in the "Prototype" section in the May issue no longer has the computer recycling tips. However, there is another site, the one for SVTC: www. svtc.org/cleancc/recycle/index.html. *This site has information about recycling computers in the Bay Area and other information as well.—Editor*

Memories

The January issue of **Poptronics** had two letters that really struck home. I was a **Popular Electronics** reader many years ago and recently received a subscription to **Poptronics**.

The letter from Paul Haines refers to the Nipcow scanning disc. Some of my memories include seeing a Baird TV system picture broadcast from NJ and received by the Radio Amateurs at their club house at Ohio State University in 1929 or 1930. This system used the Nipcow Disc with its problem of maintaining synchronization. The picture—only about 1? inches high—was of a girl bouncing a ball. The ball bounced rather slowly and changed shape as it bounced due to the low resolution available.

In 1949, I worked at The Asiatic Corporation. I was sent to NY to the CBS Laboratories to obtain information on the TV converter system proposed by CBS. At Asiatic, we made twelve of the electronic converter boxes that were used for demonstration at the court hearings between CBS and RCA. Of course, we all know the result of that court fight.

The other letter was from Andre Weitzenhoffer, which reminded me that I made crystal radio sets and one-tube regenerative receivers. In 1932, I received my Amateur Radio license W8HVK. I am now W8HVK with a bit of scheduled operating. I can't believe how much electronics I've forgotten since then.

ALLAN R. KESKINEN, W8HVK
Conneaut, OH

Keeping Up Tradition

Are people giving up on do-it-yourself electronics? I have been a long time fan of **Popular Electronics** and **Poptronics**—and for good reason. It

KEEP IN TOUCH

We appreciate letters from our readers. Comments, suggestions, questions, bouquets, or brickbats ... we want to hear from you and find out what you like and what you dislike. If there are projects you want to see or articles you want to submit—we want to know about them.

You can write via snail mail to:

Letters
Poptronics
275-G Marcus Blvd.
Hauppauge, NY 11788

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seems as if electronic-hobbyist magazines are falling by the wayside, but your magazine—although it has evolved—still remains on the newsstand. What happened to all my fellow inventors and hobbyists? Maybe computers have tempted them all to stray from the path. The majority of so-called hobby magazines are slanted towards home computing, and they seldom pique my interest. Your magazine always has something interesting to offer. Keep up the great work and thank you for a wonderful magazine.

MARCUS LEVY
Death Valley, CA

Hey, thanks Marcus. We here at Gernsback try our best to please our customers. Yes, you are right about the waning of electronics as a hobby. Chalk it up to mankind's inherent laziness, I suppose; but people are becoming less and less likely to devote their time to constructing an electronic project. More alarming is the decline of younger hobbyists. Let's not give up hope, though. Perhaps,

robotics will be the link to bind today's youth with the wonderful world of electronics. We hope you continue to enjoy our magazines—Editor

Haves & Needs

I am the owner of a very small repair shop, which operates from home. I need to locate sources of damaged VCRs, preferably in Miami. These units are usually repaired and resold. It is my understanding that there are places in the US that sell non-working units very cheaply. Could anyone let me know where such places can be found.

KENNETH CAMPBELL
Trinidad, West Indies

YESTERDAY'S NEWS

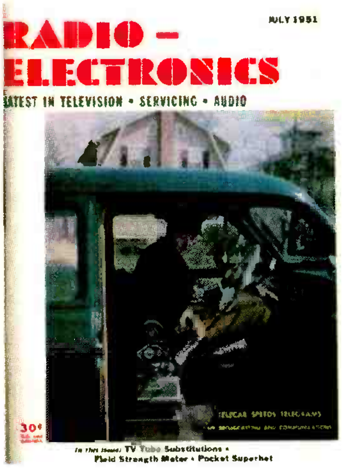
A PEEK INTO THE GERNSBACK ARCHIVES

1900
1910
1930
1940

Dateline: July 1951 (50 years ago)

The cover story for **Radio-Electronics** featured an upcoming service known as Telecar. The concept involved a roving Western Union man in a station wagon, equipped with a Teletype and radio link. This mobile-messenger service was supposed to revolutionize information exchange. (*Telecar might not have been a hit, but mobile-messaging can be seen in portable computing and wireless digital-phones.*)

1951



1960

1970

Dateline: July 1981 (20 years ago)

Do you remember your first cordless telephone? July 1981's **Radio-Electronics** introduced readers to the next-generation gadgets. Technology has smoothed the edges of these once bulky units and now millions of people enjoy the luxury of their cordless phones. (*Cordless phones would soon be plagued by intermod problems—interference from opposing radio sources—as users increased. The frequencies used by cordless phones were later bumped-up to near microwave range to avoid traffic clutter.*)

1981

Dateline: June 1991 (10 years ago)

How's this for practicality? "Build Your Own EKG" was the cover story for **Radio-Electronics** July 1991. A challenging construction article, this piece educated the readers on the electrical characteristics of our hearts and how pulses are measured and interpreted by medical professionals and hobbyists alike. (*Wouldn't it be great to have a feature on building your own MRI or laser-scalpel?*)

1991

2000

NEW GEAR

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Weighing Indicator

With accessible front-panel pushbuttons, the *VPI Weighing Indicators* are ideal for a wide range of weighing and force-measurement applications (VPI-SC, $395, and VPI-LC, shown here, $450). Measurements of force, weight, current, or voltage are displayed in five full digits; and no calibration equipment is needed to change ranges. Software is provided for easy setup.

LOAD CELL CENTRAL
Box 91
Monroeton, PA 18832
800-562-3235
www.800loadcel.com
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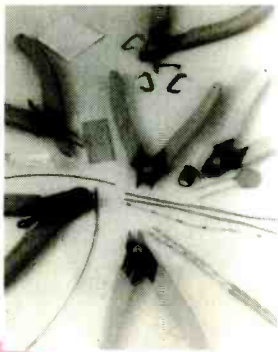
Ergonomic Hand Tools



All the *Xuron Ergonomic Hand Tools* (from $13 each) feature the Micro-Shear flush cutter, which produces a clean, square cut. Designed for repetitive tasks, these tools have soft rubber grips and light-action springs. The tool line cuts a wide variety of substrates, and different models are capable of crimping or forming soft and hard wire.

XURON CORP.
62 Industrial Park Rd.
Saco, ME 04072
207-283-1401
www.xuron.com
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High-Performance Power Inverter

Designed for people on the go, the compact *High Gear by Cobra* 12-V_{DC}–115-V_{AC} power inverters supply power to portable electronic devices, such as laptops and cell phones. Its Pentagon Protection system provides thermal shutdown, reverse polarity protection, and over-voltage and low-voltage shutdown; and there's a low-voltage alarm, as well.

The five models—HG PI150, HG PI300, HG PI500, HG PI1000, and HG PI2000 (numbers indicate wattage)—have prices ranging from $54.95 to $549.95. The *HG PI300* shown here has an MSRP of $79.95.

COBRA ELECTRONICS CORP.
6500 W. Cortland St.
Chicago, IL 60707
773-889-3087
www.cobraelectronics.com
CIRCLE 61 ON FREE INFORMATION CARD

Filter-Design Software

Version 4.0 of *Filter Express 4.0* and its companion simulator *FilterSim* are Windows-based tools for electronic and communications-systems designers. Highly intuitive to use, the software provides rapid methods for developing and evaluating DSP filters of any kind. Free downloads are available from the Web site below.

SYSTOLIX, INC.
10 Carver Lane
Sunol, CA 94586
925-862-2542
www.systolix-dsp.com
CIRCLE 63 ON FREE INFORMATION CARD

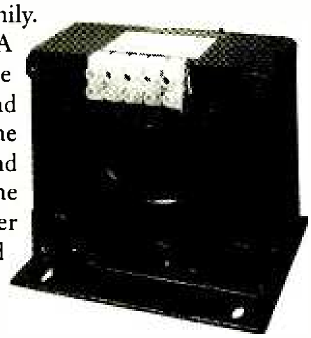
Battery In A Bag

For what you'd expect to pay for a single gel-cell 7.5 amp-hour battery alone, the *#PB7A* is a highly portable *Battery in a Bag* (priced at $33.95)—perfect for providing power for your mobile radio. The padded waterproof heavy-duty nylon case has extra room inside the buckle-down lid for accessories. Its adjustable strap makes it easy to carry.

CUTTING EDGE ENTERPRISES
1803 Mission St.,
Suite PMB-546
Santa Cruz, CA
95060
800-206-0115
www.powerportstore.com
CIRCLE 64 ON FREE INFORMATION CARD

Transformers

Three new high-power international transformers (from $225 for HPI-12 to $245 for HPI-17) have been added to the *HPI* family. The HPI-12 is 1250 VA and weighs 31 lbs., the HPI-15 is 1500 VA and weighs 35.7 lbs., and the HPI-17 is 1750 VA and weighs 38.5 lbs. All the HPI transformers offer "Touch-Safe" terminals and copper-foil electrostatic shields.



SIGNAL TRANSFORMER CO., INC.
INSILCO TECHNOLOGIES GROUP
500 Bayview Ave.
Inwood, NY 11096
516-239-5777
www.signaltransformer.com
CIRCLE 65 ON FREE INFORMATION CARD

Solder Wick

NTE Solder Wick is made from fine 100% copper wire woven together with a no-clean flux. Its fine braid promotes strong capillary action that pulls in excess solder. The residue is halide free and non-conductive. The MSRP ranges from $2.82 to $24, depending on width (.075 and .098 inches) and length (5, 10, 25, and 50 feet).

NTE ELECTRONICS
44 Farrand St.
Bloomfield, NJ 07003
800-631-1250 or 973-748-5089
www.nteinc com
CIRCLE 67 ON FREE INFORMATION CARD

Ringdown Unit

The *Quiklink Private Wire* ($75) is a tiny, two-way automatic ringdown unit, weighing only six ounces and measuring just ¾ × 4¼ × 2½ inches. It provides instant off-hook access between two telephone sets or equivalent devices, and it also works with computer modems and fax machines. Powered from either a $12\text{-}V_{AC}$ wall adapter or a $24\text{–}48\text{-}V_{DC}$ supply, the unit generates its own battery feed and ringing supply with selectable cadences.

CAMBRIDGE ELECTRONICS CORP.
Twenty Chester St.
Somerville, MA 02144-3005
617-629-2805
www.camlab.com
CIRCLE 68 ON FREE INFORMATION CARD

Panel-Mount Surge Protector

The *SurgeArrest* panel-mount Surge-Protection Devices (SPDs) prevent damaging over-voltages from entering homes, commercial buildings, and light industrial buildings. They have surge-capacity ratings that range from 40kA to 160kA per phase (from $319 to $1559). The 40kA unit is compact and will fit inside most residential circuit-breaker panels. It has an LED status indicator for easy monitoring.

AMERICAN POWER CONVERSION CORP.
132 Fairgrounds Road
W. Kingston, RI 02889
800-877-4080
www.apcc.com
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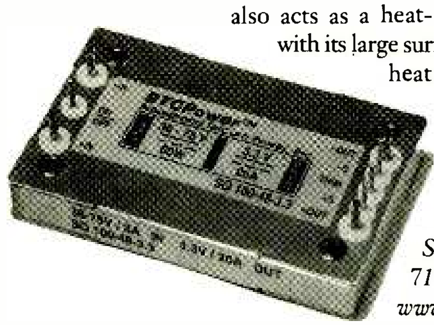
DC/DC Converter

The *BTCPower SQ* (Synchronous Rectification) *Series* ($47) units are high-efficiency quarter-brick DC/DC power converters. De-signed with a six-sided metal shield that prevents EMI, they eliminate the need for ferrite beads or other filtering devices. The shield also acts as a heat-dissipating medium with its large surface area, so neither a heat sink nor forced air-cooling is needed.



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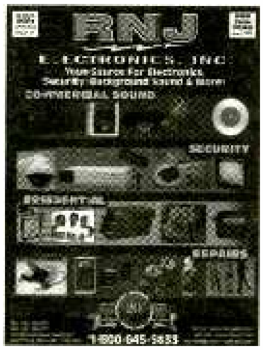
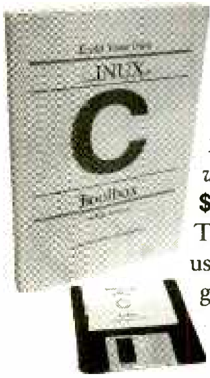


This 166-page catalog features test instruments; tools; soldering, AV, and CCTV equipment; home-theater and satellite components; videos; and educational items. Manufacturers include B&K Precision, Panasonic, Philips, JVC, Denon, and Weller. Photos, specs, and pricing information accompany each product.

Build Your Own LINUX C Toolbox

by Jack D. Dennon
Micromethods
P.O. Box 909
Warrenton, OR 97146
503-861-1765
www.seasurf.com/~jdennon
$16.95



This book is designed for readers who are using Linux and would like to do C language program development in this system. The programs presented here are simple but useful. The author starts with a text file-browsing program and concludes with developing a text editor. All programs are written in C for GNU C computer.

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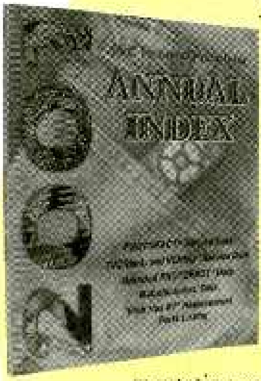
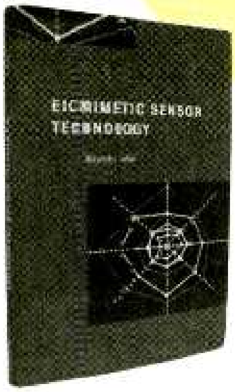


A complete index to Sam's products, this 296-page publication lists available service documentation on TVs, radios, VCRs, computers, scanners, and monitors. Brand names and model names are listed in alphanumeric order. There's also a CD-ROM version, which lists for $15.95.

Biomimetic Sensor Technology

by Kiyoshi Toko
Cambridge University Press
40 W. 20th St.
New York, NY 10011-4211
800-872-7423
www.cup.org
$74.95



Focusing on odor and taste sensors, this book will be a useful reference for researchers in fields from electrical engineering to food science. The introduction explores the principles of measurement and analysis. Biomimetic devices, electronic devices that mimic biological systems, are discussed in detail; in particular, the taste-sensing system developed by the author's research group.

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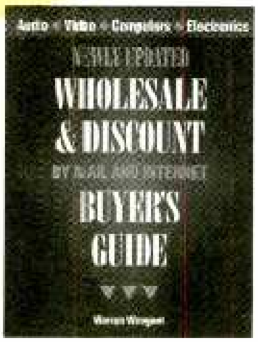


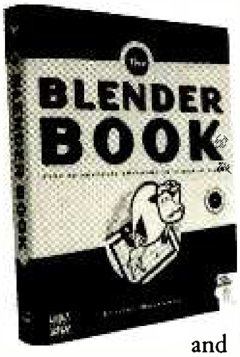
No matter what you're looking to buy by mail order or on the Internet, you can get it cheaper with this buyer's guide to audio, video, computer, and electronics products. Users will find carefully screened and researched sources with the best bargain prices. The listings include complete address, phone, and Web site information.

Restoring Pocket Radios

by Eric Wrobbel and Ron Mansfield
Antique Electronics Supply
480-820-5411
www.tubesandmore.com or
www.ronmansfield.com
$24.95

Transistor pocket radios from the 50s and 60s are becoming collector's items. This tape shows viewers how to open fragile cases, avoid causing damage, and service and restore these gems. Viewers are shown how to fix scratch volume controls, service dead or weak radios, trace signals, and align circuits, and even restore lettering. There are tips on buying and using test equipment and finding parts suppliers.

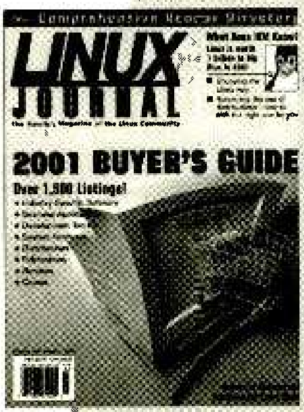
The Blender Book



by Carsten Wartmann
No Starch Press
555 De Haro St., Suite 250
San Francisco, CA 94107
800-420-7240 or 415-863-9900
www.nostarch.com
$39.95

Blender is a fast, powerful, and free 3-D graphics and animation tool that is popular with graphic and Web designers, video producers, and students. The clear, step-by-step tutorials teach users all aspects of this often tricky and non-intuitive program. The included CD-ROM offers *Blender 1.8* for all platforms; live-action image sequences; a complete texture library; and all the tutorials, scenes, and animations from the book.

2001 Buyer's Guide



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Featuring over 1500 listings of software, hardware, development tools, publications, services, and games, this comprehensive guide also contains information on infrastructure and tips on picking a distribution. There are over ten pages of Linux vendors, ranging from 1Globe to Zzyzx Peripherals.

2000 ARRL Periodicals CD

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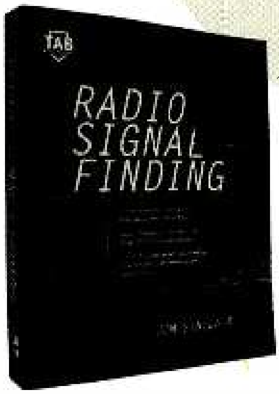
Newington, CT 06661
888-277-5289 or 800594-0200
www.arrl.org
$19.95

The entire year of *QST, QEX*, and the *National Contest Journal* are all found on this searchable CD-ROM. In addition to the complete text and illustrations for all articles, the CD includes source code for the software projects and PC board etching patterns. Minimum system requirements are Pentium processor and *Windows 95* or better.

Radio Signal Finding

by Jim Sinclair
McGraw-Hill
2 Penn Plaza, 12th Floor
New York, NY 10121
800-2MCGRAW
www.books.mcgraw-hill.com
$29.95



The ideal companion for ham radio operators, this book is packed with ideas and tips for everything from getting smoothly launched to isolating different signals. It includes complete coverage of the International Short-Wave Bands, as well as "extraterrestrial" signal finding—from satellites to moonbounce and Doppler Shifts.

Samsung ML-4500 Laser Printer

Low-cost computer peripherals—while at the top of everyone's "to buy" list—come at a price.

Nowadays, the computer-peripheral market has become even more bloodthirsty and cutthroat. More and more vendors are competing for your hard-earned cash in an ever-tightening arena.

For example, let's look at printers. Recognized names are slashing prices to the bone, while new companies try to get a toehold in the field and other manufacturers try to expand laterally into new areas.

Such is the case with Samsung. When you hear that name, a computer monitor is one of the first images that springs to mind. Of course, Samsung makes other devices than monitors, many of which might be buried deep within your system—hard drives, CD-ROMs, and the like.

It Slices, It Dices! Samsung's *ML-4500* laser printer ($199) has been touted by some as "the first laser printer to break the $200 barrier." Well, that's not quite true; Okidata marketed their Okilaser 4w a few years back. However, comparing the two machines would be like pitting Okidata's stripped-down "econo-box" car to Samsung's fully-loaded luxury sedan.

The ML-4500 is rated to crank out up to eight pages per minute at a "true 600 dpi." Features include a toner-saving button that will stretch the life of a toner cartridge from 2500 to 3500 sheets of text—an extra 1000 sheets. There's also a CANCEL/REPRINT button in case you clicked on the "print" command just a bit too fast. All the rest of the standard amenities that you would expect from a laser printer are included—panel buttons, indicator lights, and a manual-feed tray for envelopes and single sheets.

Samsung's toner-cartridge design puts the toner cartridge and image drum (the heart of a laser printer) in the same housing. Whenever you replace the toner, you're getting a new image drum as well— no more frustration over hav-ing to replace a scratched image drum when you thought your printing problems were due to low toner.

Now How Much Would You Pay? You would expect that Samsung would have cut a few corners in delivering a reasonably fast, substantially built, 600-dpi printer for $200. Suprisingly, a physical on-off switch is *not* among the missing—owners of Hewlett-Packard's LaserJet "L" series (4L, 5L, and 6L) know what I'm talking about. Realizing that, of all things, an IEEE 1284-rated printer cable is *included* makes you start to question, "All right, what's the catch?" One thing that is missing is a printed manual; all documentation is in Adobe Acrobat-format files on the included CD-ROM. However, there is a large-sheet "quick guide" to getting the ML-4500 up and running.

The unit, as it comes out of the box, is festooned with large, garish stickers advertising some of its features. Those stickers are more appropriate to a computer superstore's display aisle instead of a unit fresh out of its factory-sealed container. Depending on your personal sense of aesthetics, you'll probably be spending some time with a scraper and some adhesive solvent.

Installation under Windows is straightforward, providing you follow *Samsung's* instructions. Rather than following Microsoft's recommendations for a standardized user experience (have Control Panel's "Printer" applet search a CD-ROM for the appropriate driver), Samsung "reinvented the wheel" and used a customized install program that autostarts when you place the CD-ROM in a drive and close the tray.

Removing the driver is a similar "not-like-a-regular-Windows- driver" method: A special uninstall link is placed in the Start menu—cluttering up your already-overflowing Programs menu.

But Wait...There's More! Although the above impressions suggest that the ML-4500 is a unit to be ignored, that is *not* the case. With the unit hooked up and tested, printing to the first page is reasonably fast... and *quiet!* Compared to other laser printers, this unit barely whis-

(Continued on page 14)

Business Buzz

IN A FLASH
TriFlash, a 17- by 12-mm, high-capacity embedded flash-memory device from SanDisk Corp., is ideal for storing audio, video, data, and images on small portable devices, such as cell phones and MP3 players. An entire company directory, the phone book of a major city, or personal e-mail could be loaded on a TriFlash device. It has a simple three-pin serial interface and can accommodate—in the same footprint—all existing and future generations of flash memory. The device is optimized for high performance of both reads and writes and for low power consumption.

KEEPING TRACK
Houston-based Immobiliser, Inc. introduced GPS Vision, the world's first wireless vehicle tracking and control system. Using Internet and GPS technology, it allows vehicle owners to track and control their vehicles on the Internet from anywhere in the world. With just a click of the mouse, car owners receive the vehicle's street address location, digital mapping, car speed, and direction. GPS Vision gives fleet owners the ability to shut down the use of their vehicles and equipment after hours. In addition, an owner could even start a vehicle engine from a distance, even from another state. This plug-and-play system works with any model currently on the market.

GET THE PICTURE
Until the advent of *H*igh-bandwidth *D*igital *C*ontent *P*rotection (HDCP) for DVI (*D*igital *V*ideo *I*nterface), film studios were reluctant to release *H*igh-*D*efinition (HD) films because of copyright-protection problems. Satellite broadcasters and consumer electronics manufacturers have shown support for and willingness to incorporate DVI with HDCP in their products. Because it's a high-bandwidth, all-digital system, DVI offers new possibilities for home-entertainment systems. DVI has the bandwidth to address each pixel in a digital TV display individually, enabling the highest possible picture quality.

Silicon Image's PanelLink is the only digital interface with enough bandwidth to accommodate uncompressed high-definition digital video. PanelLink provides scalable, end-to-end, all digital connectivity between host devices and digital displays, such as flat-panel monitors, projectors, HDTVs, and digital CRTs.

Radar-Vision

The RADAR flashlight can detect a human presence through doors and walls up to eight inches thick. (*Photo by Gary Meek*)

Police officers serving a warrant or searching for a suspect hiding inside a building could soon have a new tool for protecting themselves and finding the "bad guy."

The Prototype

A prototype device called the RADAR Flashlight, developed at the Georgia Tech Research Institute (GTRI), can detect a human's presence through doors and walls up to 8 inches thick. The device uses a narrow 16-degree radar beam and a specialized signal processor to discern respiration and/or movement up to three meters behind a wall. The device can penetrate even heavy clothing to detect respiration and movements of as little as a few millimeters.

"We believe the RADAR Flashlight potentially will be useful to police officers in ambush situations," says Gene Greneker, the GTRI principal research scientist who led the development of the device.

In its current form, the RADAR Flashlight operates in the following manner: The user holds the device with a pistol-grip handle, pulls a trigger, and the device runs a 3-second self-test to verify that it is properly functioning. The user sees the results as a bar graph on a small LED display built into the device. Then the user presses the device against a wall, pulls the trigger and within 3 seconds the system automatically spaces itself from the wall at a distance designed for best performance. The RADAR Flashlight's narrow radar beam sends out a pulse of electromagnetic energy and detects the return signal. That signal is read by high-speed signal processing technology that quickly delivers bar-graph results to the display. As the person on the other side of the wall breathes, the bar-graph display rises and falls with a rhythmic response.

Research that evolved into the RADAR Flashlight began at GTRI in the mid-1980s with the patenting of a frequency-modulated radar for remotely checking vital signs of soldiers wounded on the battlefield before risking medics' lives to save the injured. This early technology also was tested for its ability to monitor vital signs of soldiers clothed in chemical or biological warfare suits, without requiring them to risk contamination by removing the protective gear.

The RADAR Flashlight operates on a narrow frequency in a license-free band, Greneker adds. It can detect motion and/or respiration through brick, wood, plaster board, glass and concrete. It will not work in water or on metal structures, such as mobile homes, because these materials are electrical conductors.

For those concerned about radiation exposure from the flashlight, Greneker says the emission is very small—meeting national standards for the maximum human exposure limits. It emits about the same amount of radiation as a person receives when standing in front of a microwave-actuated door in a store.

Testing

The RADAR Flashlight is undergoing further modification and testing. The Georgia Institute of Technology has filed a provisional patent for the device, which could become commercially available to law enforcement officials within a couple of years if the university licenses the technology to a manufacturer.

With funding in 1998 from the National Institute of Justice (NIJ), a division of the U.S. Justice Department, Greneker and his team took the RADAR Flashlight from a bulky three-part prototype to a self-contained unit that weighs about 7 pounds. The NIJ tested the device last year at the National Law Enforcement Corrections Technology Center in Charleston, S.C., and suggested further modifications. Work on those changes began this spring with additional funding from the NIJ.

"We will be modifying the RADAR Flashlight based on what law enforcement officials told us from the tests," Greneker says. "For one thing, they said it makes too much noise when it locks onto a wall (to scan). Also, for use by SWAT teams, the RADAR Flashlight needs to be operated by remote control. So we plan to put the RADAR Flashlight on a tripod at least 25 feet away from a wall and steer it by remote control to the part of the wall we're interested in scanning."

When these modifications are complete, the RADAR Flashlight will undergo more rigorous testing in various environmental conditions.

Researcher Gene Greneker and his team transformed the RADAR Flashlight from a bulky three-part prototype to a self-contained unit, weighing about seven pounds. (*Photo by Gary Meek*)

Research Notes

HOT AIR ENERGY
Researchers led by Steve Bauer at Sandia National Laboratories worked with Houston-based Haddington Ventures and its subsidiary Norton Energy Storage LLC to determine the feasibility of using a 2200-foot-deep inactive mine near Norton, OH, as a compressed air energy storage power plant.

"The intent is to cycle air pressure into the mine using compressors during off-peak electrical power at times like evenings and weekends to increase air pressure in the mine," Bauer says. "During the daily peak needs for electricity, air pressure will be bled off through modified combustion turbines to generate electricity." Working pressures in the "air tight" mine will range between about 1600 and 800 psi. Only two other such plants exist—both in caverns created in salt deposits. The Norton plant, expected to be on line in two years, will be the first in a limestone mine.

POWER FAILURES
Power providers who know of potential outages often can take action to ensure the "lights stay on." The *W*ide *A*rea *M*easurement *S*ystem, WAMS, continuously monitors grid performance across the Western power system. It provides operators with high-quality data and analysis tools to detect impending grid emergencies or to mitigate grid outages. Developed using technology from the DoE's Pacific Northwest National Laboratory and the Bonneville Power Administration, it soon will give this key information to California power companies.

KEEP IT COOL
A paper-thin coating of an innovative NASA material used to prevent space vehicles from burning up during reentry may soon protect your house, car, and boat from fire. *P*rotective *C*eramic *C*oating (PCC), invented at NASA's Ames Research Center, repels heat from virtually any surface. Wessex, Inc., in Blacksburg, VA, will develop and market the material. According to company president John Olver, "We have discovered that 99 percent of the materials in PCC will not burn; therefore, the coating inhibits the spread of flame. PCC can withstand temperatures from minus 250°F up to 3000°F without damage. It is a great material with unlimited potential."

➤ Clothing That Talks

France Telecom R&D has developed its first prototype communications jacket, which operates similarly to a hands-free kit. The jacket is being tested by mobile workers, such as construction workers, sportsmen, teenagers, and young students.

Ordinary in appearance, the prototype uses existing technology, providing the functions of a mobile telephone without a visible screen or keyboard. The telephone device weighing just 3.5 ounces is integrated into the lining of the jacket, with a keypad inside the flap of the jacket and microphones in the collar.

Simply pressing a button obtains a line or hangs up the phone. Numbers can be voice dialed by speaking a name or by keying in a number. The quality of the communication is as good as any mobile phone.

PT

Troubleshooting

Today, a technical challenge remains for researchers working on the RADAR Flashlight.

"We have one problem," Greneker says. "This instrument is so sensitive to motion that if you don't hold it still enough, it will detect its own self-motion. If we can overcome this, it would be the Holy Grail, and interestingly enough, we think we know how to solve this problem with additional research."

Bill Deck of the National Law Enforcement Corrections Technology Center cited the RADAR Flashlight's stability and LED display as key issues to target before the device is commercialized.

"The RADAR Flashlight has some potential," Deck said. "There is some interest from police departments. They gave us about 25 scenarios in which the device could be useful. For example, when an officer goes to serve a warrant, it could let him know that someone is standing behind the door, maybe waiting to ambush him."

Greneker says he is encouraged by interest from police departments and hopes the RADAR Flashlight will be commercialized soon. PT

Superconductor Milestone

Researchers in the Superconductivity Technology Center of the DoE's Los Alamos National Laboratory have developed a new process for producing high-performance tape that operates at the temperature of liquid nitrogen. When scaled up to commercial production, the Los Alamos process will enable industry to manufacture long lengths of this tape—at a rate of kilometers per day—for numerous electric power applications.

Superconducting tapes can efficiently carry vast amounts of electrical current with no resistive losses. A single, one-centimeter-wide, thin foil of this superconducting tape exhibits a current density—the amount of electrical current that can be passed through a cross section of the material—of more than one million amps per square centimeter. This means a single piece of surperconducting tape can carry 200 times the electrical current of an equivalent copper wire.

"Electric motors, transformers, transmission cables, and levitated trains will be some of the applications demanding hundreds of kilometers of these flexible superconducting tapes each year," said Dean Peterson, director of the Technology Center.

The new process involved replacing cubic zirconia with magnesium oxide as the template material for the superconducting film, thereby speeding up the template deposition process by 100 times.

In 1995, Los Alamos researchers achieved world-record performance by depositing a film of a superconducting ceramic, known as yttrium barium copper oxide or YBCO, on inexpensive nickel alloy tape by first applying a buffer layer of cubic zirconia. The zirconia layer was deposited using ion beams in a process known as Ion Beam Assisted Deposition. The first beam removes material from a zirconia target and deposits it onto the nickel tape. A second ion beam, aimed at the tape, orients zirconia grains as they are deposited. Subsequent pulsed-laser deposition of YBCO on top of the aligned zirconia template allows growth of a nearly perfect crystalline superconducting film from one to six millionths of a meter thick.

Building on this Ion Beam Assisted Deposition-pulsed laser approach, Los Alamos researchers were able to produce meter lengths of YBCO superconducting tapes with critical current exceeding 100 amps.

The researchers also recently discovered that superconductor multilayers carry unprecedented amounts of current—potentially 1000 amps in a one-centimeter-wide strip through a coating only one tenth the thickness of a human hair. This new film deposition technology is now being incorporated in producing superconducting tapes with superior current-carrying ability. PT

Keep That Computer Running

Researchers are increasingly turning to a technique called distributed computing to complete in days or weeks computing tasks that would normally take months or years. By combining the idle processing power of thousands, even millions of personal computers on the Internet, they can form a virtual machine more powerful than even the world's fastest supercomputers.

Recently, Stanford University launched Genome@Home to learn more about how genes work. Now that scientists have mapped the human genome, they'll need immense computing power to make sense of it.

You only use a fraction of your computer's processing power when you surf the Web or compose a letter or e-mail. When you step away, you're using none of it. So why not donate your excess to science?

That was the thinking behind the Search for Extraterrestrial Intelligence, the most popular use of distributed computing to date. Nearly three million Internet users have signed up for SETI@Home since May 1999, contributing a combined 570,000 years of computer time to analyze radio signals for evidence of alien contact. About 550,000 are active volunteers, many using multiple computers.

The SETI software works as a screen saver, kicking in when your computer's idle. Or it can be set to run in the background while you're doing other work. Either way, the computer analyzes the data, sends back results, and retrieves more signals.

Distributed computing has been around for years, initially used primarily on clusters of machines running the Linux operating system at NASA and universities. It migrated to the Net in the late 90s for such math problems as finding the longest prime number and cracking encryption.

Now, researchers are using similar techniques to design storage vessels for nuclear waste and study evolution. Medical researchers can test millions of drug combinations to fight AIDS or cancer, and learn how anomalies in protein formation cause diseases.

"It's wonderful that the common person can get involved," said Larry Rymal, who runs SETI on about 80 computers at a training center near Houston.

Still, some significant obstacles exist. By distributing the work, researchers can lose control over their data. The SETI project has had to contend with a handful of attempts to falsify data.

For a project to identify drugs that may disable mutant forms of the AIDS virus, The Scripps Research Institute tapped Entropia, whose network had identified the world's longest known prime number.

Entropia requires FightAIDS@Home volunteers to also devote a small portion of their computers to commercial projects. Art Olson, a Scripps biology professor who runs the FightAIDS@Home project, said setting up his own network wasn't practical. By finding a commercial partner, he said, the project is able to get 1000 times the computing power that Scripps has available in-house. The AIDS project, begun last fall, now links nearly 14,000 machines.

Some SETI users, drawn by its non-commercial nature, say they want to be careful about the projects to which they donate their spare processing time.

"A lot of people are actually prepared to spend time and share time, but not to make other people rich out of it," warned Manfred Woellner, 40, who runs a software company in North London. PT

HANDS-ON REPORT

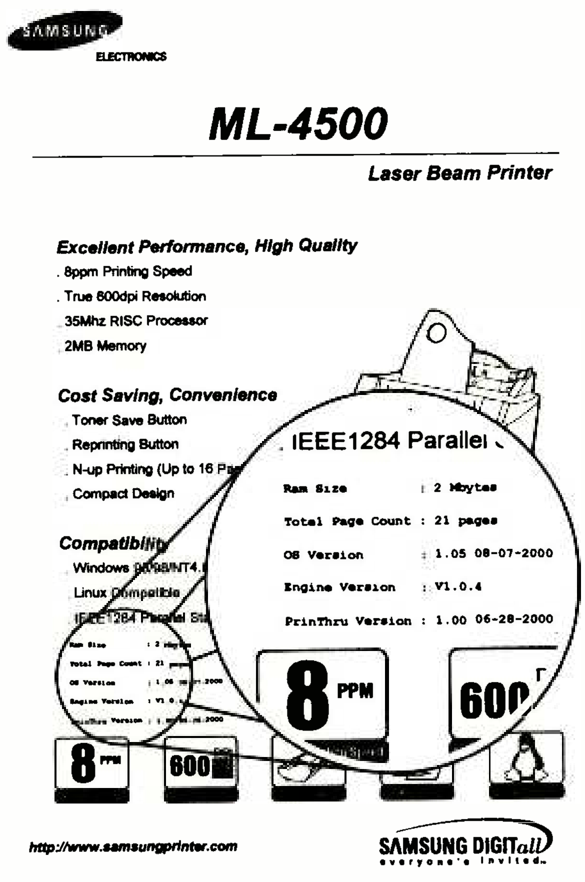
(continued from page 9)

pers while the inner gears and motors spin up to operating speed. In fact, the loudest sound while printing is the "snap" of the paper as the end of each sheet passes through some sharp-angle bend in the paper path. Most impressive!

On the subject of paper path, note that the ML-4500 is a "top-loader"—paper goes in and comes out vertically like the aforementioned HP printers. If you have a somewhat cramped location available for your printer (such as a middle shelf), take that into consideration.

Having a 600-dpi printer is a "good thing"—until you bump up against another subtle Samsung "gotcha:" The memory on this unit is *not* expandable. Two megs will handle a basic mix of text and high-resolution pictures for a newsletter or short article, but not if you want to print large, high-resolution images. Let's do the math: for an 8- by 10-inch picture at 600 dpi, you need (8 × 600) × (10 × 600) bits, or 28.8 million bits. Divided by eight means you need a bit over 3.5 megabytes to store that image in the printer—quite a bit more than the two mega-bytes available.

If you're not looking to do anything super fancy, you probably will not have a problem with printer-memory shortages. However, having a printer that puts out crisp, clean pages might soon get your creative juices flowing—a good recipe for "I-should-have-bought-better" frustration.



The ML-4500's 600-dpi output is crisp and clean for a $200 printer.

The Little Penguin That Cried. If all you know about computer operating systems come from Redmond, WA, you can stop reading. For all the "fans of Tux" out there, gather 'round for a semi-sad tale.

One of Samsung's major advertising points for the ML-4500 is that it is "Linux compatible." That phrase is plastered all over the shipping box and even appears on the test page hardcoded into the printer's memory. Indeed, if you dig deep down into the CD-ROM, there is a Linux directory containing .rpm (*RedHat Package Manager*) files and a README file with installation instructions.

Installation instructions are detailed in the README file only— the manual has not a hint about non-Windows information. For all the "Linux-friendly" hype connected with the ML-4500, you would think that Linux installation instructions would be a bit more prominent.

The install script and package files insert the ML-4500 into the Red Hat *printtool* utility and replace the version of *Ghostscript* on your machine with one that's been patched to understand the ML-4500's data format. To explain, UNIX systems output print files to a Postscript interpreter like *Ghostscript* for translation to the data format needed by non-Postscript printers.

Things went sour when Mandrake 7.2 (the target test system) choked on the .rpm files. Apparently, Samsung uses version 4 of the .rpm format—an update not widely available on non-Red Hat distributions. Indeed, Samsung warns that only Red Hat is supported and guaranteed. That is like saying that software will only install under Windows95 OSR2 for Compaq Presario 4800-series systems built between January and June 1996. Calling something "Linux compatible" when you can only use it under Red Hat 6.1 is not exactly "compatible!"

The bottom line is that we never got the ML-4500 working under Linux. Samsung (apparently not realizing the root cause of the .rpm incompatibility) sent replacement package files, which—obviously—failed to install as well.

As this is being written, there have been reports on Usenet of successful installations under non-Red Hat Linux systems. Apparently, Samsung has posted the patch code for *Ghostscript* on their Web site, but it is difficult to locate. Armed with that file, you could patch your own copy of *Ghostscript* to work with the ML-4500. There have also been reports of ML-4500 successes under *CUPS* (the *Common UNIX Printing System* software that some Linux distributions are leaning towards). If you need that information, you can find the archived newsgroup messages at DejaNews'... oops, sorry, Google's newsgroup archives.

Although the ML-4500 might sound like more trouble than it's worth, it is a well-built, dependable printer that runs quietly and puts out a crisp page of 600-dpi images. If you can work around the limitations, you can't beat it for cost-effectiveness.

For more information, contact Samsung USA, Consumer Electronics, 105 Challenger Rd., Ridgefield Park, NJ 07660; 201-229-4000; *www.samsungusa.com*; or circle 80 on the Free Information Card. P

GIZMO®

Wake-Up Calls

How many times do you hit the snooze bar each morning? Sony's *ICF-CD823 Snoozinator CD/Clock Radio* ($80) lets you choose your snooze time, in eight-minute intervals, for up to one hour. Its two separate wake-up times can be set for CD, radio, or alarm. The space-saving sound-stage design, though small in size, disperses the sound throughout the room.

Sony Electronics Inc., 1 Sony Drive, Park Ridge, NJ 07565; 800-222-SONY; *www.sony.com*.

CIRCLE 50 ON FREE INFORMATION CARD

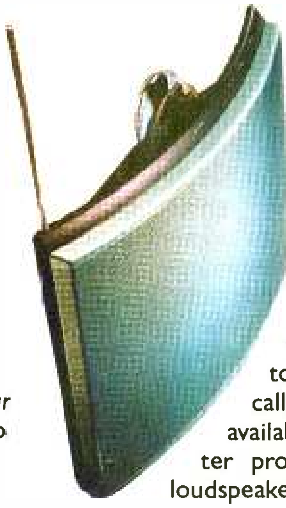
Multi-Satellite Dish

The *TRK-S22* ($149) is an 18 × 24-inch DirecTV-approved multi-satellite dish antenna with two dual LNBs and a four-output (4 × 4) multi-switch for easy receiver hookup. The HDTV-compatible antenna comes with mount assembly, including bracket, arm, mast, and base; clearly labeled cables for D-I-Y installation; and all necessary hardware.

Terk Technologies Corp., 63 Mall Drive, Commack, NY 11725; 631-543-1900; *www.terk.com*.

CIRCLE 52 ON FREE INFORMATION CARD

BeoSound 1



Boasting high style and high fidelity, the *BeoSound 1* portable stereo ($1500) is a gently curved, thin arc of light blue, accented in silver, black, green, and red. The stereo offers easy-to-use features. Its motorized antenna and CD-clamper each rise gracefully from the top of the unit at the press of a button. The FM tuner automatically searches for and stores all available radio stations. For better projection, each of the five loudspeakers is powered by its own dedicated amp.

Bang & Olufsen America, Inc., 1200 Business Center Drive, Suite 100, Mount Prospect, IL 60056-6041; *www.bang-olufsen.com*

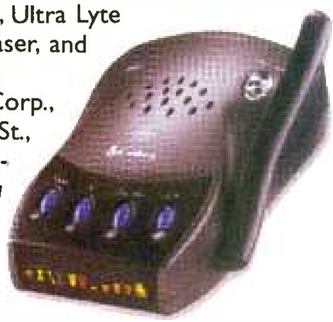
CIRCLE 51 ON FREE INFORMATION CARD

Weather-Savvy Radar Detector

The *ESD-9220WX Radar Detector* ($189) alerts you to more than speed traps. A built-in ten-channel weather radio includes NOAA Weather Alert for impending storms. The Strobe Alert warns of emergency vehicles at intersections, while the Safety Alert warns of approaching vehicles and other road hazards. As for speed traps, the ESD-9220WX detects X, K, KA, VG-2, Ultra Lyte Laser, LTI 20-20, ProLaser, and ProLaser II signals.

Cobra Electronics Corp., 6500 West Cortland St., Chicago, IL 60707; 773-889-8870; *www.cobraelectronics.com*.

CIRCLE 53 ON FREE INFORMATION CARD

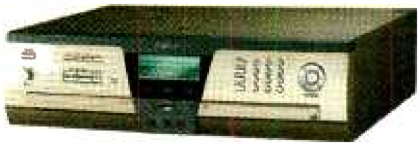


CD/MP3 Jukebox

Holding up to 240 hours of music in its 20-GB hard drive, the *Cyberboy CB-200 Digital Audio Recorder and Jukebox* ($499) from CMC Magnetics Corp. sports both a Multimedia Card slot and a CD-R/CD-RW read-compatible CD-ROM drive. You can record CD tracks directly from the CD drive, store them to the hard drive as MP3 files, and then transfer them to a Multimedia Card.

Hotan Corp., 6700 Golden Gate Dr., Suite B, Dublin, CA 94568; 925-829-5311; *http://cmc.taiwanet.com*.

CIRCLE 54 ON FREE INFORMATION CARD



FRS Radios

Family Radio Service (FRS) radios, which require no licensing or service fees because they operate in the FCC-approved FRS-spectrum UHF-radio band, are increasingly popular. The easy-to-use radios provide two-way communications with a range of up to two miles. The *Cherokee FR-465* ($169.95) includes the Vitalert Emergency Communications System, which indicates when another radio has gone out of range.

Wireless Marketing Corp., 1092 National Parkway, Schaumburg, IL 60173; 847-839-0015; *www.wirelessmarketing.com.*

CIRCLE 55 ON FREE INFORMATION CARD

CDs on the High Seas

Designed specifically for boat installations, the *MDC5110 CD* marine head unit ($199) uses clear-coated circuitry and a rust-resistant chassis built to withstand heat, wind, rain, cold, and salt water. It features a detachable faceplate that can be removed from the boat and safely stored. The unit includes a CD player, an AM/FM tuner with 18 FM and 12 AM station presets, and an amplifier.

Jensen Mobile Electronics, a Recoton Company, 2950 Lake Emma Road, Lake Mary, FL 32746; 407-333-8900; *www.jensenaudio.com.*

CIRCLE 57 ON FREE INFORMATION CARD

Digital Surround A/V Preamp

Designed for today's high-end home theaters, the *AS-2631 5.1-channel A/V preamplifier* ($800) reproduces seven independent channels—six audio channels and one subwoofer channel. It automatically detects and decodes Dolby Digital or DTS input signal formats. There are eight different on-screen surround modes from no surround to large hall. The AS-2631 has eight audio inputs and six video inputs.

Proton U.S.A., 13855 Struikman Road, Cerritos, CA 90703-1031; 562-404-2222; *www.proton-usa.com.*

CIRCLE 56 ON FREE INFORMATION CARD

Digital Pics

The *FinePix 4700 ZOOM* digital camera ($799) uses Fujifilm's Super CCD for vivid, colorful pictures. The digital camera also boasts a 3X aspherical optical zoom lens, a 2-inch LCD screen, a pop-up flash, a USB port, five programmed exposure modes, and the ability to capture 80 seconds of continuous AVI video with sound on its bundled 16-MB SmartMedia card.

Fuji Photo Film U.S.A., Inc., 555 Taxter Road, Elmsford, NY 10523; 800-800-FUJI; *www.fujifilm.com.*

CIRCLE 58 ON FREE INFORMATION CARD

Dual-Tray CD Recorder

Said to have the industry's fastest CD-to-CD-R dubbing speed, TDK's first home audio CD recorder, the *DA-3826* ($549), offers 4X recording of both full discs and individual tracks. It records on both CD-R and CD-RW discs and provides a full complement of digital and analog inputs and outputs for any music source.

TDK Electronics Corp., 901 Franklin Ave., Garden City, NY 11050; 800-835-8273; *www.tdk.com.*

CIRCLE 59 ON FREE INFORMATION CARD

Data-Acquisition Software

CE-Wedge ($199) is designed for interfacing serial devices—such as bar-code scanners, calipers, micrometers, scales and other simple serial devices—to any Windows CE program. An easy-to-use data-collection program, CE-Wedge features a one-screen, one-minute set-up with complete on-line help. A free 30-day evaluation version can be downloaded from *www.tal tech.com/cgi-bin/fs2k.cgi.*

TAL Technologies, Inc.; 800-722-6004; *www.taltech.com.*

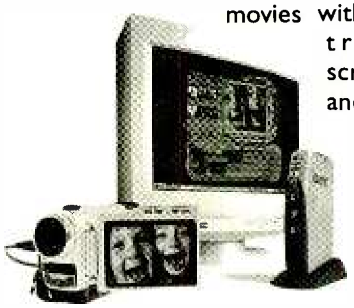
Mobile Pen-Based Scanner

The *Cross :Convergence Pen* ($89.99)is a wireless scanner pen that makes it possible to scan barcodes on thousands of products as well as publications with Digital Convergence *Cues*. Users simply press the scan-activating button on the pen, quickly drag across any bar or product code, and a bookmark is stored for the corresponding Web page. Up to 300 codes can be scanned between uploads.

Cross Pen Computing Group, A. T. Cross Company; 401-333-1200; *www.cross.com.*

Dazzling Video

The *Digital Video Creator* (just under $200, MSRP) video-editing system with *MovieStar* editing and publishing software is an easy way to capture, edit, and share video with friends and family. Anyone can transform home videos into Hollywood-style movies with professional transitions, scrolling titles, and voice-over narration. Edited movies can be shared via VHS tapes, CD, e-mail or on the Web.



Dazzle Multimedia, Inc.; 510-360-2300; *www.dazzle.com.*

Don't Move That Mouse

Combining optical sensor and DSP technology with Internet and document-scrolling capability, the *Targus Screen-Scroller Optical Mini Mouse* ($49.99) is an optical pointing device that can be used on any surface. The Screen-Scroller features a "Scroller Wheel," which allows users to scroll up or down without moving the mouse, and it comes with a USB connection.

Targus, Inc.; 800-242-3133 or 203-852-1102; *www.targus.com.*

Multi-Function Center

The *Brother MFC-7300c* (ESP, $299) combines video-capture capabilities and printing, faxing, and copying—all in color—into a compact, space-saving design. As a color printer, it provides fast print speeds, with up to 12 ppm monochrome, 10 ppm color, and up to 1200 by 1200 dpi photo-quality output. The MFC-7300c can also send either B/W or color faxes. In addition, high-quality color scanning is provided via the automated document feeder.

Brother International Corp.; 800-276-7746; *www.brother.com.*

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SURVEYING THE **DIGITAL** *DOMAIN*

REID GOLDSBOROUGH

mailto: digitaldomain@gernsback.com

Money And The Internet

Pundits have predicted that the digital age would usher in the paperless office and the cashless society. Ironically, it seems as if computers have led to more paper, not less; and getting cash may be more convenient with computerized ATMs, but the need for paper currency is no less. Significant change is in the works—at least on the money front. Today, you can carry out transactions using your personal computer and the Internet without exchanging cash. You can buy, and you can sell, and you don't even need a credit card. Online auctions have been the catalyst behind the innovations, according to Mark Morgan, a research analyst who specializes in e-finance for the San Francisco investment bank Putnam Lovell. The biggest mover here is a little-known, meteorically growing, and controversial company named PayPal.

Look out Visa and AmEx! PayPal means business—at least in cyberspace. PayPal is leading the way for fledgling on-line creditors, by allowing its over seven million users to purchase and trade, without cash, over the Net.

PAYING TABS WITH PIXELS

Out of the heart of the Silicon Valley, PayPal has vaulted in little over a year from nowhere into first place as the world's largest Internet-based payment network. More than five million people now use its PayPal service, according to a company spokesperson. This constitutes more than 10 percent of all Internet traffic in the financial services sector—more people than are served by big names such as Citibank, Wells Fargo, and Bank of America combined.

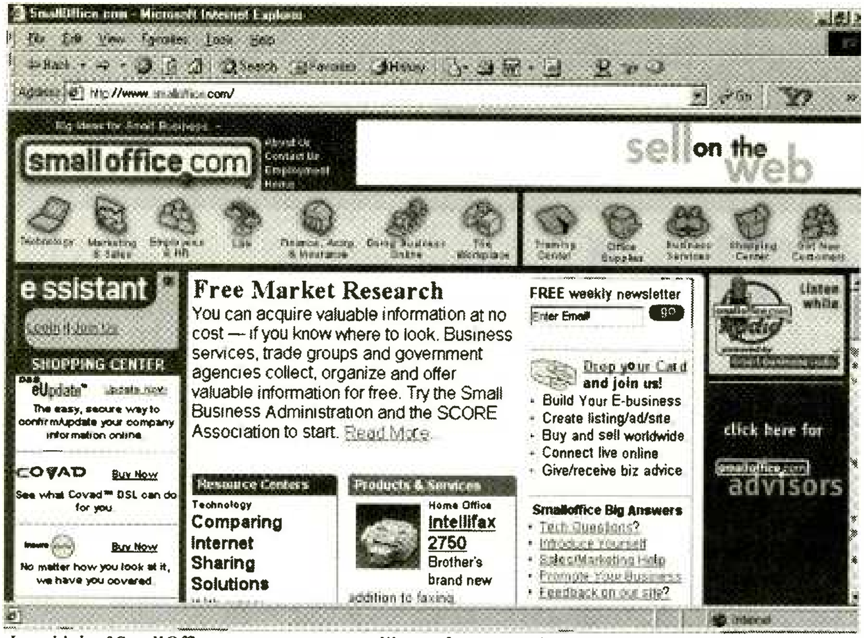
For both consumers and businesses, PayPal offers useful services and, for businesses alone, useful lessons as well. Using PayPal, at *www.paypal.com*, you can quickly and conveniently pay for goods or services by having money transferred from your bank account, credit card account, or PayPal money market account. The kicker here is that you can sell over the Internet without a credit card merchant account, which for individuals and even small businesses can be difficult or expensive to obtain.

PayPal used to promote itself as being "always free," in its logo no less, but it now charges if you buy or sell more than specified amounts. PayPal's abruptly changing its terms of service created a storm of protest—Internet message forums were flooded with scathing complaints and calls for boycotts. It can still be a good deal, compared with other options.

In what undoubtedly is a side effect of this, the Better Business Bureau just gave PayPal an "unsatisfactory" rating. PayPal will likely weather this deluge in part because a key competitor, ExchangePath, just went belly up. However, it could have handled things better. Sure, in today's brutal dot-com shakeout, businesses need to make money rather than just coax venture capital and grow market share. The transition from free to pay should be planned and managed. PayPal's lesson to other businesses is a common sense one: Don't promise what you may not be able to deliver.

CYBER-CREDIT COMPETITORS

PayPal isn't the only player in the "person-to-person payment" market. Ecount, based in Conshohocken, PA, is carving out space for itself by marketing to banks and credit card companies rather than directly to individuals or small businesses, says Matt Gillin, the company's CEO and president. Individuals can still sign up, at *www.ecount.com*, and more than 800,000 have—often those wary of using credit cards over the Internet.



Just think of SmallOffice.com as a resource library for stay-at-home entrepreneurs—and then some. Whether you have questions, are researching demographics for customers, or are a complete novice, SmallOffice.com can point you in the right direction.

You can use the service with any merchant who accepts MasterCard payments, unlike with PayPal, which requires the merchant to have a PayPal account.

You pay for online purchases out of your Ecount, which you fund through a major credit card. The company plans to offer bank account transfers in the future. You're charged a small fee only when you add or withdraw money from your account or opt to receive a traditional plastic MasterCard debit card from the company. You withdraw funds with your credit card or MasterCard debit card or by having a check mailed to you. Other services battling for position in the online payment space include eCharge at *www.echarge.com*, MoneyZap at *www.moneyzap.com*, and c2it at *www.c2it.com*.

GUARDING YOUR VIRTUAL WALLET

Any electronic payment service worth its silicon makes security top priority, but you have to do your share, too. Don't use the same password for your e-cash account as your e-mail account. Recently, hackers got into the PayPal accounts of some Hotmail users by hacking their Hotmail passwords.

Also, beware of "spoof" sites with names such as PayPai that try to trick you into giving up your password. It's better to log directly onto sites such as PayPal than to go to them via possibly bogus links in e-mail messages. E-payment companies have grandiose plans, with dollar bills flashing before their eyes. The ultimate goal: One payment system that replaces not only cash, but credit cards and checking accounts as well.

CON-ARTISTS IN CYBERSPACE

Not only can you spend money on the Web, but you can earn money, too. Can you get rich quick on the Internet? Sure, you can, if you believe the flood of e-mail messages sent by "entrepreneurs" hoping you'll invest in their enterprises. Don't believe them. Those sending this growing torrent of come-ons are almost always shysters. They often lie from the get-go. "ADDITIONAL INFORMATION REQUESTED FROM ROBERT ALLEN," shouted one recent message. I never requested any information in the first place. Typically, the appeal is to greed. "Earn $50,000 in only 90 days!! It really works!"

Sometimes, these misguided opportunists go for your emotions, such as guilt. "Why haven't you contacted me?" pleaded one. Soon, greed dominated the message, which described a program where you can "earn millions of dollars." In scam-speak, the message righteously proclaimed, "This is NOT a get-rich-quick scam." Here's one that tried appealing to a noble ideal. "The GOLDEN rule," it began. What's the golden rule it advocated? Making money by pitching the same con to millions of others. Sometimes the clueless people boggle the mind. "HAPPY BIRTHDAY," I was cheerfully greeted by one come-on, trying to entice me to read the message. Only the chances of my birthday falling that week were one in 52—terrible odds. You should delete all e-mail solicitations like these that you receive.

SPAM: JUNK MAIL EVOLVES

"If someone e-mails solicitations indiscriminately, delete them without reading," agrees Paul Edwards, co-author (along with his wife Sarah) of the book *Working From Home*—lawyer, lecturer, and perhaps the country's leading expert on home-based businesses. The reason is that unsolicited, untargeted bulk e-mail, called *spam*, has long been a violation of Internet norms. Spam uses Internet resources paid for not by the sender but by the recipient. This is why it's illegal to send junk faxes and why legislation is pending to restrict unsolicited commercial e-mail as well.

Bona fide businesses don't send spam, or if they do, they do so once and realize their mistake. Scam artists, on the other hand, send spam over and over. Don't bother asking them to take you off their list. They typically just use your e-mail response as verification that you have a working e-mail address, often selling your address to other spammers.

Unfortunately, some companies make the mistaken assumption that if you buy a product from them, they've created a "relationship" with you and are therefore entitled to e-mail you unsolicited ads. Smart companies know this angers too many customers. The best way to build an e-mail list is to ask people if they're interested in receiving e-mail from you or to buy a list of people who've already agreed to receive commercial e-mail about a particular type of product.

ON-LINE OPPORTUNITY

Many spam come-ons are for illegal pyramid schemes or similarly structured but legal *m*ulti-*l*evel *m*arketing (MLM) companies. The difference between the two is that MLM, sometimes called network marketing, involves

(Continued on page 56)

TED NEEDLEMAN

mailto: peakcomputing@gernsback.com

Top-Of-The-Line Sound

A few columns back, we looked at some of the options available in speakers for your PC. There's no doubt that adding a better set of speakers will audibly improve the quality of sound that your PC produces and that the upgrade will be affordable and easy.

No matter how good the speakers are that you purchase, however, they can only be as good as the audio quality that your sound card produces. Even if you already have a decent quality sound card installed, it may not provide some of the newest features, such as 5.1-channel Dolby Digital output.

A NECESSARY UPGRADE?

Unlike video cards, where a new generation of chipsets appears every year or so and is quickly taken advantage of by game developers, sound cards are generally not a "must-have" type of upgrade. The reasons for this are pretty basic.

The most important reason is that even an inexpensive PC usually provides a very good quality of audio for most purposes. In some cases, this audio is FM synthesis; while, in others, it's software wavetable synthesis. Your current audio may be produced by either a plug-in peripheral card or by an audio chipset contained on the PC's motherboard, or it may actually be generated by the PC's CPU under the direction of the computer's core logic chipset. In fact, a PC with embedded audio—where the audio chipset is contained on the motherboard or generated by the CPU—may be difficult to upgrade or may not be upgradable at all.

DOING THE AUDIO TWO-STEP

Before considering upgrading your audio card, there are two pieces of information you need to pull together—why do you want to upgrade and is an upgrade even possible?

The latter question is the first one to answer. Obviously, if you can't add a new audio card to your PC, the whole decision is moot. Check your manual to see what type of audio your PC provides. If it's an add-in peripheral card and if you have PCI-slots available on your motherboard, you're home free. All of the newer audio cards use the PCI-bus, so upgrading an audio card in a PC using older ISA slots is usually a waste of time and money.

Santa Cruz from Voyetra Turtle Beach features the Cirrus Logic SoundFusion Digital Signal Processor.

Even PCs with embedded audio can frequently be upgraded. You need to see whether there's a jumper on the motherboard or a setting in the system BIOS to disable the on-board audio. If there is one, you can add a new audio card. If the documentation is unclear, try checking with the PC vendor. You can also use a shareware utility such as *SANDRA* or *Dr. Hardware* to find out what type of motherboard your PC uses and then check on the motherboard manufacturer's Web site for this information.

THREE OF THE BEST

Let's take a closer look at some cutting-edge sound cards. Assuming that you can upgrade, the second question to answer is whether you should. New sound cards provide some neat features—most notably, multi-channel sound support and a variety of different outputs. If you won't take advantage of these features, why spend the money? Even an original SoundBlaster card sounds very nice when you hook up a good quality three-piece set of speakers to it.

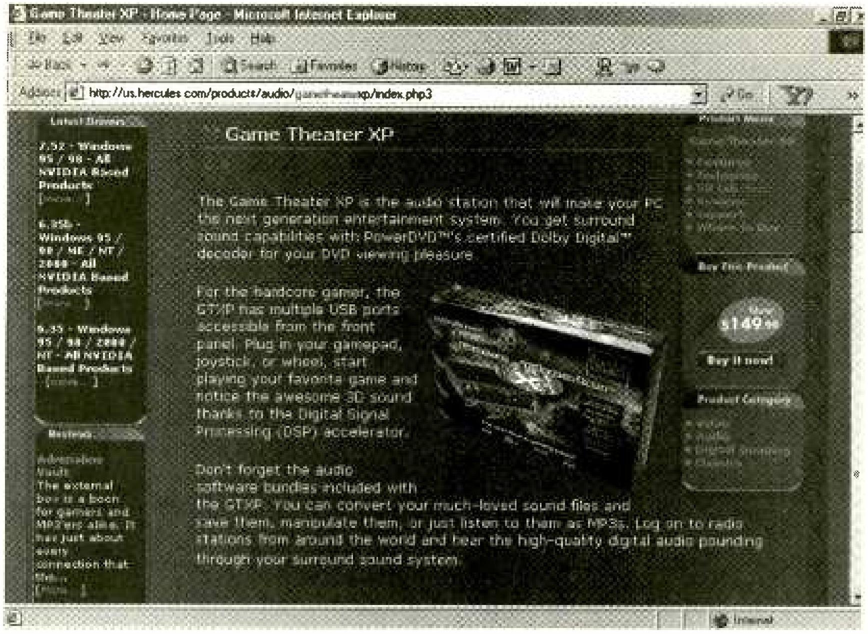
We tested a trio of sound cards from the three most popular sound card vendors. The cards we looked at aren't the only models these vendors offer—we looked at each vendor's top-of-the-line offering. After all, why bother upgrading if you aren't going to go for the best?

To be honest, there aren't a lot of vendors left in the audio card aftermarket. While there are a number of other vendors besides these three, most of them provide OEM or "white box" cards for original installation or repair, rather than upgrading.

SANTA CRUZ

The least expensive card of the trio was the Santa Cruz from Voyetra Turtle Beach. This card is widely available for about $80 or so, and it was the only one of three that didn't come with some type of additional patch bay or box. Of course, that's also why it is $50 to $100 less expensive than the other cards reviewed here.

That's about the only feature, however, that Santa Cruz lacks. The card uses a Cirrus Logic SoundFusion DSP (Digital Sound Processing) chipset, which provides hardware wavetable sound. There's 8 MB of memory avail-



Hercules has more to offer than video cards. The Game Theater XP is also designed around a Cirrus Logic chipset, and the XP moonlights as a four-port USB hub.

able for wavetables and for the card to build effects. The primary effect, of course, as with all current audio cards, is 3-D positional sound. This quality adds considerably to the realism of both games and "live" music. Santa Cruz uses the Sensaura technology to provide this positioning. The card is also compatible with Microsoft's DirectSound 3D, as well as Aureal's A3D 1.0 and Creative Labs' EAX technologies.

Other audio effects are controllable through software. This software lets you create "environments" such as a concert hall, adjusting phasing and reverb. You can even use the DSP capabilities to provide echo canceling, which is useful if you perform voice recognition. A suite of software includes the popular *AudioStation* for playing different media types and sources, *MIDI Orchestrator* and *Digital Orchestrator* for using MIDI files and devices, *Audio View* (a WAV file editor), and several sample versions of music utilities.

While Santa Cruz doesn't provide an external patch panel, it does offer a host of output jacks. These jacks allow you to get true front- and rear-channel output, as well as digital outputs for speaker systems that provide Dolby Digital. This feature allows you to use 4.1 and 5.1 speaker sets, which are almost always equipped with Dolby Digital decoders. There's an S/PDIF input, but it's a header on the card and is only for use with a CD drive that can provide digital S/PDIF output. The other two cards reviewed here have external S/PDIF I/O connectors, so they offer a bit more flexibility in this regard.

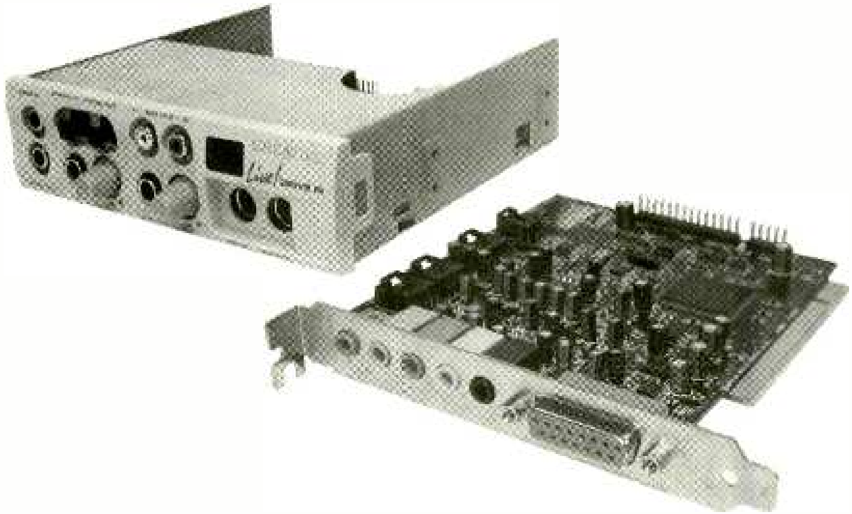
However, the real test of an audio card is not specifications—it's sound. All three cards were tested with the same set of speakers, Altec Lansing's new ATA-5. This is a terrific 4.1 set, with satellites each containing a mid-range driver and tweeter, along with a fairly hefty subwoofer. It provides Dobly Digital decoding for excellent front- and rear-channel separation and positioning.

Santa Cruz installed easily; but it does require several IRQs, which may present a problem if your PC is heavily loaded with peripheral cards. Other than this, installation is easy. The VersaJack—the top one on the card's rear panel—is software controlled to provide several different types of output, including AC-3 Dolby Digital. Once this was set, the ATA-5s kicked in with outstanding sound on all of the media we tested including games, music, and DVD movies. If you don't need the patch panels, the Turtle Beach Santa Cruz would be an excellent and affordable choice.

GAME THEATER XP

One notch up in price and features is the Game Theater XP from Hercules. Hercules was famous for its video cards for many years, but they went belly up a few years ago. Guillemot, the Canadian vendor that is also well known for its audio and video cards, purchased the name. Guillemot has already breathed new life into Hercules with a complete line of excellent video cards. The Game Theater XP is a top-of-the-line card for both gamers and other home users who need excellent audio quality as well as superior connectivity.

The Game Theater XP uses the same Cirrus Logic SoundFusion chipset that the Santa Cruz card employs, so its capabilities are similar. Unlike the Santa Cruz card, however, there's only one connector on the Game Theater XP. You use this connector to attach an included cable between the card and a modest-sized box that sits on your desk or on the top



The latest and greatest product from Creative Labs is the SoundBlaster Live Platinum 5.1 Edition. The Platinum incorporates the LiveDrive II—an innovative interface that fits into a standard 5.25-inch bay.

SOURCE INFORMATION

Creative Labs, Inc.
1901 McCarthy Blvd.
Milpitas, CA 95035
408-428-6600
www.soundblaster.com
CIRCLE 110 ON FREE INFORMATION CARD

Hercules, Inc.
877-484-5536
www.hercules.com

Voyetra Turtle Beach, Inc.
5 Odell Plaza
Yonkers, NY 10701
800-233-9377
www.voyetra-turtle-beach.com
CIRCLE 111 ON FREE INFORMATION CARD

of your tower-style PC. This box, which Hercules calls a "rack," is overflowing with connectors—a game player's and audiophile's dream!

The front of the rack is deceptively sparse. There are line-in jacks, a microphone jack, and a headphone jack—the last two with volume controls. A DB-15 connector is provided for game controllers. With recent versions of Windows, including Windows 98/ME/ and Windows 2000, there are a pair of USB ports, giving you an easy place to plug in a USB peripheral.

On the rear of the "rack," there are even more connectors, including another pair of USB ports and the connector for the cable to the Game Theater XP card. There are also outputs for up to six speakers, a set of mini-DIN MIDI ports, and digital inputs and outputs.

Add in the really large collection of software, and the $149 suggested retail price of the Game Theater XP doesn't feel excessive. As with all three of the cards we tested, sound quality and positioning from the Game Theater XP was excellent.

SOUNDBLASTER LIVE! PLATINUM 5.1

Finally, we tested the Creative Labs SoundBlaster Live! Platinum 5.1 Edition. With a retail price of just under $200, this was the most expensive of the three.

Creative's SoundBlaster was one of the first sound cards available for the original IBM PC, and Creative Labs is the only vendor to have survived from that time. The SoundBlaster Live!, in its different incarnations, is the most popular OEM sound card—if you've recently bought a higher-end PC, chances are good there's already a SoundBlaster Live! in it. The Live! Platinum 5.1 uses Creative's own EMU10K1 chipset, which provides hardware wavetable generation and Creative's EAX audio-effects control. As with the other cards we tested, you can adjust parameters such as reverb, chorus, and the like.

Different models of the SoundBlaster Live! are available, and the $200 Platinum 5.1 is the most expensive. That's because this model includes LiveDrive II—a panel that fits into an open 5.25-inch drive bay and provides a number of I/O connectors on the front of the PC. Creative was the first vendor to pioneer this technology, with the original LiveDrive. Included are RCA jacks for I/O, optical connectors for using fiber-optic connections to home-theater components that support this technology (or to a Sony PlayStation 2, which also has optical connectors available), coaxial S/PDIF input and output jacks, mini-DIN MIDI connectors, and several volume controls. Unique to the LiveDrive II is a small infrared remote control that you can use to both switch between outputs and control the volume.

As with the other cards tested, the Platinum 5.1 produces outstanding quality sound and comes with a large bundle of software. Because it requires the installation of the LiveDrive, it needs an empty 5.25-inch drive bay and takes a bit longer to install. The actual installation, however, should pose no problem for any reader who has ever installed an upgrade card or disk drive.

YOU PAYS YOUR MONEY...

All three of these upgrade possibilities are excellent choices to get the best sound quality at an affordable price. None of them are difficult, or particularly time-consuming, to install. Keep in mind, however, that unless you are willing to also upgrade your speakers to take advantage of the new capabilities offered (or have already done so), a less expensive upgrade might make better financial sense. P

In-Circuit Capacitor Tester

MARVIN SMITH

I've spent a lot of time finding bad electrolytic capacitors in the TVs, VCRs, and camcorders I repaired. A few were shorted. Most had developed high *E*quivalent *S*eries *R*esistance (ESR). That's an internal resistance in series with the capacitance. Result: The capacitor has high impedance and does not function properly. A regular capacitance meter isn't helpful because it measures only capacitance, not ESR. If you did want to measure the capacitance, the meter indication could be affected by components tied to the capacitor; to get an accurate measurement, you sometimes have to use your soldering iron to lift (isolate) the capacitor. Then if the capacitance is correct, you have to re-solder it back on the board. This is a most tedious task. Some capacitance meters can't even measure above 20 µF, so you'd be stuck if you had to test a large-valued capacitor, like 470 µF. Build the *In-Circuit Capacitor Tester*, and you'll speed up your repairs by being able to test capacitors of 1 µF or above right on the circuit board.

Improving On An Old Idea. In-circuit capacitor testers are nothing new. You'll find ads for in-circuit capacitor testers—sometimes called "ESR meters"—in electronic hobby and servicing magazines; I'm sure they do a good job. However, there are advantages to the tester described here. Cost, for one—the parts cost about $60, and most are available from RadioShack. Some of the advertised meters can't detect shorted capacitors—this one can. Some can be damaged if you don't discharge the capacitor before connecting the probes. Don't worry with this tester—back-to-back diodes across the input discharge the capacitor for you and protect the tester. To prove this feature, I connected the probes across a 470-µF capacitor charged to 150 volts with no damage; I drew quite a spark, but the meter still works! A word of caution: Even though the meter won't be damaged by charged capacitors, **DO NOT** test capacitors in units with power on—you could damage the unit you're repairing (that would be a bad move).

When Good Electrolytics Go Bad. If you looked inside an aluminum electrolytic capacitor, you would see two foil strips and a paper insulator strip rolled into a cylindrical element. The paper insulator is soaked with a critical part of the capacitor—the moist electrolyte. Figure 1 shows an equivalent circuit of a capacitor. The ESR, which combines the resistance of the leads, the foils, and the electrolyte, is shown as a resistor in series with the capacitance. If the electrolyte dries out, the ESR increases and the capacitance decreases. The electrolyte can dry out because of high temperatures caused by high ripple currents, or a bad end seal may let it leak out. Loss of electrolyte results in an *open* capacitor, the most common failure. Less often, the capacitor may develop a short between the foils. The CONDITION meter will indicate 0 for open capacitors, and the SHORT LED will light for shorted ones. Some capacitors fail simply because they have reached the end of their estimated life. One manufacturer guarantees a certain line of their surface-mount capacitors for 2000 hours—that's only three months!

This technician's gadget lets you test capacitors right on the circuit board and speed up your repairs.

How The Tester Works. The tester generates a 100-mV, 100-kHz square wave with an impedance of 22 ohms across its probes. The tester doesn't measure capacitance—it displays on the CONDITION meter how well the capacitor bypasses this 100-kHz signal. Note that both the ESR *and* the capacitance must be good for the capacitor to test well. So, in effect, the tester is verifying the capacitance.

The schematic of the tester is shown in Fig. 2. The tester comprises a 14-pin quad op-amp, three transistors, three diodes, 21 resistors, six capacitors, a potentiometer, a 0–100 microammeter, a 9-volt battery, an LED, and an on/off switch.

Op-amps like to be powered by equal plus and

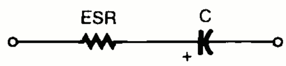
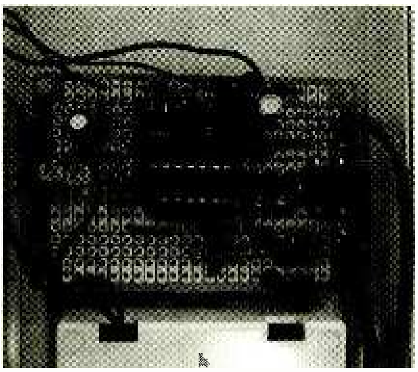


Fig. 1. Placing a resistor and capacitor in series demonstrates the principle of Equivalent Series Resistance. ESR is often the cause of faulty electrolytic capacitors.

minus voltages. A standard 9-volt battery powers the tester; however, we want ± 4.5 volts referenced to ground. Op-amp IC1-a generates the ± 4.5 volts for the tester. Resistors R1 and R2 are connected in series across the battery, and the midpoint is connected to pin 3 of IC1-a, the non-inverting input of IC1-a. The output at pin 1 of IC1-a is tied to the inverting input at pin 2 of IC1-a, and *connected to ground*. This does not short out the op-amp or cause high currents.

Op-amp IC1-a is connected in the negative feedback configuration, because the output is tied to the inverting input. Normally, an op-amp will adjust its output to make its input voltages equal. However, here the output is tied to ground. Therefore, the op-amp does the only thing it can—it regulates the voltage at its *power supply pins* to place the midpoint of R1 and R2 at 0 volts. Since R1=R2, half of the battery voltage is above ground and half below; thus, we have our ± 4.5 volts. Capacitors C1 and C2 suppress oscillations and provide bypassing for the ± 4.5 volts. This circuit configuration is a simple way to *split* a battery into equal plus and minus voltages, provided the difference in the plus and minus currents drawn by the circuitry doesn't exceed the output current capability of the op-amp.



This extreme close-up shows the component placement inside the In-Circuit Capacitor Tester. Following along with the schematic, readers can even use a breadboard to construct this unit.

Op-amp IC1-b is connected as an astable-multivibrator and generates a key signal—an 8-volt peak-to-peak 100-kHz squarewave. Resistor R6 couples this to the base of Q1, the driver for Q2. The waveform at Q2-C, a 0 to +4.5-volt 100-kHz squarewave, is connected to bridge resistors R9 and R11. The voltage at the junction of R9 and R10, and at the junction of R11 and R12 is a 0 to +100-mV squarewave with an average DC value of +50 millivolts. As you'll see later, this DC offset allows us to detect shorted capacitors.

Op-amp IC1-c is a differential amplifier with its input resistors, R13 and R15, connected to the 22-ohm bridge resistors. Its gain amplifies the millivolt-level 100-kHz bridge signal to drive the CONDITION meter and the SHORT LED. The non-inverting input always *sees* this reference signal. The inverting input is connected to the junction of R9 and R10. The probes are connected across R10. When the probes are open, the bridge is balanced; the inputs to the differential amplifier are equal; and the CONDITION meter indicates 0. When you connect the probes across a good capacitor, it kills the AC waveform at the inverting input, but leaves the average DC value of 50 mV. The bridge is now unbalanced according to AC standards; a 3.6-volt peak-to-peak waveform appears at pin 8 of IC1-c, and the meter indicates 100. If the capacitor is shorted, the bridge is not only unbalanced AC-wise, it is now unbalanced according to DC standards—the inverting input now sees 0 volts instead of the average level of 50 mV. The 50-mV average reference signal at the non-inverting input shifts the 3.6-volt peak-to-peak waveform at pin 8 of IC1-c up to an average of +2 volts; this turns on Q3 and lights the SHORT LED. IC1-d and D3 rectify the 100 kHz signal from IC1-c to supply the DC current for the CONDITION meter.

Construction. You can choose your own enclosure, but I recommend the 4- × 6-inch hand-held case and the circuit board mentioned in the parts list. The case has a compartment for the 9-volt battery, and the board has printed circuit pads for soldering the parts. Room is at a premium, but all parts will fit into the case if you carefully position the parts on the cover and on the board. Refer to the internal photo of the tester as a guide.

Refer to the photograph to see

PARTS LIST FOR THE IN-CIRCUIT CAPACITOR TESTER

SEMICONDUCTORS

IC1—TL084ACN quad op-amp, integrated circuit
Q1, Q3—2N3904 NPN transistor
Q2—2N3906 PNP transistor
D1, D2—1N5404 3-amp silicon rectifier diode
D3—1N914 general-purpose silicon diode
LED1—Light-emitting diode, 2 mA low current, red

RESISTORS

(All resistors are ¼-watt, 5% units.)
R1, R2, R3, R4—10,000-ohm
R5—1500-ohm
R6—68,000-ohm
R7, R14, R16, R17—47,000-ohm
R8—12,000-ohm
R9, R11, R13, R15—1000-ohm
R10, R12—22-ohm
R18—47-ohm
R19—7500-ohm
R20—15,000-ohm
R21—750-ohm
R22—5000-ohm panel-mount linear-taper potentiometer (Calrad 25-301 or similar)

CAPACITORS

C1, C2—10-µF, 25-WVDC, electrolytic
C3—0.001-µF, ceramic disc
C4—0.1-µF, ceramic disc
C5, C6—1-µF, 50-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS

Plastic case, 4- × 6-inch (RadioShack 270-213 or Pac Tec K-HP-9VB or similar)
PC circuit board (RadioShack 276-150 or similar)
M1—0 to 100 microammeter (Calrad 60-166 or similar)
S1—Miniature SPST switch (GC 35-006 or similar)
9-volt battery
Knob, ¼-inch bushing

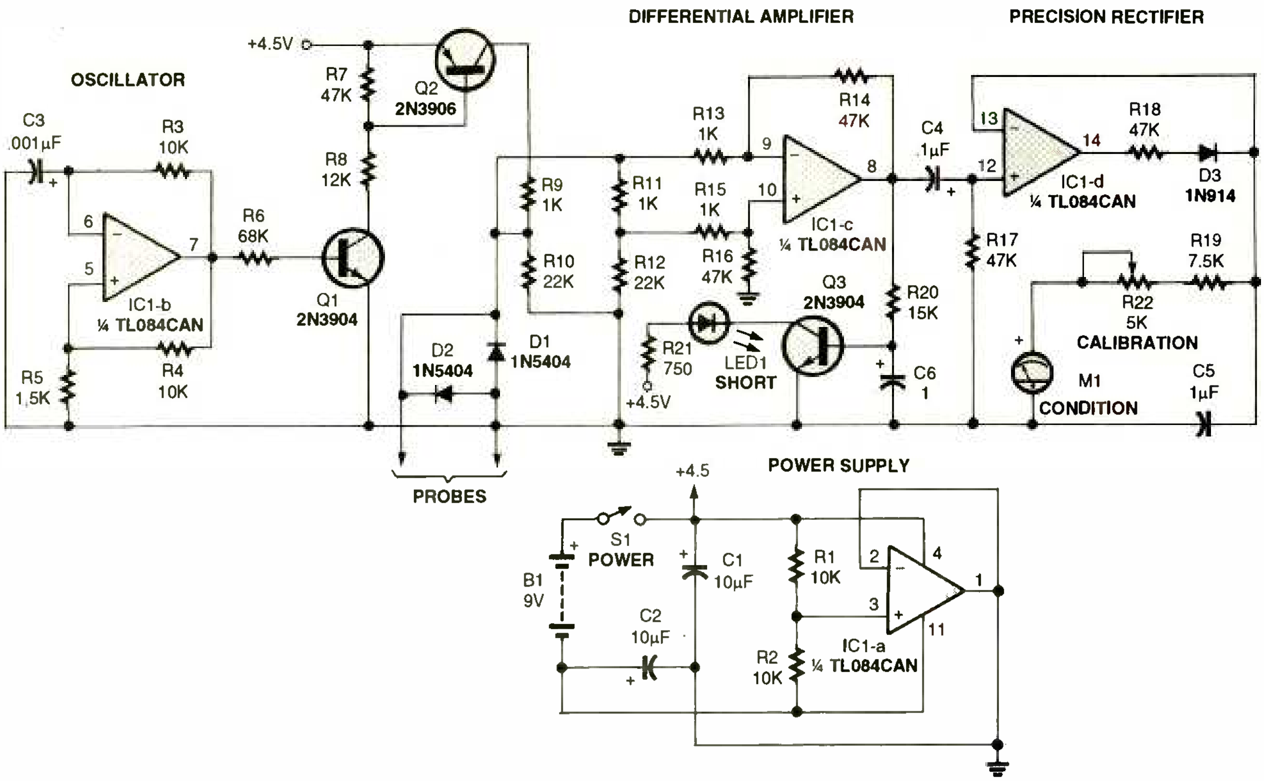
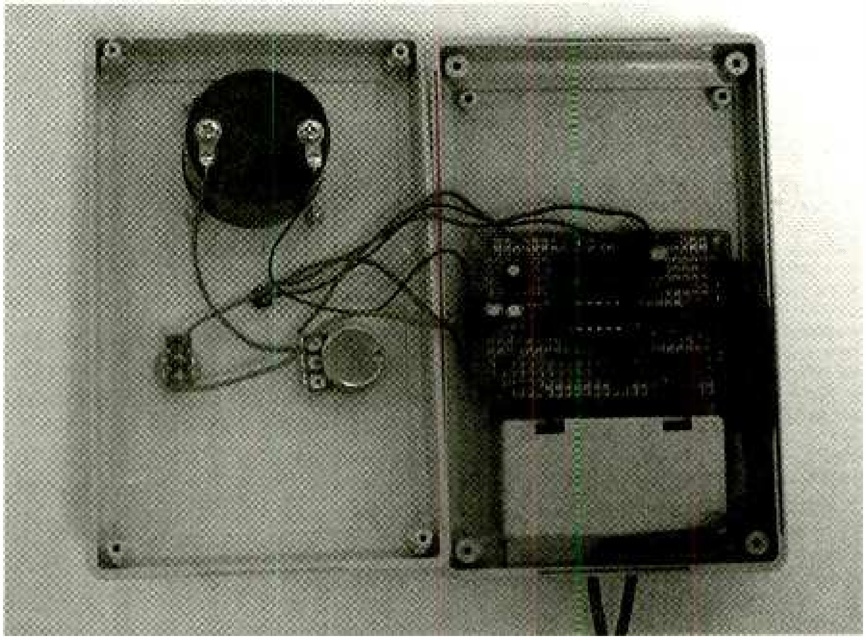


Fig. 2. The In-Circuit Capacitor Tester is simple in design and highly effective. The schematic above shows the complete circuit that is centered around a quad op-amp.

how the completed unit is assembled. The first thing to do is temporarily mount the board to the bottom of the case with a screw. You will then remove the board to mount the components. There is a pre-drilled post molded in the bottom of the case next to the battery compartment. Find a miniature screw that will self-thread the hole in the post. Center the board and position it no more than ⅛-inch from the battery compartment. This will leave room for the meter body. Mark the board hole closest to the post hole and drill out the board hole to clear the screw body. Temporarily mount the board on the bottom with the screw. With a pen or pencil, draw a circle around the head of the screw. Keep board components clear of this circle so they won't interfere with the screw when you install the completed board.

Your biggest challenge is to make the meter hole in the cover. The meter in the parts list fits in a 1½-inch diameter hole. Use a hole saw to make the cleanest hole, but be sure to use a piece of wood under the cover for support. For the SHORT LED, drill a hole slightly smaller than the diameter of the LED, and then ream or file the hole for a press fit. Use dry transfer letters for the labels on the top cover, and then spray the cover with clear acrylic to bond them. Drill two holes slightly larger than the probe leads in the bottom—½-inch apart and about 3/16-inch below the top edge.

When mounting the components on the board, leave the lower left area of the board free for the potentiometer. Refer to Fig. 2 for the circuit schematic. A close-up photo shows the components mounted on an experimenter's



The author's prototype has been opened to reveal its inner workings. The LED, meter, calibration knob, and power switch are all mounted on the unit's cover.

board. Drill larger holes for the oversize leads of D1 and D2. Use press-in terminals in the pads for D2 for soldering the probe leads. Connect the board pads with insulated solid wire; 26 gauge is a good size to use. The pads are close together, so watch for solder bridges. Because of the low-output impedance of the tester (22 ohms), the probe leads are soldered directly to terminals across D2; banana jacks would add noticeable contact resistance.

Testing. Set the POWER switch off. Rotate the CAL control counterclockwise. Connect the 9-volt battery and insert it in the compartment. With the probes open, set the POWER switch on; the CONDITION meter should indicate 0 and the SHORT LED should be off. Touch the probes together; the meter should indicate near full scale and the SHORT lamp should come on. With the probes touching, adjust the CAL control for a meter indication of 100. If the tester doesn't do this, set the POWER switch off and check the wiring. If the wiring appears to be correct, see Table 1 and use a scope to verify the signals at these key points referenced to ground.

TABLE 1

Test Point	Signal
IC1-1	0 V_{DC}
IC1-2	0 V_{DC}
IC1-3	0 V_{DC}
IC1-4	+4.5 V_{DC}
IC1-5	1-volt peak-to-peak 100-kHz squarewave
IC1-6	1.4-volt peak-to-peak 100-kHz triangle waveform
IC1-7	8-volt peak-to-peak 100-kHz squarewave
C1-11	-4.5 V_{DC}
Q2-C	0 to +4.5-volt 100-kHz squarewave
Junction of R9, R10	0 to +100-mV 100-kHz squarewave
Junction of R11, R12	0 to +100-mV 100-kHz squarewave

If the above signals are correct, check the voltage at IC1-8. With the probes open, the voltage should be 0 ± 0.2 volts. Touch the probes together; the signal at IC1-8 should be a 3.6-volt peak-to-peak 100-kHz-rounded squarewave at an average level of +2 volts, and the SHORT LED should be lit.

Application. Simple. Set the POWER switch on. Touch the probes together; the SHORT lamp should come on. With the probes still touching, adjust the CAL control for a meter indication of 100. You're now ready to run down those bad electrolytics. Just connect the probes across a suspect capacitor and see what the meter indicates. Polarity doesn't matter; the low 100-mV output will not forward-bias capacitors or surrounding components. In fact, both probes and their leads can be red. The meter doesn't indicate the actual current through the capacitor, but shows the *condition* of the ESR and the capacitance. Think of the meter indication as a grade for the capacitor—as in school, 100 is very good, 20 is poor. For a good grade, both the capacitance *and* ESR must be good.

You'll find that a good capacitor will not always give a full-scale indication. All capacitors have *some* ESR. Most good axial or radial capacitors above 1 µF will give a meter indication of 95 or higher. Physically small capacitors have high ESR. Some new surface-mount capacitors give an indication of around 60, so it's always best to test a known-good capacitor of the same type as the one in the unit under repair and see what the indication should be. A safe rule is to replace a capacitor if the meter indication is under 50. Some capacitors are obviously bad—they don't even move the meter!

The tester circuitry draws 15 mA from the 9-volt battery. At this rate, the battery should last about 30 hours. Replace the battery when you can't set the meter to 100 with the CAL control.

The MPX 2000

WILLIAM SHEETS and RUDOLF F. GRAF, KA2CWL

The *MPX 2000* is a multi-feature FM stereo transmitter that offers full coverage of the 88–108 MHz band in 100-kHz steps. This unit is intended for use by hobbyists, experimenters, and others needing a low-power short-range FM stereo transmitter. The left and right audio channels may be used independently to transmit two separate audio channels. The MPX 2000 is also suitable for hobby Part 15 operation where a transmitter with digital frequency readout and keypad entry of frequency is desirable.

This low-powered unit is fully crystal controlled. The pilot and subcarrier signals are both generated from a quartz crystal. A phase-locked loop (PLL) system assures frequency accuracy and crystal stability; while the use of a keypad and microprocessor permit ease of frequency entry without having to set jumpers or switches, ensuring that the programmed frequency will be correctly produced.

Stereo Transmission. When FM stereo transmission was introduced back in the 1960s, there were millions of monophonic FM receivers in use. Whenever anything new is introduced into a mass market, it is desirable to maintain compatibility with existing equipment and not make it obsolete. The new stereo system had to be backwards compatible with mono FM. The new stereo transmissions had to be received by existing mono receivers as monophonic audio, much like color TV transmissions were received as black and white on the millions of black-and-white TV sets still in use. What this meant was a stereo audio format was necessary, whereby the main audio channel was transmitted as the sum of left and right (L+R) audio channels. In addition, a signal is also transmitted that is the difference of the channels (L-R). By adding the signals, the right channel cancels, and the left channel alone appears. By subtracting the (L+R) and (L-R) signals, the left channel cancels; and the right channel similarly is now obtained. A mono receiver would reject the (L-R) component and reproduce only the (L+R) component as a mono signal.

The trouble is that the sum and difference channels (L+R) and (L-R) both are audio that occupies the baseband of 20 to 15000 Hz. Using analog methods, in those pre-digital days, there was no way to separate the channels as is. What was done was to superimpose the difference (L-R) component on a subcarrier in the ultrasonic range, where it would be inaudible. A pilot carrier must also be transmitted to assist in demodulating this subcarrier back to audio. The stereo receiver has to extract this subcarrier and pilot signal, process them to recover the (L-R) difference signal as audio, and then perform the adding and subtracting (called matrixing) to obtain the separate L and R channels. Then two audio channels (L and R) and two speakers can be used to obtain true stereo reproduction.

Command the FM band with this do-it-yourself transmitter.

A stereo-generator system must be used to process the incoming audio channels into a form suitable for transmission by a standard FM transmitter on a standard FM channel 200 kHz wide, with 75-kHz peak deviation. The usual pre-emphasis and deviation limiting must be provided for, and the frequency response of the audio should not be degraded from standard mono transmissions. Since available deviation is limited by FCC regulations to 75 kHz, the L and R channel total audio must not ex-ceed that for an equivalent mono channel. In addition to the pilot signal, some provision must be made for the use of auxiliary subcarriers, such as SCA transmissions on 67 or 92 kHz.

The circuitry needed for all this processing, while using quite a few components, is quite simple and straightforward. It involves only low frequencies and is easily implemented with just a few ICs and transistors. Indeed, there once existed an IC that did the whole job (BA1404 or BA1405), but this IC has suffered the fate common to many ICs—discontinuance. Thousands of hobbyist stereo FM transmitters both in kits and individual projects were constructed around the BA1404/BA1405 ICs. While they may be available in surplus for a few years, they have no future, as there is little mass-market demand for these chips. While they were OK for low-end uses, real FM stereo

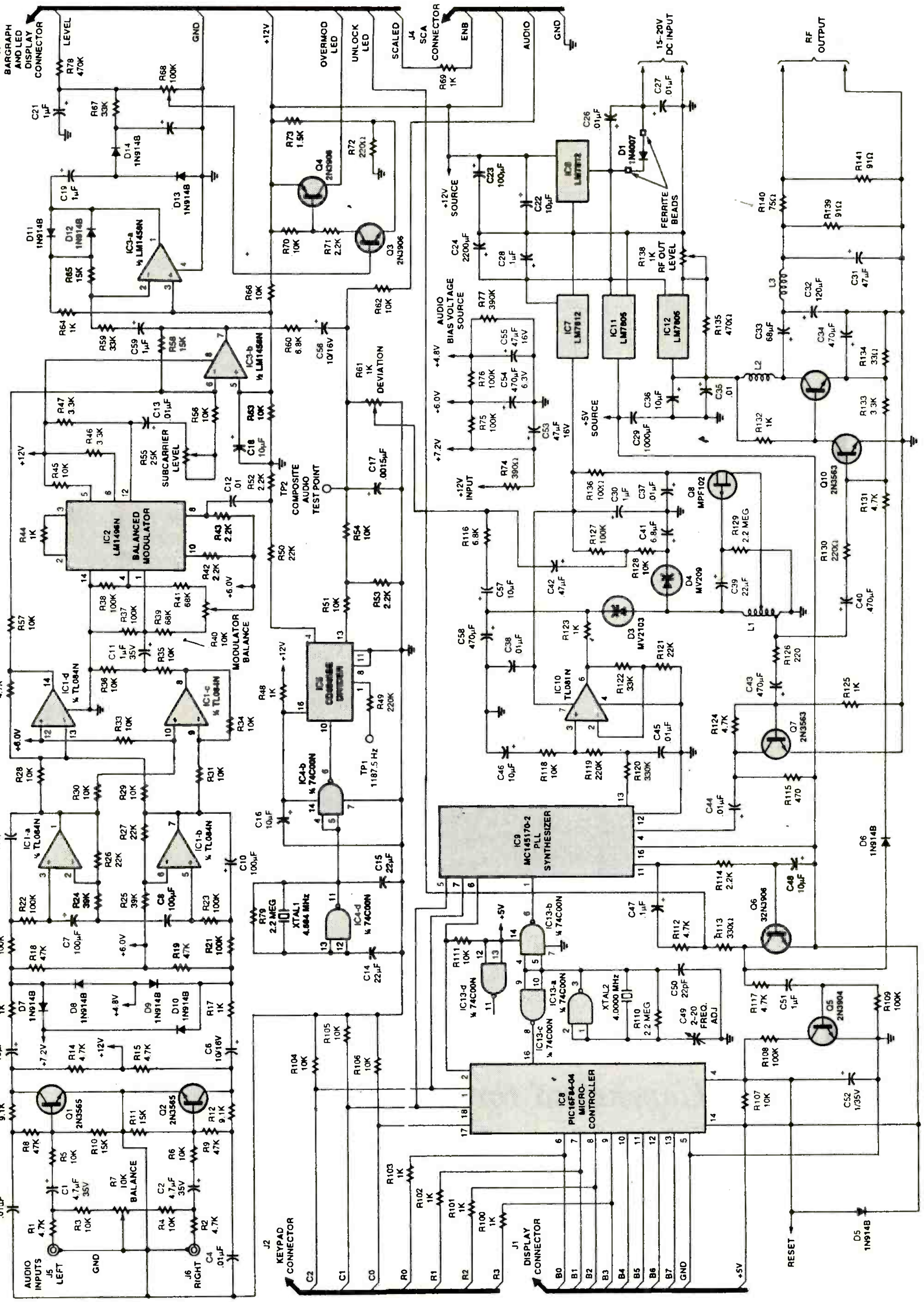


 Fig. 1. This is the schematic diagram outlining the circuitry for the MPX 2000.

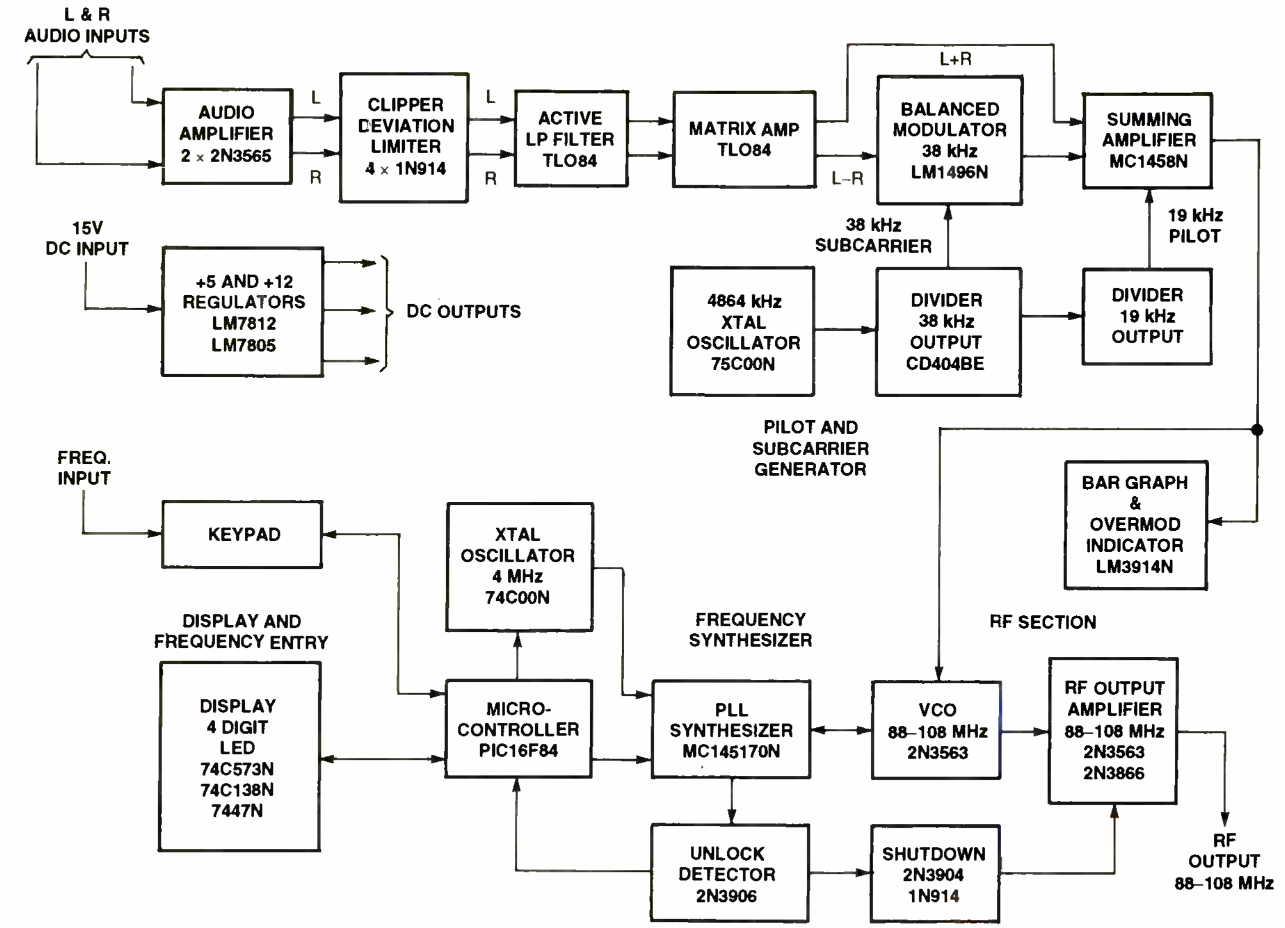


Fig. 2. A detailed block diagram—like this one depicting the signal flow within the MPX 2000—is a vital tool in designing and troubleshooting complex circuits.

demands performance and signal-to-noise ratios beyond the capabilities of these chips. Today, it is not difficult to build a stereo generator using discrete transistors and a few "classic" IC devices widely available from several manufacturers, together with a handful of resistors and capacitors that will give "broadcast quality" stereo sound to a LP hobby transmitter. In addition, all waveforms are accessible for study and for learning how the stereo system works.

Stereo Generation. The stereo generation process is as follows: The two input channels L and R (left and right) are first fed to a preamplifier where the audio is amplified and pre-emphasized. This means that higher frequencies are boosted relative to lower frequencies by a controlled amount. This improves the signal-to-noise ratio (s/n) of the received audio. In the receiver, exactly the opposite is done (de-emphasis), which reduces high-frequency receiver noise and produces an overall improved s/n and, therefore, "cleaner" high frequencies. In US FM practice, a high-pass filter with a corner frequency of 2.1 kHz, corresponding to an R-C circuit time constant of 75 microseconds, is used. Therefore, below about 1000 Hz no alteration is made to the audio. At 1 kHz a boost of around 1 dB occurs, at 2.1 kHz a boost of 3 dB, and at 4.2 kHz a boost of 7 dB, and so on, at 6 dB per octave, until 15 kHz.

The audio then is limited in amplitude by a limiter, generally a diode peak clipper, to protect against overmodulating the transmitter. This is done for both L and R channels. Program input should be limited in frequency to 15 kHz to avoid artifacts and aliasing effects and to make the job of the lowpass filter easier. The stereo-generation process assumes that no input frequencies above 15 kHz will be present. Next, a low-pass filter is used to reduce audio components above 15 kHz, both input and those resulting from any clipping. In European systems, a pre-emphasis time constant of 50 microseconds, corresponding to a zero at 3.15 kHz, is used instead of 2.1 kHz.

Next, the processed audio channels are added and subtracted algebraically in a matrix amplifier circuit. The L+R and L-R signals are now generated. The L+R signal is the main component of the "baseband" signal and is fed to a summing amplifier where it is combined with other components to be discussed later. The output of this summing amplifier is fed to the transmitter audio input.

The difference L-R signal must be separated in frequency from the L+R signal in order to keep them separated while being transmitted on the same channel. This is done by transforming the L-R signal into a double-sideband suppressed-carri-

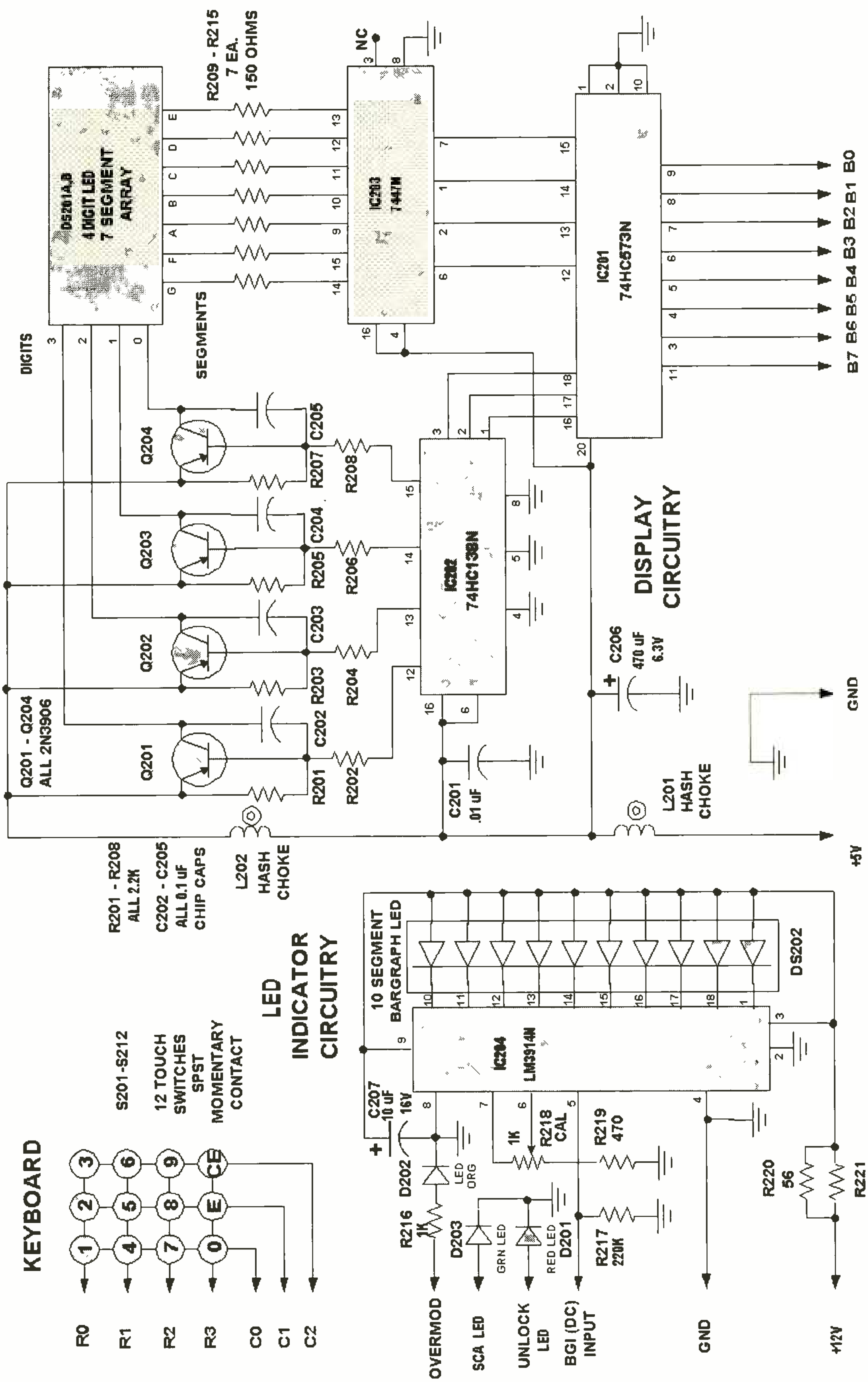


Fig. 3. This is the schematic for the display-board circuitry

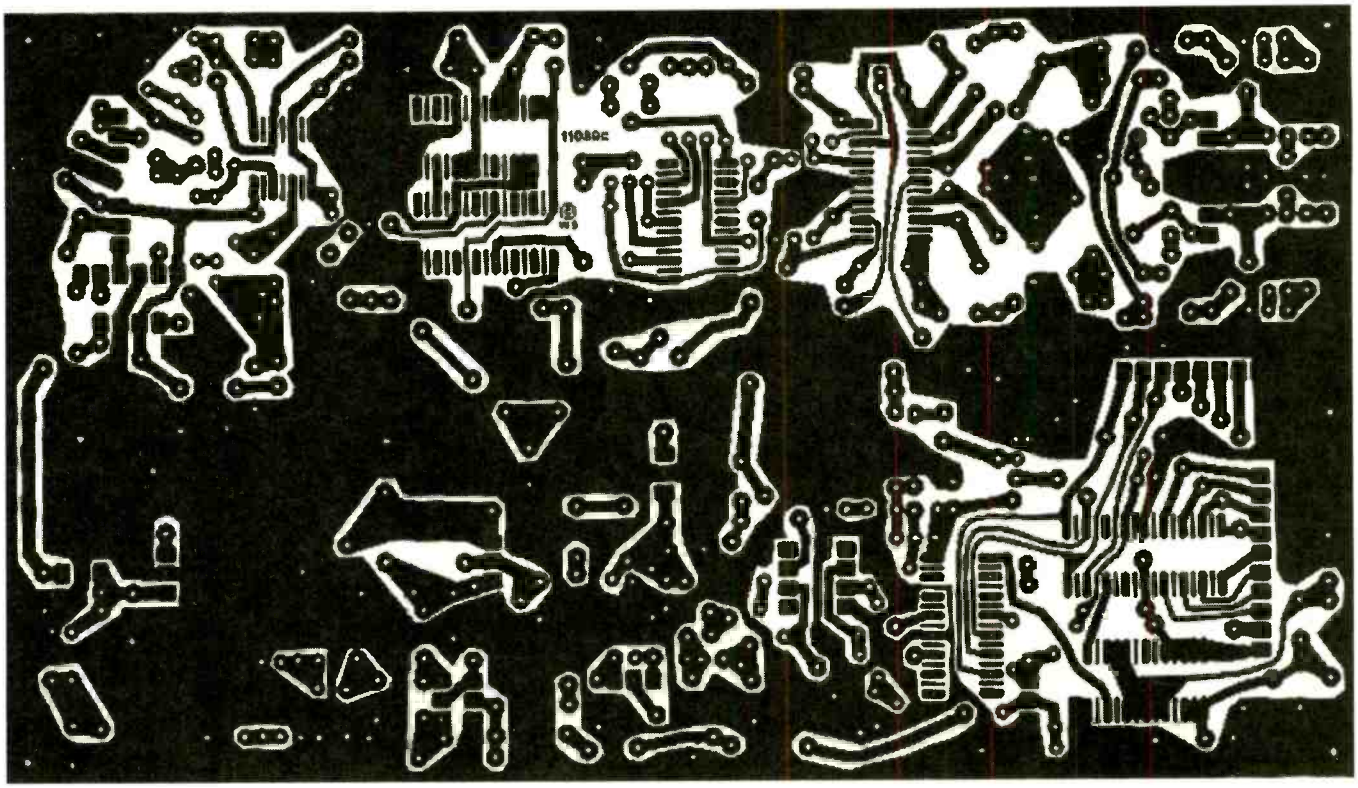


Fig. 4. Here is one of the foil patterns for the mainboard. The MPX 2000 uses a double-etched board..

er AM signal at a frequency high enough so its lowest frequency components will be far above the highest frequency components in the main L+R signal. A balanced modulator circuit is used for doing this operation. A carrier frequency of 38 kHz has been standardized for this purpose, and a pilot signal of half this frequency at 19 kHz is also generated.

The pilot signal can be doubled at the receiver and used to generate a local 38-kHz signal for demodulation of the subcarrier into L-R audio, and it can also be used to signify the presence of stereo audio. Also, the pilot carrier is used by some receivers as a signal to switch from mono to stereo and back to mono if the pilot at 19 kHz falls below a minimum level, indicating insufficient signal for good stereo reception. For TV stereo audio, 31.468 kHz and 15.734 kHz—2X and 1X the horizontal scan frequencies—can be used if the audio response is limited to about 12 kHz or so. A double-sideband suppressed-carrier signal is used because if a standard AM signal were used, the carrier at 38 kHz would "hog" a large part of the allowable deviation of 75 kHz total permitted. This result would reduce the available deviation for the sideband components, which really carry the desired audio information the FM. In addition it would reduce the signal-to-noise ratio and contribute a filtering problem by getting rid of the carrier component at 38 kHz, while keeping the higher frequency audio components at 10–15 kHz relatively "clean."

The audio out of the balanced modulator has components from 23 to 53 kHz. This corresponds to the sum and difference of the audio components at 0 to 15 kHz with the 38-kHz subcarrier (which is suppressed). This signal, together with the 19-kHz pilot signal, is fed to the summing amplifier. The pilot carrier and the subcarrier frequencies must be held to within one hertz or so. This is not as bad as it sounds, about 52 parts per million for the pilot carrier and 26 parts per million for the subcarrier. Since the subcarrier is referenced to the pilot, the 52-PPM tolerance at 19 kHz can easily be held with a crystal-controlled oscillator. The 38-kHz signal can be generated and then divided by two to get the 19-kHz pilot.

Although crystals for 38 kHz are available, they can be delicate and sometimes expensive. A crystal in the 2- to 6-MHz range is, by contrast, cheaper, more rugged, and easily available. Therefore, the best approach is probably to use a crystal in the MHz range and use a CMOS divider chip to divide the higher frequency by some power of two to get 38- and 19-kHz signals. This approach is used in our MPX 2000. A 4.864 MHz crystal is used in an oscillator. Its frequency is divided by 128 to get 38 kHz and then again by two to get 19 kHz. The outputs from the divider are square waves, but the balanced modulator used to generate the subcarrier needs a square wave, anyhow. The pilot is inherently filtered by the bandwidth of the audio system. Only two common digital CMOS ICs are used in this circuit, and cost is very low.

The output from the summing amplifier has the following spectral components:

The sum of the L and R channels (L+R) consisting of audio program components up to 15 kHz. This is the part received and used by mono FM receivers.

A pilot signal at 19 kHz of sufficient

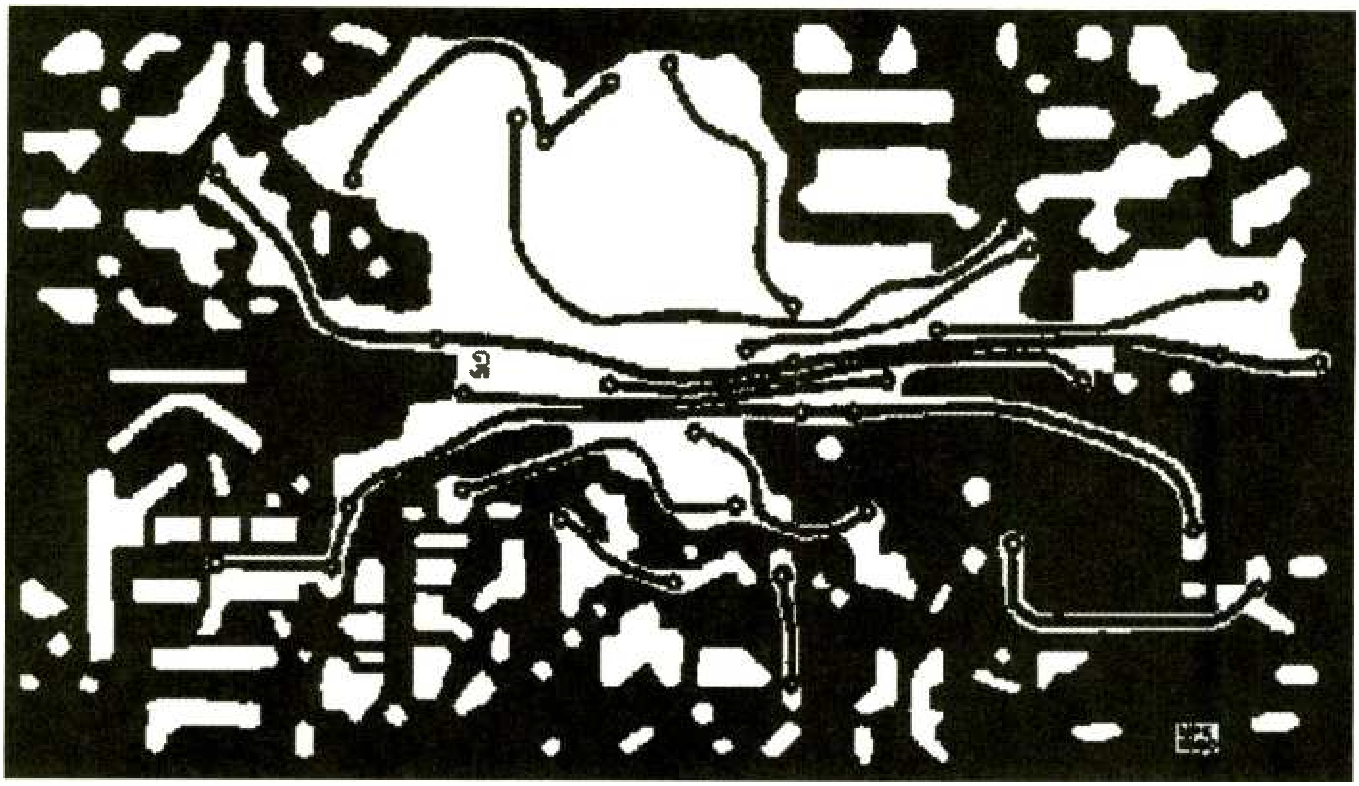


Fig. 5. This is the foil pattern for the other side of the main PC board. The double-sided design makes it easier to distribute the DC voltages needed to run the transmitter.

amplitude as to produce around 10 percent of the total deviation permitted for the transmitter. This signal is used for stereo detection and for regeneration of the 38-kHz subcarrier at the receiver

A double-sideband suppressed-carrier signal having frequency components from 23 to 53 kHz, which carry the L-R signal needed by the stereo receiver

Optionally, subcarriers at 57, 67, or 92 kHz used for data transmission or for SCA programming for use by private organizations. The MPX 2000 is ready to support this mode with an external SCA generator.

Therefore, an FM stereo transmitter must have modulation capability up to as high as 100 kHz, with reasonable flatness of frequency response. Ideally, frequency response should be flat with constant time delay vs. frequency, which implies a linear phase response vs. frequency. Distortion, both harmonic and intermodulation, should be kept low to avoid crosstalk and unwanted spurious mixing products, which interfere with audio programming. These components may show up as noise, whistles, audio artifacts, or loss of separation. Additionally, distortion on the transmission path between transmitter and receiver must be avoided as much as possible for best stereo reception. Multi-path transmission effects that occur at VHF frequencies can cause severe distortion and ruin stereo reception. Antennas used with FM stereo transmitters and receivers must have adequate bandwidth (rarely a problem) and enough gain to ensure adequate received signal.

Circuit Signal Flow. The MPX 2000 circuitry will now be discussed. Refer to the schematic shown in Fig. 1 and the block diagram shown in Fig. 2 for this discussion. Audio input at line level (1 volt peak-to-peak at a 500- to 10,000-ohm impedance) is fed into jacks, J5 and J6, which are left- and right-audio input channels, respectively. Resistors R1 through R4, with R7, make up an input network, and R7 is used to obtain an equal audio gain for both L (left) and R (right) channels. Q1 and C1, along with resistors R5, R8, R10 and R14, all make up the L audio preamp, which has a gain of about 5 at 1000 Hz. Gain is shaped to produce a 75-microsecond pre-emphasis standard on FM receivers used in North America. The R channel is identical (Q2 and associated components). Capacitor C5 and resistor R16 feed amplified audio into a clipper consisting of diodes D7 and D8. These are biased by voltages from the network formed by R74, R75, R76, and R77. Audio is limited to 3 volts peak-to-peak by these diodes. The R channel uses the same circuitry. The purpose of the clipping is to prevent exceeding the maximum deviation (75 kHz) with excessive audio input. The clipper acts as an audio limiter. Next, both channels are fed into a 2-pole active filter consisting of a quad op-amp, IC1, a TLO84N; resistors R20, R22, R24, and R26; and capacitors C7 and C9 (left channel). The right channel has identical circuitry. The active filters cut off at 15,000 Hz and serve to reduce aliasing distortion.

The audio signals are fed to a matrixing network using the other two sections of IC1. In one amplifier, the L and R channels are summed to produce the signal

(L+R) and the signal (L-R). Both signals are necessary for stereo generation. The signal (L+R) is the main monophonic channel that occupies the band 20 to 15,000 Hz, and it is the signal received in a monophonic FM receiver. This allows stereo to be received as mono on an FM receiver without a stereo decoder, ensuring compatibility.

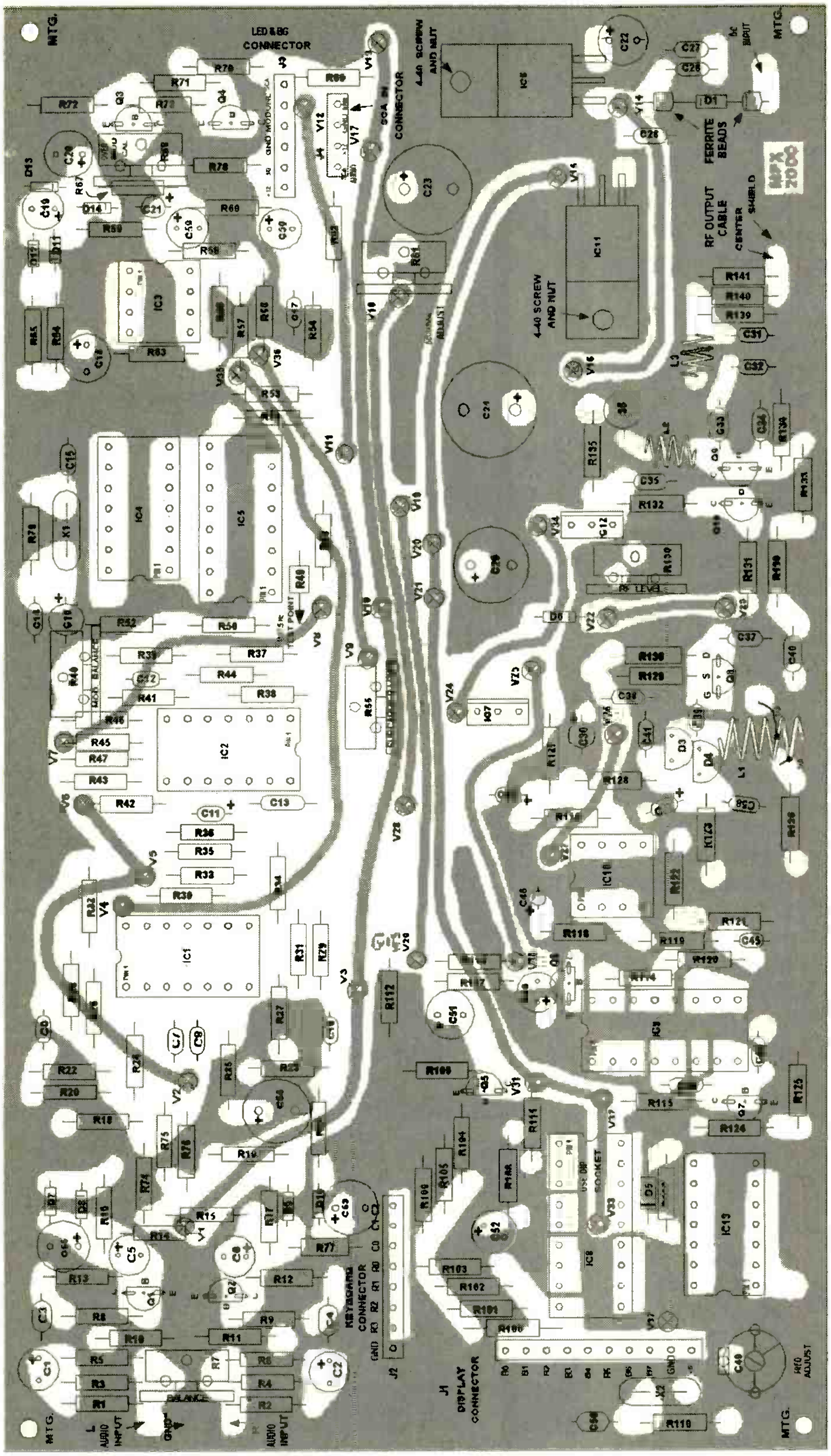


Fig. 6. When you are ready to solder components to the main board use the parts layout shown here as a guide. Pay attention to what side of the board you solder the components on.

The signal (L+R) is fed to summing amplifier IC3 via R57 where it will be combined with two other signals, the subcarrier signal (L-R) and the 19 kHz pilot. The signal (L-R) is the difference between the channels. This audio signal has the same frequency components as the main signal (L+R) and cannot be transmitted in the same channel as the (L+R).

To solve this problem, the signal (L-R) is then modulated on a subcarrier at 38 kHz. The result is a double-sideband AM suppressed-carrier signal occupying a band from 23 to 53 kHz (38 kHz plus and minus up to 15 kHz). It is produced with a balanced modulator circuit, IC2, and its associated components. Audio (L-R) is fed into IC2 via R35, R36, and C11. Pins 1 and 4 of IC2 are fed DC bias via R37, R38, R39, and R41. Resistor R40 is used to balance the voltages at pins 1 and 4. Balance occurs when they are identical. Resistor R44 sets the circuit gain; and R42, R43, R45, R46, and R47 are biasing resistors for the input and output of IC2.

The 38-kHz subcarrier is inputted at pin 8, and output appears at pin 12. In the absence of input, the audio output is zero; and, in practice, R40 is adjusted to null the 38-kHz output with no L-R input. The 38-kHz signal is obtained from frequency divider, IC5, a CD4040BE. This IC is driven by a crystal oscillator/buffer at 4864 kHz, made up from two sections of a 74C00N NAND gate. Capacitors C14 and C15 and IC1 make up the oscillator circuit. In addition, a 19-kHz signal for the pilot carrier and an 1187.5-Hz signal useful for testing are obtained from the CD4040BE at pins 13 and 1, respectively. The 1187.5-Hz signal is taken off through a series resistor, R49, and can be used to test the audio section, but is otherwise not used in the system. The subcarrier output is taken off through C13 and level control R55 and is fed to summing amplifier, IC3.

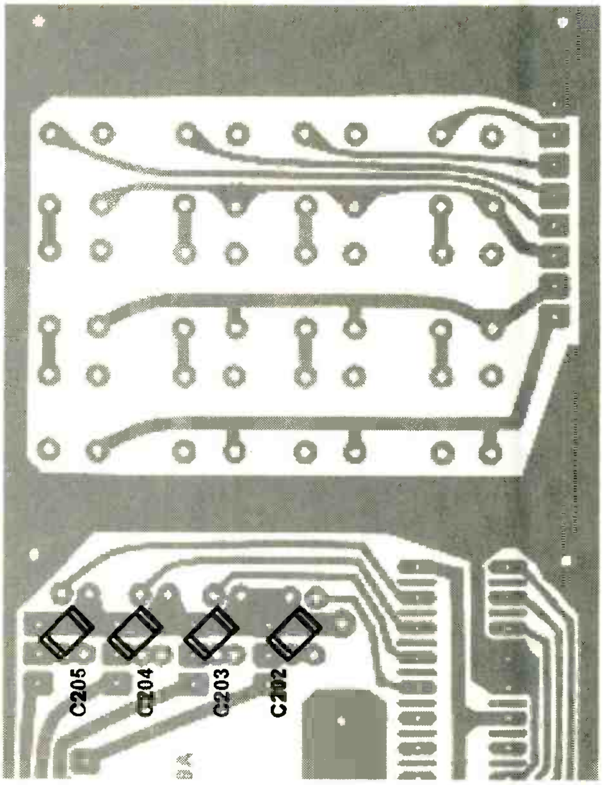
The output of IC3 is the sum of (L+R) and the (L-R) signal. It is fed to network C17–R61 via R60. In addition, the 19-kHz pilot signal from IC5's pin 13 is fed to this point via attenuator R51, R53, and R54, where it is reduced to 7 to 10 percent of the peak audio level. This 19-kHz signal is used by the receiver to generate a 38-kHz subcarrier for recovery of the audio (L-R) component from the 38-kHz subcarrier signal received along with the main (L+R) signal. Adding and subtracting (L+R) and (L-R) will result in 2L and 2R, which are the individual L and R audio channels.

The signal appearing across network R17–C61 is called the baseband or composite stereo multiplex signal. This signal is fed to the transmitter modulator. In order to ensure good audio quality on the transmitted signal, some audio-level monitoring is needed. The MPX 2000 uses a 10-segment bar-graph level indicator, which consists of ten LEDs mounted side by side to simulate a solid-state meter movement. In addition, another LED is provided which lights when the peak audio level that would result in overmodulation is reached. Audio from the summing amplifier is taken via R59, fed to an op-amp, a section of IC3, and then rectified to produce a DC level corresponding to the peak audio signal. Resistor R65 sets the gain of this stage to unity; and C19, D13, D14, and C20 make up a half-wave voltage-doubler detector. Diodes D11 and D12, and resistor R64 are used to improve the linearity of the circuit at lower signal levels. They increase the gain of IC3 to permit low-level signals to overcome the 0.6 volt drop normally encountered in silicon diodes.

The audio components are removed by R67 and C21 and applied across potentiometer R68. The DC voltage is fed to the bar-graph level display via R78. A part of this voltage appearing from the wiper of R68 to ground is fed to the base of Q3. The emitter of Q3 is biased at 1.5 volt via R72 and R73. Potentiometer R68 is adjusted so that when the audio signal lights all ten segments of the bar-graph display plus 10 percent more, there will be sufficient voltage (2.2V) available at the base of Q3 to cause it to conduct. This signal turns on Q4 via R70 and R71, causing voltage to appear from the collector of Q4 to ground. This voltage is fed to an LED on the display, lighting it, and indicating overmodulation. The display panel will be described separately in another part of this discussion.

Frequency Modulation. An RF carrier that can be frequency modulated is required. It should be variable from 88 to 108 MHz to cover the entire FM broadcast band, and it must be stable within 10 kHz or better. The MPX 2000 uses a *p*hase-*l*ocked *l*oop (PLL) frequency synthesizer to generate all 200 channels at 100-kHz spacing, between 88.1 and 107.9 MHz—the standard FM broadcast band. The synthesizer is frequency modulated by applying audio to its *v*oltage-*c*ontrolled *o*scillator (VCO). Contradictory as it seems, we want the VCO to be rock stable and to vary the frequency. With proper design, this can be accomplished without any serious compromises in transmitted audio quality or synthesizer performance. The VCO is the heart of the transmitter, and the synthesizer circuitry serves to keep it exactly on the desired transmit frequency.

Free-running oscillators were used in the past for this



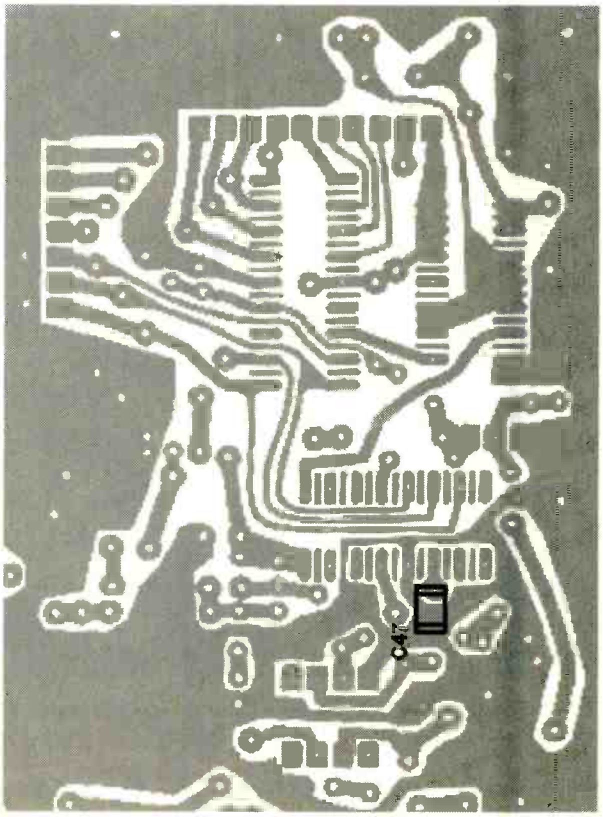


Fig. 7. These two guides show the soldering points for required chip capacitors.

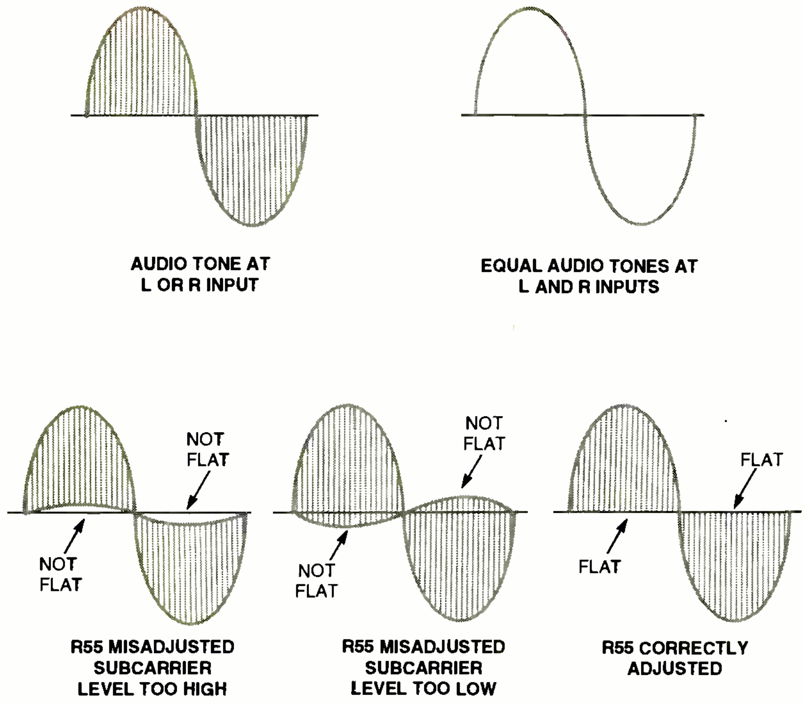


Fig. 8. These waveforms can serve as a guide for signal chasing. An oscilloscope can be used to compare the composite audio-signal to the nominal waveform shown above.

application. This approach is still used in low-end, low-cost FM transmitters. It is difficult to keep these transmitters on frequency, and, therefore, they can be hard to use, especially with digitally tuned receivers. Stability of better than 100 kHz is difficult to come by with this approach. The use of frequency synthesis eliminates this problem. The VCO output must be buffered to eliminate frequency pulling caused by varying antenna loads, proximity effects, etc.

In the MPX 2000, JFET Q8 is the VCO. Inductor L1 and the combined capacitances of tuning varactor D4 and modulator varactor D3 together make up the L-C tuned circuit that determines the transmitter frequency. JFET Q8 is biased by R129 and R136. The drain of Q8 obtains DC from R136. Feedback is from a tap on L1, which is fed to the source of Q3 via C42. Capacitor C40 and resistor R130 couple some output from the VCO to buffer amplifier circuit Q9–Q10, made up of R132, R133, R134, and C34 and C35. Inductors L2 and L3 and capacitors C33, C32, and C31 make up an RF output network and harmonic filter for the buffer amplifier. Resistors R139, R140, and R141 ensure proper termination of this network and feed RF to the antenna. Resistors R135 and R138 make up a regulator circuit to feed regulated 5.6 volts to the buffer amplifier. In case of synthesizer malfunction, a DC level from the synthesizer IC is fed to R131 and cuts off the buffer, killing the RF output and reducing the possibility of transmitting outside the FM band.

Frequency Control. Voltage from the PLL chip phase/frequency detector tunes the VCO. The PLL chip (IC9) is a Motorola MC145170-2. Inside this chip, a sample of the VCO signal is compared with a reference frequency. If they are not in phase and frequency agreement, an error voltage is generated. This is used to change the tuning voltage on the VCO to achieve frequency and phase agreement (lock). Resistor R126 and capacitor C43 feed a sample of the VCO signal to amplifier Q7. Collector resistor R115 biases Q7, and the signal to drive IC9 appears across it. Capacitor C44 couples this signal to chip IC9. Integrated circuit IC13 generates a clock signal at 4.000 MHz via XTAL1, trimmer C49, and C50. Capacitor C49 is used to adjust the frequency to exactly 4.000 MHz, which is used both as a reference signal for the PLL synthesizer and for microcontroller IC8. Two sections of IC13 are used as buffers to provide this signal to IC8 and IC9.

The synthesizer frequency depends on several data words programmed into IC9. The needed data words are provided by IC8, a PIC16F84 microcontroller. This microcontroller has built-in software to program IC9 and to manage other tasks, such as the control of the frequency display and scanning the keypad for frequency entry. Other functions necessary are system shutdown in case of malfunction, rejection of out-of-band frequency entries, and automatically setting to the last transmitted frequency upon power-up.

When a valid frequency is entered, a voltage appears at the phase-detector output pin (13) of IC9. This voltage is fed to network R118, R119, R120, and C46. This network determines some of the loop characteristics of the synthesizer. The output of this network is fed to op-amp IC10 and then to tuning varactor D4. At lockup, this will be a steady DC voltage, varying from 3–4 volts at the low end to as much as 10 volts at the high end of the FM band.

In case of loss of lock, IC9 produces pulses at pin 11. These pulses are integrated by R114 and C48. The DC voltage turns on Q6, placing 5 volts across R113 and R112 and D6. This sequence sends a voltage to the unlock indicator LED, D201, and cuts off the RF buffer via D6 and R131. In addition, the rising voltage is coupled to the base of Q5 via R142 and C51, turning on Q5 momentarily. This action causes Q5 to conduct, resetting the microcontroller via R108 and resetting network D5–R107. Capacitive coupling is used to couple the signal to Q5 so as not to permanently reset the microcontroller; otherwise, a lockup condition will occur. Normally, resetting will be a sufficient cure if the problem is incorrect frequency entry or a "glitch," as resetting the microcontroller will reprogram IC9 with the correct data. During this process, the RF output is disabled.

Modulation is achieved by applying baseband audio from R61–C17 to varactors D3 and D4. This allows better modulation and fewer compromises than if audio were applied to the tuning varactor D3 alone. Integrated circuit IC7 provides a regulated 12 volts to the PLL and helps filter out any noise disturbances appearing on the power supply.

The audio section is supplied with 12 volts regulated from IC6, and IC11 supplies 5 volts to the microcontroller, display logic, and PLL synthesizer IC. The use of separate regulators for audio and digital functions helps to reduce circuit noise. DC input to the MPX 2000 should be between 15 and 20 volts to allow sufficient headroom for the regulators, keeping dissipation within reasonable limits. (This can be reduced a few volts with low dropout regulators). Care must be taken to use a wall transformer that is adequately filtered so that the input voltage waveform to the MPX 2000 never gets below 15 volts. With less than 15 volts input, there will not be sufficient DC voltage to allow full VCO swing; and some of the 88–108-MHz tuning range will be lost at the high-frequency end. Also, adequate RF decoupling of the DC supply is needed to reduce the possibility of RF-induced ground hum on the transmitted signal. RF chokes may be needed in both power leads in certain situations.

Display-Board Design. Let's discuss the display-board circuitry (refer to Fig. 3 for schematics). This board contains a 4 × 3 matrix of touch switches arranged in 4 rows and 3 columns, a 4-digit LED multiplexed display, and the bar-graph LED and its associated driver, an LM3914 (IC204). In addition, three other LEDs that serve as overmodulation (D202), PLL unlock (D201), and SCA subcarrier ON (D203) are also on this board. The keyboard is polled periodically by the microcontroller for switch closure by applying a logic level to a row and looking to see if this level appears on one of the three columns. Each switch has a unique row and column location; and the switches are scanned sequentially, 1 through 10 (10 is represented by zero). There are two other keys, E (enter) and CE (clear entry). The desired frequency is entered, most significant digit first. Since we have four digits, the most significant digit is zero for frequencies below 100.0 MHz. This zero does not have to be entered, but it is recommended. This eliminates possible "glitches" or entry errors and fully clears the keyboard memory. When the first entry is made, two zeros appear on the display to the left of the entered digit. The leftmost is blanked on leading zeros. For example, 99.5 MHz will be displayed as 995 instead of 0995.

No changes are made in the PLL programming or the transmit frequency until the enter key is pressed. The digits appear on the display as they are entered and shift right to left. If more than four digits are entered, the leftmost will be shifted out. After the display shows the desired frequency, the E key is pressed. If it is a valid (legal FM channel) entry, the display retains it, the PLL shifts the transmitter frequency to it, and it is also stored in memory. It will come up when the MPX 2000 is powered up the next time. If an illegal entry (<88.1 or >107.9) is made, the microcontroller rejects it and simply reverts to and displays the current

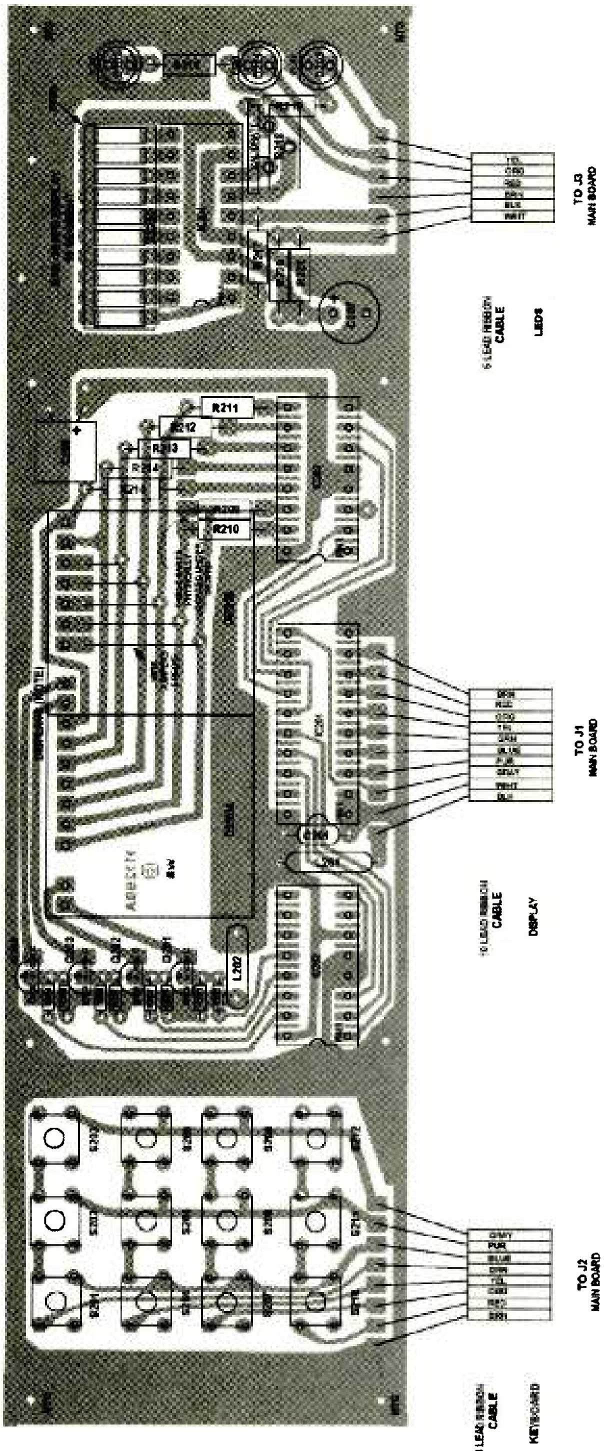


Fig. 9 This parts-placement diagram shows the display-board components' location. Pay careful attention not to apply too much stress on the cable ribbons.

frequency. If an error is made during entry, press the CE key and the current frequency once again appears. When the MPX 2000 is powered down, the current frequency is retained in memory and reappears on the next power up. No memory backup battery is needed for the microcontroller.

The display section is a conventional 4-digit multiplexed display using four seven-segment common

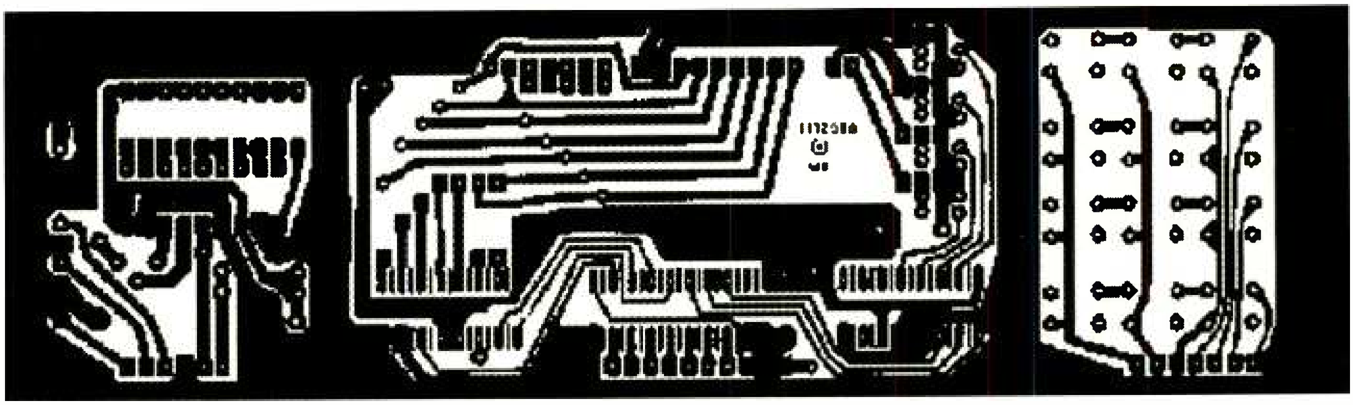


Fig. 10. Here is the display-board foil pattern. The display board is exactly half the size of the main board.

anode LED digits, driven by a 7447N TTL driver IC. Resistors R209 to R215 are current-limiting resistors for the individual segments. No decimal point is used in this display. There are eight logic inputs from the microcontroller, and those feed a 74HC573N 8-bit latch IC201. The digit data is latched into the 74HC573N by a strobe pulse from the microcontroller at the appropriate time, and this data contains the binary value of the particular digit and its position on the display. A 74HC138N decoder decodes the digit-select information, and its output turns on one of four 2N3906 switching transistors Q201–Q204, via bias resistors R201–R208. Inductors L201 and L202, along with capacitor C206, are noise-suppression chokes to reduce switching noise. The display segments are operated at 20 mA each and if an 8 is shown, 140 mA must be switched by the 2N3906 associated with that digit. Chip capacitors C202–C205 slow down switching speeds to further reduce noise spikes .

While an LED display can be noisy and can consume a lot of current, it is much brighter, has more eye appeal, and is easier to read than an LCD. LED readouts need no illumination. The display is shut down by the microcontroller about 15 seconds after the last keypad press, cutting off the display multiplexing and leaving a few segments lit on the least significant digit to serve as a power on indicator. This approach eliminates residual switching noise generation and conserves current. The display can be awakened by pressing the zero key to check the current frequency setting. It will stay on for 15 seconds and go back to sleep.

The display and multiplexing could have been handled directly by the microcontroller without the three ICs. However, the software overhead would be larger, and the current for the LED display would be too much to be directly handled. This approach was tried, but there were problems—the display was too dim, performance of the microcontroller was a little slow, and some additional "glue" circuitry was needed because of the limited number of pins available on the PIC16F84. In cases like this, a "hardware versus software" tradeoff has to be made. The hardware multiplexing approach was used here as it gave the best results. A larger microcontroller could also have been employed, but this was not investigated.

The bar-graph display is conventional and uses a LM3914 linear bargraph driver (IC204). DC input from the main board is applied to pin 5 of IC204, and the sensitivity is determined by the setting of R218. Approximately 0.8 volts DC is needed to light all ten segments of LED display DS202. Resistor R218 is set so that ten segments light when the main board audio system is producing full audio level just short of limiting. This represents 100 percent modulation. Resistors R220 and R221 limit power dissipation in IC204, and C207 bypasses the V_{CC} line to the display. LED D201 is fed from the unlock detector on the main board. When it is illuminated, it indicates that the PLL is unlocked. LED D202 is powered from the main board and is illuminated when audio clipping occurs, indicating over modulation. LED D203 is used to indicate that the optional SCA audio-subcarrier system is activated.

The MPX 2000, once programmed to a desired frequency, will operate without the display board, since its functions are mainly supervisory. The board may be disconnected during operation with no effect on the transmitted FM signal. However, it is needed for reprogramming of frequency.

Overall power requirements of the MPX 2000 are 15 to 20 volts DC at 350 mA. The display consumes much of this current. If the display is asleep, the current is about 160 mA. When the display is disconnected from the main board, current consumption drops to 125 mA. Operation below 15 volts is not recommended unless low-dropout regulators (LM2930, etc.) are substituted for the LM7812s used here. Operation above 20 volts may cause overheating of the 5-volt and 12-volt regulator ICs. Heatsinks should be fitted to these ICs if operation over 20 volts is expected. The DC input is polarity protected by D1 and accidental polarity reversal will do no harm; the MPX 2000 simply won't operate and won't draw any current until the supply polarity is corrected.

Construction. Although the MPX 2000 PC boards aren't difficult to assemble for someone with a little experience, it is important to follow a certain assembly sequence to avoid mistakes that could lead to hard-to-find problems. In particular, a number of through-hole connections (vias) are required to connect traces on both sides of the board.

Plated-through boards are great

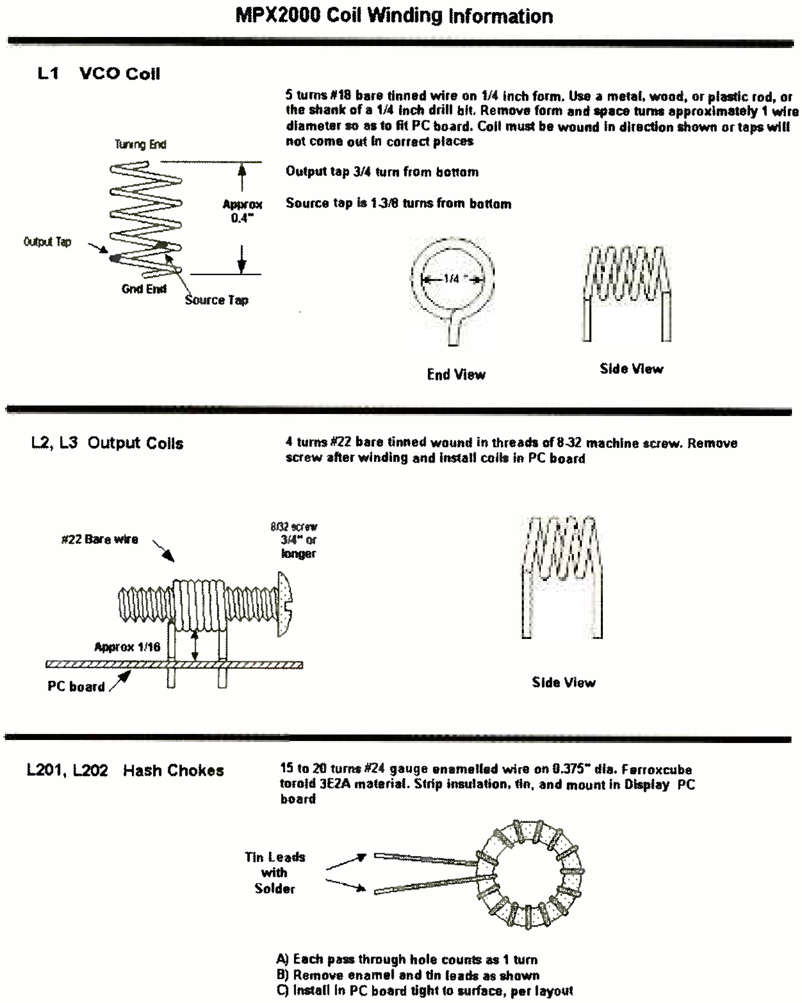


Fig. 11. Carefully follow these instructions in order to fabricate your own coils and chokes for use in the transmitter.

for mass production of PC boards. They reduce assembly cost and facilitate soldering. However, the use of homemade boards generally precludes plated-through holes. Making a few assembly errors in constructing any new project is expected. If you must remove a component from a plated-through board, you will find it very difficult and will probably ruin the component and the PC board, as well. That is why we do not recommend the use of plated-through PC boards in this project.

The boards are best assembled and tested circuit by circuit. First, the main board can be prepared, using Figs. 4 and 5 as references for the PC-board foil patterns. Figure 6 and Fig. 7 can be used as guides for component placement on the main board. Build one section at a time, starting with the installation of jumper vias and the parts for the power-distribution circuitry. After the power circuitry is completed, a power supply of 15 to 20 volts DC and a DC voltmeter are needed to test the circuitry—a VOM or a DVM will do. Power up the board, and using the meter check the continuity of the power-distribution circuitry. Next, the audio (MPX) circuitry can be assembled and tested. If these test results are OK, the display board should then be assembled. At this point, the main board will have the microcontroller section installed; and this can then be tested together with the display board if desired. After this is done, the RF circuitry can be assembled. Now, the entire MPX 2000 can be checked out. At this time, the project will be operational. There are no critical adjustments to be made, and it should work the first time with the default settings given in the assembly procedure that follows, assuming that there are no mistakes.

While it is possible to simply "stuff" the PC boards and wait until after completion of assembly for testing, this is not recommended unless you are *very* experienced.

After completing the power-distribution circuitry, install all vias and any parts that connect to them—the regulators and DC power supply filtering and bypassing components. Check your work and make sure all connections are soldered. Connect +15 to +20 volts DC to D1 (positive lead) and the negative lead to ground on the PCB. Check for the following voltages. All voltages assume that the regulator ICs supply an exact 5 or 12 volts. Since they have a 5 percent tolerance that is acceptable for this application, remember to allow for this if the voltages are a little low or high, as they will be dependent on exact regulator voltage. Consult the parts-placement diagram for the physical location of the test points as needed. Table 1 is a list of voltages to check.

Next, inspect all V points (see parts-placement diagram) to make

TABLE 1

• Junction C26, C27, D1 (Input)	+15 to +20 V_{DC}
• Junction C28, IC6, IC11, IC12, IC7	+14.4 to +19.4 V_{DC}
• V31	+5.0 V_{DC} ±5%
• V1	+12.0 V_{DC} ±5%
• V6	+6.0 V_{DC}
• Wiper, R40	+6.0 V_{DC}
• Junction R74, R75, C53	+7.25 V_{DC}
• Junction R76, R77, C55	+4.75 V_{DC}
• Junction IC7, C30	+12.0 V_{DC}
• Junction IC12, C36	+5 to > +12.0 V_{DC} (Should vary with R138. Set for +5.6)

sure they are soldered and a clean contact exists between the traces on both sides of the board. The purpose of these tests is to make sure that all sections of the PC board will get DC power and that all signal traces are intact. Then, install the audio and MPX generator circuit components.

Audio And MPX Generator Benchcheck. Apply +15 to +20 volts as before to the DC input and check for the following voltages (Table 2). It is assumed that all voltages that you obtained were as specified in the first checkout of the PC board, before the audio components were installed. Ten percent tolerance is OK. Preset all potentiometers—except R138—to the center of rotation.

TABLE 2

• Q1 and Q2 Collector	+3.6 V_{DC}
• IC1 Pin 4	+12.0 V_{DC}
• IC1 Pins 1, 7, 8, 14	+6.0 V_{DC}
• IC2 Pins 1, 4	+3.1 V_{DC} (varying with R40)
• IC2 Pins 2, 3	+2.4 V_{DC}
• IC2 Pins 8, 10	+5.9 V_{DC}
• IC2 Pins 6, 12	+8.5 V_{DC}
• IC2 Pin 5	+1.2 V_{DC}
• IC3 Pins 1, 7, 8, 14	+6.0 V_{DC}
• Q4 Collector	0 V_{DC}
• Q3 Collector	+12.0 V_{DC}
• Q3 Emitter	+1.5 V_{DC}
• Junction R67, R68, R78, C21	0 to +0.2 V_{DC}
• IC5 Pin 16	+7.5 to +9.0 V_{DC}

Next, set R40 so that the voltage between pins 1 and 4 of IC2 is zero. Make this adjustment with the most sensitive scale on your meter to as low as 1 mV, if possible. Using a scope and audio generator, you can apply a 1-volt peak-to- peak audio signal to the L and R inputs and trace the signals through the circuitry. This is excellent for uncovering any errors—so far. Using a source of stereo audio—such as a CD player, cassette player, or a stereo receiver—you can trace the signals through the circuitry with an audio amplifier and speaker. You will not be able to hear the pilot and the subcarrier signals (unless you are a cat or a dog), as they are above the audible range of frequencies. Refer to the waveform diagram (Fig. 8) for audio waveforms. Adjust R7, R40, and R55 as needed to get these waveforms. If you don't have the test equipment for this procedure, then leave all potentiometer adjustments where they are. If the DC voltages were all correct and your assembly is error free, all should be OK so far.

Construction Of The Display Board. The display board consists of three separate circuits: the keypad, LED display circuitry, and the bar-graph metering and status LEDs (see Fig. 9 and Fig. 7). These should be tested in conjunction with the microprocessor section, but some initial tests can be made on this board without it. This board is single sided and the foil pattern is shown in Fig. 10.

Insert the 12 touch switches that make up the keypad. If you like, you can check out the keypad with an ohmmeter to see if continuity exists between a row and column when the corresponding switch is pressed.

Next, assemble the display section (center of display board). Make sure that you first install the jumpers below the site for the LED displays. You can use low profile DIP sockets here if you wish to avoid soldering the ICs directly onto the PC board. Now, install LED assembly DS201. This consists of two identical 2-digit subassemblies. Next, fabricate and install hash chokes L201 and L202. These are not critical as to inductance, and 15 to 20 turns will be OK.

Install a 20-pin socket where DS202 is to be located. This socket MUST be used so the top of DS202 will be at the same height as DS201. Then plug DS202 in the socket making sure the rounded corner or pin 1 indicator faces the corner of the PC board. No harm will be done if DS202 is inserted backwards, except that DS202 will fail to light.

Next, install IC204, the LM3914N BG driver chip. You can use a DIP socket if you wish, as before. Install LEDs D201, D202, and D203, making sure to observe polarity. Also make sure the tops of these LEDs are the same height as DS201 and DS202. This completes the display-board assembly.

Microcontroller And Logic. First, install ten-pin header (J1) and eight-pin header (J2) as shown in the display-board parts-placement drawing. Make sure V32 and V33 are well soldered, as you will not be able to get at them after this step. Next, apply DC power to the board as before and check for +5 volts on the J1 pin shown. Remove DC power and allow a minute for the capacitors to discharge. Then, install the programmed PIC16F84 microcontroller and all related parts. The microcontroller must be programmed with the appropriate software in order to operate properly. If you are building this project from scratch, you will have to do this for the project to work. Refer to the books and data sheets published by Microchip Corporation to see how this is done. You can write your own software or, if you prefer, a preprogrammed microcontroller can be purchased from the source mentioned at the end of this article.

Make sure to install an 18-pin socket at IC8. This is required to allow easy removal of IC8 so that future changes can be made to the internal operating software if needed. You may also install a DIP socket for IC13, but this is optional. The display board can be connected to the main board using ribbon-lead cable of the kind used in PC internal cabling, and this is recommended. You can use Molex or similar connectors with 0.100-inch spacing to plug directly into the headers on the main board. However, installing these connectors generally requires a special crimp tool. Alternatively, you can use solder-type connectors or "press on" types. Check out a computer parts catalog for suitable connectors.

Connectors are not absolutely needed, although it does make testing easier. However, it takes time to install these connectors and may not be worth the time and effort to do it. Once the MPX 2000 is assembled and packaged in a case, these leads will not usually have to be disconnected again. You can check out the microcontroller section now, but it requires wiring it to the display board and disconnecting it again. If the wiring is correct, there is little to go wrong here.

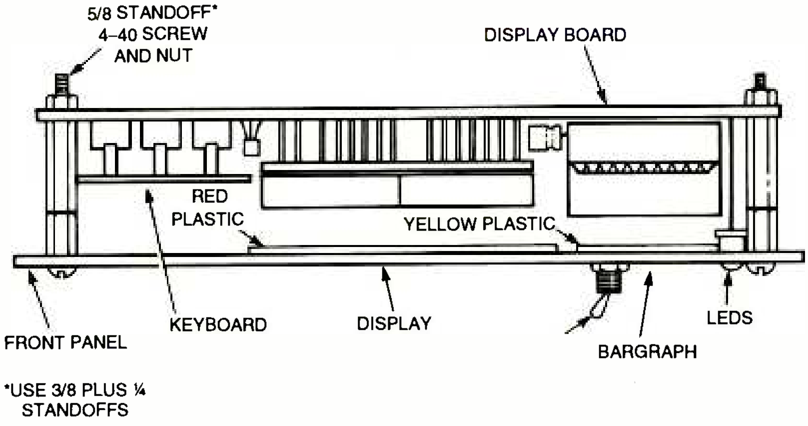


Fig. 12. Here is the front-panel design used by the authors. The container should provide adequate space for the boards to fit snugly, yet without crimping the various cables connecting the display to the main board.

PLL And RF Section. This section is the last to be assembled and when completed, the MPX 2000 PC boards will be ready for final testing and installation in a case of your choosing. Once again, refer to Fig. 6 for parts-placement information. First, install all the resistors and then the capacitors, followed by transistors Q5 through Q10 and all the diodes. Next, install remaining ICs—IC9 and IC10. Again, you can use low-profile DIP sockets for IC9 and IC10, if you wish. Make sure to observe correct IC orientation. The final step is the fabrication of L1, L2, and L3. Inductor L1 is five turns of #18 tinned wire wound around a ¼-inch mandrel. The coil (L1) is installed in the PC board with the turns spaced evenly so it fits the PC board. A tap consisting of a short wire lead soldered to the appropriate point on the PC board is then connected to the first turn of the coil as shown in Fig 11. Inductors L2 and L3 are made from four turns of #22 bare tinned wire, wound using the threads of an 8-32 screw as a mandrel. They will look like small springs when completed—the screw controls the dimensions, so you cannot go wrong. Shape the leads as shown in Fig 11. Remove the screw and install the coils in the PC board. Make sure no adjacent turns short together on L1, L2, or L3. Next, check over all work done so far for any errors. You are then ready to do final testing. The display board must be connected to the main board first.

After installing all components, make sure that the ICs, diodes, and capacitors are correctly oriented. Power up the board as before and note the following:

Bar-graph display DS202 should momentarily flicker and then go out; this is normal and a good sign that things are working. The frequency display should light and either show a valid FM station frequency or three zeros. The left-most (MSB) digit is zero blanked and will not display a zero. Next, examine the keyboard layout in the display-board parts-placement diagram. It is pretty standard. Now, enter an eight, which should display as the right digit. Enter another eight, and now the two right digits should show "88." Enter a one. The display should show "881." Press the E (enter) key. The display should still show "881." Next, remove DC power, and after about ten seconds reconnect power. The display should light up "881." Try entering each digit—1-9—in sequence. The newly entered digit should appear on the right and move left as new digits are entered; the fourth digit will disappear off the left side as new digits are entered. Press the E key, and unless the display is showing a frequency between 881 and 1079, the display will revert to 881 or whatever valid frequency it previously showed. To reject an entry, press the CE (clear entry) key; and the display will show the previous valid frequency.

Try entering a few valid FM frequencies, each time pressing the E key after frequency entry. Removing power and re-powering should result in retention of the frequency in memory. If the frequency displayed differs, try re-entering all four digits (i.e. 0995 for 99.5 MHz instead of 995). The leading zero is needed and does not show.

It sometimes happens that a 1 is retained in memory when a frequency of 100 MHz or more was previously entered. Entering a new frequency less than 100 MHz may not erase the fourth digit and the 1 will be retained, confusing the microcontroller. This is not a fault, but a result of suppressing the leading zero for purely aesthetic reasons, making the operator forget that it is still really there. It is best to enter 0883 rather than 883, for example, especially if the previous frequency was 100 MHz or higher. When you are done, enter "0981" as this will be needed for later testing. If all works as specified, you can assume that the microcontroller and display circuit are OK.

Next, apply an audio signal of about 1-volt p-p to the L input. The bar-graph indicator should show several lit segments. Adjust R218 on the display board so all ten segments light. Then increase the signal about ten percent and adjust the potentiometer R68 on the main board, so that D202 on the display board (to the right of DS202) just lights. Reduce audio drive and D202 should extinguish, with DS202 showing fewer segments lit as the audio input is decreased. This checks out the metering circuit.

PARTS LIST FOR THE MPX 2000

SEMICONDUCTORS

IC1—TL084N quad op-amp
IC2—MC1496N balanced modulator/ demodulator
IC3—MC1458N dual high-performance op-amp
IC4, IC13—74C00N quad 2-input NAND gate
IC5—CD4040BE 12-stage binary/ripple counter
IC6, IC7—LM7812 12V voltage regulator
IC8—PIC16F84-04 programmable microcontroller
IC9—MC145170-2 PLL synthesizer
IC10—TL081N JFET op-amp
IC11, IC12—LM7805N voltage regulator
IC201—74HC573N
IC202—74HC138N
IC203—7447N BCD-to-7-segment decoder/driver
IC204—LM3914N voltage-level indicator
Q1-Q3, Q5—2N3904 NPN RF-AMP DRIVER
Q4, Q6, Q201-Q204—2N3906 PNP RF-preamp
Q7, Q10—2N3563 IF-amp
Q8—MPF102 JFET N-channel amp
Q9—MPS3866 or 2N3866 oscillator, amp driver
D1—1N4007
D2—Not used
D3—MV2103 or equiv.
D4—MV209 or equiv
D5-D14—1N914B or 1N4148
D201—T1 ¾ red LED
D202—T1 ¾ yellow or orange LED
D203—T1 ¾ green LED
DS201—Seven-segment 2-digit display
DS202—Ten-segment bar-graph

RESISTORS

(All resistors are ¼-watt, 5% units unless otherwise noted.)
R1, R2, R14, R15, R32, R112, R117, R124, R131—4700-ohm
R3-R6, R28, R29-R31, R33-R36, R45, R51, R54–R57, R62-R64, R66, R67, R70, R104-R107, R111, R118, R128—10,000-ohm
R7, R40—10,000-ohm potentiometer
R8, R9, R18, R19—47,000-ohm
R10, R11, R58, R65—15,000-ohm
R12, R13—9100-ohm
R16, R17, R44, R48, R69, R100, R101, R102, R103, R123, R125, R132, R216—1000-ohm
R20-R23, R37, R38, R109, R127—100,000-ohm
R24, R25—39,000-ohm
R26, R27, R50, R121—22,000-ohm
R39, R41—68,000-ohm
R42, R43, R52, R53, R71, R114—2200-ohm
R46, R47, R133—3300-ohm
R49, R119, R217—220,000-ohm
R55—25,000-ohm potentiometer
R59, R122—33,000-ohm
R60, R116—6800-ohm
R61, R138, R218—1000-ohm potentiometer
R68—100,000-ohm potentiometer
R72, R126, R130—220-ohm
R73—1500-ohm
R74, R77—390-ohm
R75, R76, R108, R136—100-ohm
R78—470,000-ohm
R79, R110, R129—2.2-megohm
R113—330-ohm
R115, R135, R219—470-ohm
R120—330,000-ohm
R134—33-ohm
R139, R141—91-ohm
R140—75-ohm
R201-R208—2200-ohm, ¼ Watt
R209, R210-R215—150-ohm
R220, R221—56-ohm
R80–89, R137, R142–200—Not used

CAPACITORS

C1, C2—4.7-µF, 35-WVDC, electrolytic
C3, C4, C26, C27, C43-C45—.01-µF, 10%, 50V, Mylar
C5, C6, C16, C18, C22, C36—10-µF, 16V, electrolytic
C11, C19, C20, C21, C30, C51, C52, C59—1-µF, 50V, electrolytic
C12, C13, C35, C37, C38—.01-µF, 50V, GMV, ceramic-disc
C17—.0015-µF, 10%, 50V, Mylar
C23, C29—1000-µF, 16V, electrolytic
C24—2200-µF, 25V, electrolytic
C28—0.1-µF, 50-WVDC, Mylar
C31—47-pF, 5%, NPO, ceramic-disc
C32—120-pF, 5%, NPO, ceramic-disc
C33—68-pF, 5%, NPO, ceramic-disc
C34, C40, C43, C58—470-pF, GMV, ceramic-disc
C41—6.8-pF, NPO, ceramic-disc
C42—0.47- or 1.0-µF, 35V, tantalum electrolytic
C44, C201, C14, C15, C39, C50—22-pF, 5% , ceramic-disc
C46—10-µF, 6V, tantalum electrolytic
C47, C202, C203, C204, C205—0.1-µF, 60X120, 50V, chip
C48, C56, C57, C207, C7-C10—100-pF, 5%, NPO, ceramic-disc
C49—2-20-pF, trimmer, 7.5 mm
C53, C55—47-µF, 16V, electrolytic
C54, C206—470-µF, 6.3V, electrolytic

ADDITIONAL PARTS AND MATERIALS

S201-S212—Touch switches, momentary contact
L1, L2, L3—See text and figures
L201, L202—Ferrite toroid 3E27 Material
XTAL1—Crystal, 4.864 MHz
XTAL2—Crystal, 4.000 MHz
Connector, 0.1-inch, 10 pins
Connector, 0.1-inch, 8 pins
IC socket, 18 pin
IC socket, 20 pin
Label, Keyboard
3-feet #24 enamel wire
2-feet #22 tinned wire
1-feet #18 tinned wire
Ribbon cable, 8 inches, 24 conductor
PC board, main
PC board, display
Ferrite beads, 43 Material
4-40 × ½-inch BHMS
4-40 Hex Nut
4-40 Lockwasher

NOTE: The following items are available from North Country Radio, PO Box 53, Wykagyl Station NY 10804-0053; *www.northcountryradio.com*: A complete kit of parts, consisting of all items listed on the parts list. That includes drilled and etched main and display PC boards, preprogrammed microcontroller, all resistors, capacitors, diodes and LEDs, displays, transistors, integrated circuits and all miscellaneous parts as well as a detailed theory, assembly and test manual: $154.95 plus $5.00 for p/h in the US.

A complete case package that includes the plastic case (NC225) shown in the photo in this article, drilled and lettered front and rear panels, all connectors, and wire and cables as needed to finish the kit, as well as all necessary instructions, $39.95 plus $1.00 for postage and handling if ordered with the above parts kit or $39.95 plus $5.00 for postage and handling if ordered separately.

Collapsible 8-section whip antenna with BNC connector and right angle adaptor $14.00 plus $1.00 for postage and handling if ordered with the parts kit or $14.00 plus $5.00 for postage and handling if ordered separately

PLEASE NOTE:
For shipment outside the US, please add $10.50 for the first item, plus $3.50 for each additional item ordered. NY residents must add 8.25% sales tax to the price of any of the above items

Now repeat with audio connected to the R input. No difference should be noted, and no readjustment should be needed.

Final Test and Setup. You will need a VOM or DVM, an FM stereo receiver of some kind, and a source of line-level stereo audio. The MPX 2000 is designed so that 1-volt peak to peak (0.316 volts RMS sine wave) at the input will produce the required deviation, and the audio-input level should not exceed this figure. The input impedance is approximately 10k ohms. Power up the board and check the voltages in Table 3.

TABLE 3

• IC9 Pin 16	$+5\ V_{DC}$
• IC10 Pin 7	$+12\ V_{DC}$
• IC10 Pin 6	$+3$ to $+12\ V_{DC}$
• Q5 Collector	$+5\ V_{DC}$
• Q7 Collector	$+1.5$ to $+3.8\ V_{DC}$
• D4 Center pin	$+3$ to $+12\ V_{DC}$
• Junction D2, D3, R128	$+12\ V_{DC}$
• Q8 Collector	$+12\ V_{DC}$
• Q8 Base	$+5$ to $+7\ V_{DC}$
• Q8 Emitter	$+4.5$ to $+6.5\ V_{DC}$
• Q10 Collector	$+1.4\ V_{DC}$
• Q9 Emitter	$+0.7\ V_{DC}$
• Q9 Collector	$+5.6\ V_{DC}$ (adjust R138 as required)

After this test, remove power from the MPX 2000. If any of the voltages were incorrect, you need to find the problem before proceeding further. If these voltages check out, you may proceed. Now, you can power up the MPX 2000. The numbers 981 should appear in the display and, if not, enter this frequency, as described before. On power up, the bar-graph display (DS202) and the unlock LED (D201) should both flicker and go out. Measure the voltage at TP1, pin 6 of IC10. It should be >3 and <11 volts. Now, enter a frequency of 107.9 MHz. When the E button is pressed, D201 should flicker and go out, indicating lockup of the PLL. The UNLOCK LED may take several seconds to extinguish. This is normal due to the long loop-time constants used. If D201 stays lit, check voltage at TP1. It may be 11 volts or higher. Spread the turns of L1 until this voltage drops below 10 volts and D201 goes out. Next, program in a frequency of 88.1 MHz. Check to see if D201 flickers and goes out. Measure the voltage at TP1. It will be around 3 to 3.5 volts. If D201 is still lit, compress the turns of L1 slightly until the voltage rises slightly and D201 goes out. Recheck at 107.9 MHz and 88.1 MHz until lock is obtained at both frequencies, indicated by D201 extinguishing. It is normal for D201 to flicker slightly when changing frequency. Should you be unable to get both 88.1 and 107.9 to lock up with one setting of L1, check to make sure you have at least 12 volts at the output of regulator IC7. If not, you can replace it or add a diode in the common leg of IC7 to raise the voltage slightly.

Once the PLL is adjusted, set up an FM receiver on 98.1 MHz or somewhere near this if 98.1 MHz is busy in your area. Enter this frequency into the MPX 2000. Then, D201 should extinguish after a few seconds, and you should hear a carrier in the receiver, as evidenced by the quieting of the receiver. Momentarily power down the MPX 2000—this is to confirm that the carrier is indeed coming from it and not from some other source. Restore power and the carrier should reappear in a few seconds when D201 extinguishes.

Next, connect audio to the L and R inputs. The bar-graph display should indicate something, and you should hear the audio in the FM receiver. The receiver's stereo indicator should be on, and the audio should sound like any other FM station. Make sure you do not apply excess audio, as this will cause distortion and degrade stereo separation. Adjust R55 for best separation. If you have access to an audio generator and scope, you can get an exact alignment by adjusting for the waveforms shown in the waveform diagram. Adjust audio-input level for best sound in the receiver without distortion and clipping. With this audio-input level, set R218 on the display board so that the LED bar graph shows all ten segments lit on the loudest audio peaks. Slightly increase input audio and adjust R68 so that the overmodulation LED D202 just flashes. Then back off the audio-input level so that it barely flashes on the loudest audio peaks. This sets the proper audio drive level.

Packaging. The MPX 2000 may be packaged in any suitable metal or plastic case. Remember that this is an audio device, and it also generates RF signals. For that reason, the use of shielded cables for audio input and RF output is recommended. Keep the display board as far as possible from audio lines and the main board, as it does generate some switching noise. Such noise could appear as buzz or hum on the transmitted signal until the display goes to sleep. Once programmed, the MPX 2000 will operate without the keyboard and LED frequency display as long as the frequency is not changed. We recommend that accessibility to the keyboard be limited to keep curious individuals from playing with the MPX 2000 and inadvertently changing frequency. This can be done with a removable panel or cover over the display. The LEDs indicating lock and modulation should be kept visible at all times to signal improper operation. Figure 12 can be used as a guide for front-panel design.

A good RF-ground and antenna system is essential in reducing RF-ground-induced hum, a problem with low-power FM transmitters. Simply using a wall transformer and a whip antenna plugged into the RF output jack might not provide adequate RF grounding. To check if hum is RF-induced, power the MPX 2000 from a battery. If this

(Continued on page 56)

Of Rheostats and Potentiometers

Q *I was under the impression that a rheostat has the exact same schematic symbol as a potentiometer and that both have the same wiper-over-the-fixed-resistor design. My understanding was that the rheostat simply could dump a ton more power than a pot (potentiometer) just like those big ceramic "doohickies" that take upwards of 20 or more watts (while pots were limited to maybe one watt). Now, I'm getting the impression that the above may not be the case. Could you offer any insight here?—K.B., via e-mail*

A By definition, a potentiometer has three terminals—two fixed (connected to either end of the resistance element) and one movable (called the wiper) that slides across the resistance element, illustrated in Fig. 1A. Some

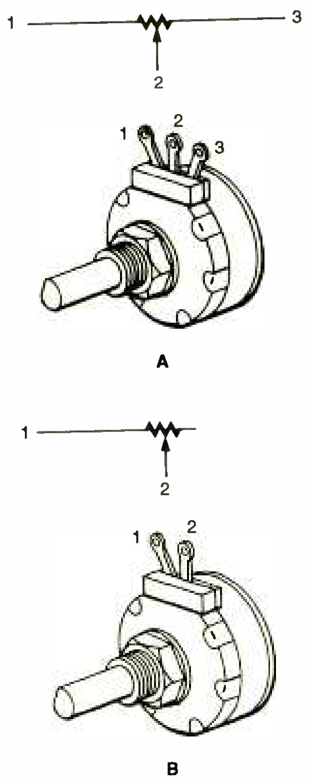


Fig. 1. Schematic symbols and representative devices show the difference between a potentiometer (A) and a rheostat (B).

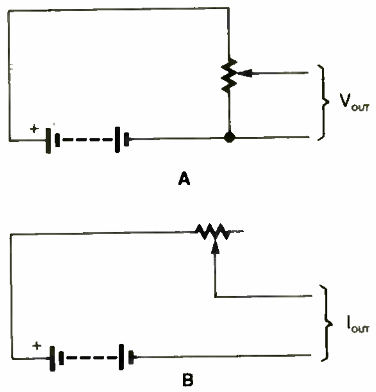


Fig. 2. Potentiometers (A) are used as voltage-control devices, while rheostats (B) are used as current-control devices.

older pots may have one or two extra fixed terminals stationed somewhere along the resistance element, and those were used for tone compensation in old radios. A rheostat has only two terminals—one fixed and the wiper, as shown in Fig. 1B. A pot is used to vary voltage in a circuit and is usually parallel-connected, as shown in Fig. 2A. A rheostat is used to vary current in a circuit and is usually series-connected, as shown in Fig. 2B.

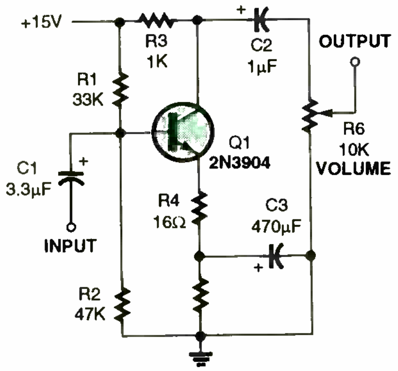


Fig. 3. A simple preamplifier uses a potentiometer (R6) as a volume control.

As you mention, rheostats tend to be high-power devices. Historical uses were for control of theater lighting and DC motors. Rheostats were also used in those cheap, battery-operated, reel-to-reel tape recorders of the early 1960s, in series with the motor, to compensate for battery drain so that the playback speed would be close to correct. Today, we have replaced most rheostats with solid-state power-control circuits. However, the 2001 Dodge 1500 pick-up truck still has one as part of the headlight switch for controlling the dashboard-light intensity. If you have the dash lights dimmed for an extended period of time, you can feel that the area around the headlight switch gets warm, attesting to the power being dissipated by the rheostat.

One of the more common uses of a potentiometer is the volume control of a radio, where the voltage from a preamplifier is varied from zero to maximum and fed to the output amplifier, as shown in Fig. 3. These days, you'll more likely find a pot being used in the rheostat configuration in a 555-timer circuit to vary the frequency, as illustrated in Fig. 4.

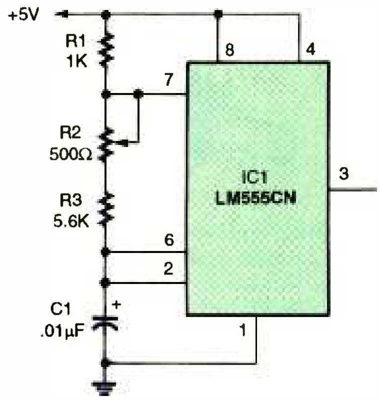


Fig. 4. This 555, wired for the astable mode, uses a potentiometer in the rheostat configuration (R2) to provide a variable timing resistance in conjunction with R3.

Of course, a pot can always be wired as a rheostat, by using only one of the fixed terminals, as shown in Fig. 5A—not the best way, since an intermittent wiper will create an open circuit. The best way is shown in Figs. 5B and 5C, where one of the fixed terminals is connected to the wiper. Now, an intermittent open wiper will be limited to the maximum resistance of the pot. Note that you'll change the rotational characteristics of the pot, depending upon which fixed terminal is connected to the wiper. In Fig. 5B, clockwise (CW) rotation decreases the resistance while, in Fig. 5C, counterclockwise (CCW) rota-

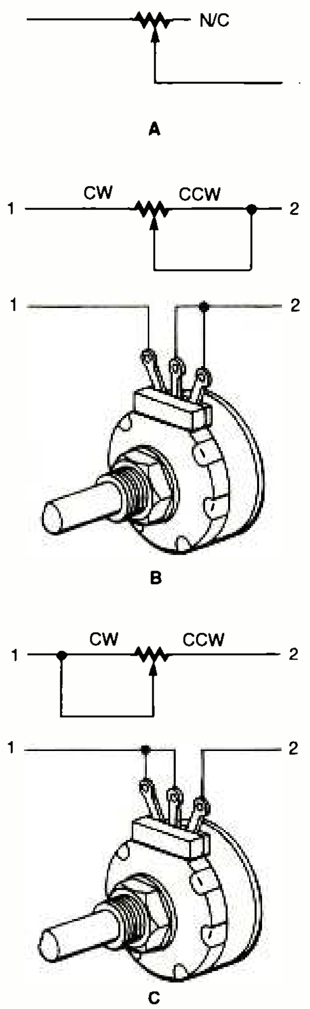


Fig. 5. Wiring a potentiometer as a rheostat as in (A) is not the best way. Wiring for a counter-clockwise increase in resistance (B) or for a clockwise increase in resistance (C) makes a big difference in the way an adjustment feels to a technician and in how the component will act in the circuit.

tion decreases the resistance.

The direction of rotation is important if you want the right feel for the adjustment. For instance, we would normally prefer that brightness, temperature, frequency, or sound level increase with a clockwise rotation.

You will be hard pressed to find a true rheostat in the Newark or Allied catalogs these days. Since both components are so similar in construction, it's more economical to always include the third terminal. That way the part is more versatile, and only one part number need be inventoried rather than two.

Web Electronics Forums

Q *Now that I've seen the Gernsback Forum, I wonder whether there are any other general electronics forums on the Internet.—S.S., via e-mail*

A There are all kinds of forums on the Internet, but I think that overall you'll find the Gernsback forum to be one of the best, if not the best. The high level of technical expertise held by the denizens of Electronic Bench and Resource Bin is buffered by their playfulness and a desire to help beginners without making them feel stupid.

The sidebar presents several forums and a few quick comments about each. I've tried to remain unbiased and only present what I see. There may be some of you who are not on the Internet and may be disgusted with the ever increasing push toward it, especially in my references for information. I assure you that I had that same frame of mind as recently as two years ago. As much of a techno-nerd as I am, it took the discovery of that plethora of forums and the goldmine of information that is out there to convince me to get an Internet account for my home computer.

As this was being written, Google had just acquired Deja's Usenet Archive, and the huge forum that posted to the Usenet news groups went dormant. When/if that one is reactivated, I'll let you know.

Semiconductor-Lead Identification

Q *How can one identify the emitter, base, and collector leads of a transistor? I have heard that there is no standardized order of the leads. Does the coding on the transistor's housing somehow indicate the order? Is there a standardized coding for integrated circuits?—A.M., Lilburn, GA*

A There's a question where I can say "Yes" and "No." The closest that we have come to EBC lead standardization was with the TO-3, TO-5 and TO-18 style of metal-transistor cases. If there were three leads on the TO-5 (e.g., 2N2905) and TO-18 (e.g., 2N2222A) styles, the emitter was the lead nearest

ELECTRONICS FORUMS ON THE INTERNET

http://209.61.188.48/indices/33195.html
This forum is not very active.

http://network.wenzel.com/Hobby
A subset of the Wenzel Associates (makers of crystal oscillators) Web page.

www.delphi.com/experimenter/start
This is a brand new forum with little activity.

www.designnotes.com/dndiscussion/designforum_toc.htm
Don't let the "design" part fool you. This forum has a lot of basic stuff on it.

www.industrycommunity.com/ee/ee-1-next1/index.html
This is more industry-related, but still has some interesting content of a general nature.

www.insidetheweb.com/mbs.cgi/mb426630
This is "Harry's Messageboard" operated out of Sweden and, though slanted toward amateur radio, has a lot of good general content.

www.nutsvolts.com/.ubbcgi/Ultimate.cgi
Watch that dot before "ubbcgi"! This is a new forum hosted by what may be the only U.S. magazine competitor to **Poptronics**. It uses my favorite forum engine, Infopop.

www.poptronics.com
To find this forum, click on "Electronics Forum" at the left and then on "New Electronic Bench Preview" (or on "New Resource Bin Preview"). These are the new forums to which Gernsback is switching, and they have posting and editing capabilities unavailable on the old forums. Electronic Bench is just starting to take off and getting to be a lot of fun.

www.poptronics.com
or ***www.gernsback.com***
After clicking on "Electronics Forum," at the next page go to the bottom and click on "Electronic Bench" or "Resource Bin." These are the original forums, and they are very active still. "Editor's Board" is currently dormant, but I'm hoping that it will be revived soon since it is a great place to post timely corrections to the magazine.

http://pub1.ezboard.com/bbasicelectronics
I love this forum. It's probably more like our Gernsback forum than any other, with similar types of individuals participating. Their material may not be as sophisticated due to the newbie nature of many of the posters.

www.twysted-pair.com/wwwboard/wwwboard.html
Howard Sharp is interested in helping out beginners. This is a nice forum, but it isn't as active as ours. Erase the URL back to the ".com," and you'll be on his home page with some electronics tutorials.

the tab on the rim; the collector was on the opposite side; and the base was in the middle. Sometimes there was a fourth lead, and it was connected to the case. With the flat end facing you and leads pointing down, you will see most of the plastic-packaged TO-92 transistors, such as the 2N3904, run EBC, left to right. However, there are enough exceptions (usually putting the collector lead in the center) that you can't just assume that basing arrangement for a TO-92. Therefore, the best answer is to look up each transistor to determine the basing. And where to look them up? Try to find used copies of the *D.A.T.A. Book* series of data books. They're generic listings that cover more device types than any other source. They're very specific books—there are separate ones for transistors, diodes, thyristors, linear ICs, digital ICs, memory, discontinued transistors, etc.—so it takes a lot of books to cover a lot of device types. Unless you're fabulously wealthy, you can't afford the new books. Other sources are the NTE, SK, or ECG cross-reference guides, which are definitely within the budget of anyone.

You won't always be able to use the numbers on the transistor case to obtain information. Many times, large numbers of transistors made for a specific customer are marked with house numbers, which can only be found on the internal confidential documents of the equipment maker.

The majority of ICs are parts of families. Overall, most ICs will be either digital or analog. Digital ICs can be broken down into smaller families, such as bipolar or CMOS. They can further be defined by specific characteristics and put into families, such as 74LSxxx, 74HCTxxx, 4xxx, etc. Analog ICs are a little more difficult to categorize by type numbers and are organized into categories based upon their function, such as op-amps, voltage regulators, comparators, and audio-control circuits, to name a few. Some categories, such as power supply regulators, have families like the 78xx-, 79xx-, or LM340T-xx series.

*D*ual-*In*-line *P*ackages (DIP) for IC housings are the most common, although *S*urface-*M*ount *T*echnology (SMT) is the host of a whole new constellation of package types. There are several sources of data for ICs on the Internet, but I still prefer using paper versions of databooks. I can mark them up, make notes, make changes, color-code the page edges, file them in order by manufacturer or IC type, and find data much more quickly than by browsing on the Internet. My 40 running feet of shelf space that's devoted to databooks is minuscule compared to what our former columnist Don Lancaster claims to have. Old, outdated databooks are just as valuable as the newest, especially if you repair older equipment. *Never* throw old databooks away!

HOW TO GET INFORMATION ABOUT ELECTRONICS

On the Internet: See our Web site at *www.poptronics.com* for information and files relating to **Poptronics** and our former magazines (**Electronics Now** and **Popular Electronics**) and links to other useful sites.

To discuss electronics with your fellow enthusiasts, visit the newsgroups *sci.electronics.repair, sci.electronics.components, sci.electronics.design,* and *rec.radio.amateur.homebrew.* "For sale" messages are permitted only in *rec.radio.swap* and *misc.industry.electronics.marketplace.*

Many electronic component manufacturers have Web pages; see the directory at *www.hitex.com/chipdir/,* or try addresses such as *www.ti.com* and *www.motorola.com* (substituting any company's name or abbreviation as appropriate). Many IC data sheets can be viewed online: *www.questlink.com* features IC data sheets and gives you the ability to buy many of the ICs in small quantities using a credit card. You can also get detailed IC information from *www.icmaster.com*, which is now free of charge although it formerly required a subscription. Extensive information about how to repair consumer electronic devices and computers can be found at *www.repair faq.org*

Books: Several good introductory electronics books are available at RadioShack, including one on building power supplies.

An excellent general electronics textbook is *The Art of Electronics*, by Paul Horowitz and Winfield Hill, available from the publisher (Cambridge University Press, 800-872-7423) or on special order through any bookstore. Its 1125 pages are full of information on how to build working circuits, with a minimum of mathematics.

Also indispensable is *The ARRL Handbook for Radio Amateurs*, comprising over 1000 pages of theory, radio circuits, and ready-to-build projects, available from the American Radio Relay League, Newington, CT 06111, and from ham-radio equipment dealers.

Back issues: Copies of back issues of and past articles in **Electronics Now**, **Popular Electronics**, and **Poptronics** can be ordered on an "as available basis" from Claggk, Inc., Reprint Department, P.O. Box 12162, Hauppauge, NY 11788; Tel: 631-592-6721. To ensure receipt of the correct material, readers must supply complete information on the article or issue that they wish to buy.

Poptronics and many other magazines are indexed in the *Reader's Guide to Periodical Literature*, available at your public library. Copies of articles in other magazines can be obtained through your public library's interlibrary loan service; expect to pay about 30 cents a page.

Service manuals: Manuals for radios, TVs, VCRs, audio equipment, and some computers are available from Howard W. Sams & Co., Indianapolis, IN 46214; (800-428-7267). The free Sams catalog also lists addresses of manufacturers and parts dealers. Even if an item isn't listed in the catalog, it pays to call Sams; they may have a schematic on file which they can copy for you.

Manuals for older test equipment and ham radio gear are available from Hi Manuals, PO Box 802, Council Bluffs, IA 51502, and Manuals Plus, 130 N. Cutler Dr., N. Salt Lake, UT 84054.

Replacement semiconductors: Replacement transistors, ICs, and other semiconductors, marketed by Philips ECG, NTE, and Thomson (SK), are available through most parts dealers (including RadioShack on special order). The ECG, NTE, and SK lines contain a few hundred parts that substitute for many thousands of others; a directory (supplied as a large book and on diskette) tells you which one to use. NTE numbers usually match ECG; SK numbers are different.

Remember that the "2S" in a Japanese type number is usually omitted; a transistor marked D945 is actually a 2SD945.

Hamfests (swap meets) and local organizations: These can be located by writing to the American Radio Relay League, Newington, CT 06111; (*www.arrl.org*). A hamfest is an excellent place to pick up used test equipment, older parts, and other items at bargain prices, as well as to meet your fellow electronics enthusiasts—both amateur and professional.

Ferrite Cores

Reader Don Pomeroy had some great comments concerning the ferrite rod with which we've been dealing. He reminds us that two-piece ferrite transformer cores are used to facilitate manufacturing, but usually at the price of some electrical performance—mostly in the ability of the core to saturate. He mentions that many of these transformer cores are deliberately manufactured with a calculated gap in the core to prevent the core from saturating during current peaks, which would otherwise distort the waveform. That was the way that the old filter chokes of the golden era of radio were made. Rather than interleaving I and E core sections as transformers do, the I and E sections are *stacked separately and then put together with the I section on top of the E section with a gap between them. Then the normal DC current would not saturate the core, and it would remain an effective reactance for the AC current.*

I had given the impression in the column that the cores of transformers and inductors were always glued or clamped tightly together with virtually no gap. Not true. Thanks, Don, for that reminder.

Old Correspondence-Course Test Equipment

I've had a barrage of questions asking about manuals for test instruments that came with various correspondence courses. Some courses used Heathkit instruments (Cleveland Institute of Electronics, perhaps), and with those there are usually no problems with documentation. However, it's extremely difficult to find documentation for Conar (National Radio Institute) and Bell & Howell. I suspect that a lot of folks took those courses and then just trashed everything and put the equipment in the attic. About the only stuff we can find for Conar is the amateur radio equipment, and we find very little on their test equipment. I would be delighted if any readers would let me know if they have manuals for Bell & Howell, Conar test equipment, or any equipment that was used with courses that were not as well known as the aforementioned. I'd love to have a copy that I can distribute to those in distress.

60-LED Watch

Q *I like the 60-LED watch that was discussed in* **Poptronics** *(December 2000). Please tell me the actual price and where I can get it.—H.S., Germany*

A There's a little mix-up there. The December 2000 "Q & A" article answered a question regarding how one can build a 60-LED clock. The reader was referred to the November 1995 **Electronics Now** "Q & A" column, where such a circuit was presented as a construction project. I'm sorry, but this is not an item that is available for sale.

My Bibliography

Q *I am a beginning electronics student, and I am writing to ask for your advice in locating sources of useful study materials. In my studies, I have purchased quite a few books that contain some useful, but mostly vague, information. Since you have been in the field for many years, could you please suggest several book titles in electronics?—B.C., Milan, MI*

A Suggesting a list of titles will be subjective at most, for no two readers digest information in the same way or agree on a specific author's style. Of course, I have preferred titles that I've zeroed-in on over the years. They're my favorites because the presented information is down-to-earth and practical, often is in a cookbook style, avoids a lot of unnecessary math (but you can't eliminate it entirely), and covers a lot of territory. Still, no one book can do it all, even in a narrow subject area. In addition to the two books recommended in the usual "How To ..." sidebar, the "My Bibliography" sidebar provides subject area, title, author, and International Standard Book Number (ISBN) for several suggested books. With the ISBN alone, you should be able to special order these books through any bookstore. In addition, a subscription to **Poptronics** with its frequent tutorials is a must. I would also suggest the various versions of the *Engineering Notebook* series by Forrest Mims, available at RadioShack.

You had a couple of thousand other questions in your letter, B.C. and thoughtfully enclosed stamps for a return answer. I collect stamps and appreciate the commemoratives. Though I yearn to answer the questions, individual replies are just impossible, considering the number of questions received.

MY BIBLIOGRAPHY

These are recommended books that I have found over the years to be excellent sources of relevant and practical information in several basic areas of electronics.

Analog Integrated Circuits
Design of Active Filters with Experiments by Howard M. Berlin, ISBN 0-672-21539-X

Design of Op-Amp Circuits with Experiments by Howard M. Berlin, ISBN 0-672-21537-3

IC Op-Amp Cookbook by Walter G. Jung, ISBN 0-672-21695-7

DC/AC Electronics
Introductory Circuit Analysis by Robert L. Boylestad*, ISBN 0-02-313161-6

Digital Integrated Circuits
Digital Circuits and Systems by Douglas V. Hall*, ISBN 0-07-025537-7

CMOS Cookbook by Don Lancaster, ISBN 0-672-21398-2

TTL Cookbook by Don Lancaster, ISBN 0-672-21035-7

Solid State (Transistors, Diodes, etc.)
Electronic Principles by Albert Paul Malvino*, ISBN 0-07-039957-3

Introductory Electronics Devices and Circuits by Robert T. Paynter*, ISBN 0-13-482993-X

Transistor Circuit Approximations by Albert Paul Malvino*, ISBN 0-07-039878-X

*Textbook (more expensive), but usually there's a lab manual available for building circuits.

A Scanner Without A USB Cable?

Q *I have a Bearcat BC-201 (not a 210) scanner that I've had for a long time. My nephew recently bought what turned out to be a broken copy of the same exact model at a hamfest. I called Uniden Bearcat, who simply said that they never heard of that model. I bought mine when there was a takeover of Bearcat by Uniden. How can I get a schematic? I've tried all the sites in your February issue.—P.M., via e-mail*

A A lot of folks reading this will be surprised that it isn't just Hewlett-Packard, Visioneer, et al., who make scanners. We might inform these individuals that, in this case, we're talking about the original scanner, a programmable radio receiver, rather than the computer peripheral. At least by trying those sites from the February column, you know where the documentation isn't.

I'd suggest getting in with the scanner crowd and see what you can find. The Strong Signals site has a forum where you could send out a distress call to individuals who are more likely to be able to help. Check them out at *www.strongsignals.net/msgboard/index.html*. Other readers might be interested in this site as well, for they have a parallel forum for frequencies below 30 MHz, *i.e.*, short-wave listening. Just click on that topic at the top of the Strong Signals forum cited above. We also might have some readers who have information on this desktop radio scanner.

Repairing PC Power Supplies

Q *The world is filling up with defunct PC switching-power supplies, and their low cost makes repair uneconomical given today's high labor rates. However, I believe that I could repair them for a profit as I am retired and my labor rate is zero. The problem is the lack of documentation. I wonder if you could publish typical schematics for the different types and a brief theory of operation.*

Also, can the five-volt section of a PC supply be changed to produce 12 or 15 volts? I could rewind the transformers and replace output devices if that was all that was required.—D.C., Hudson, MA

A Since, as you mention, the PC supplies are relatively inexpensive, they come with little documentation and no factory support. There are so many manufacturers and varieties out there that it's nearly impossible for a third party such as Sams to develop service literature in that area.

There are a couple of Internet resources that might be helpful. Our own Sam Goldwasser has a posting titled, "Notes on the Troubleshooting and Repair of Small Switchmode Power Supplies." Find it at *www.repairfaq.org/REPAIR/* and then click on "Small Switchmode Power Supplies."

The PC Mechanic site at *www.pcmech.com/byopc/index.htm* has a forum listed on the left side of their home page. Under that forum, you can pose hardware questions to the group. I tossed yours out there, but got the "ain't worth the trouble" reply that was expected, even considering your specific situation. The comment was made there that a lot of those supplies were rejected because the design left them marginal in performance and reliability.

Modification of the supplies would almost require a schematic to find the specifics for the control circuits. Unlike linear supplies, most switchers develop their various voltages by specific turns on the transformer secondary and sampling one of those for regulation. There wouldn't be enough overhead on the primary side to just boost it up to get two or three times the voltage from the 5-volt output. It would take transformer rewinding, modifying the sampling circuit, and the changing of several capacitors to higher voltage ratings to achieve your goals. You would also have to modify any over-voltage or crowbar circuits.

Because of all those excess working supplies out there, it would be nice to find a "cookbook" method of supply modification for experimenters who want to use them in ways not conceived of by the manufacturers. Unfortunately, I'm afraid that the sheer number of supply types makes publishing something like that impractical, too. Anyone who does modify a switcher must remember to keep the supply in its original box to maintain safety.

Sidebar Correction

Thanks to reader George Ribley who noticed that the address for Manuals Plus that is referenced in the monthly "How To Get Information About Electronics" sidebar had changed. As of the May issue, we have published the new address.

On the subject of sidebars, we're looking at revamping the "How To..." and the "Writing to Q&A" sidebars. This magazine and column is for our readers, so give us your input. Do these sidebars, with their current full content, need to be in the magazine every month? Should they be trimmed down? Eliminated? Changed so that they appear only once or twice a year in their full glory and just skeletons the other months? Should the information be put on the Internet site rather than in the magazine, or would that be an impediment to readers without Internet access? Let me know what you think. Communicate!! Our address is in the "Writing to Q&A" sidebar and will still be there after any changes.

Writing to Q&A

As always, we welcome your questions. Please be sure to include:

(1) plenty of background material,

(2) your full name and address on the letter (not just the envelope),

(3) and a complete diagram, if asking about a circuit; and

(4) type your letter or write neatly.

Send questions to Q&A, **Poptronics**, 275-G Marcus Blvd., Hauppauge, NY 11788 or to *q&a@gernsback.com*, but do not expect an immediate reply in these pages (because of our backlog). We regret that we cannot give personal replies. Please no graphics files larger than 100K. P

mailto: amazingscience@gernsback.com

JOHN IOVINE

PIC Microcontroller Basic Compilers

A few months ago, we constructed a robot that used a PIC microcontroller for its neural intelligence (brains). The PIC microcontroller was programmed with a compiled basic program. At the time, I didn't have the space to write about the compiler or the programmer used to program the PIC chip. We are going to correct that omission.

Currently, I use the PICBasic Compiler and the PICBasic Pro Compiler for all my microcontroller work. These compilers are for writing programs for the PIC series of microcontrollers from Microchip Technology, Inc. I choose these compilers for a number of reasons.

Let Me Count The Ways

One, you can write programs in Basic. Despite all the reports for the last 20 years predicting the demise of Basic, it's still here and with good reason. It is a programming language with the shortest learning curve—beginners can easily become proficient in it.

Two, despite the fact the program is written in Basic, which is a slow interpreted language, the compiler converts the Basic language commands to the microcontroller's very fast Machine Language (ML) equivalent. The compiler saves the ML program as a .hex (hexadecimal) file. It is the .hex file that is programmed into the PIC microcontroller.

Three, it's fast. What makes this system fast is that the ML program resides in microcontroller and doesn't require any language or "token" interpretation.

Four, it's a very economical way of implementing PIC microcontrollers into your projects.

While the compiler compiles the program, we still need a programmer to take the compiled program and load it into the PIC microcontroller. The EPIC programmer does this job and is compatible with both compilers.

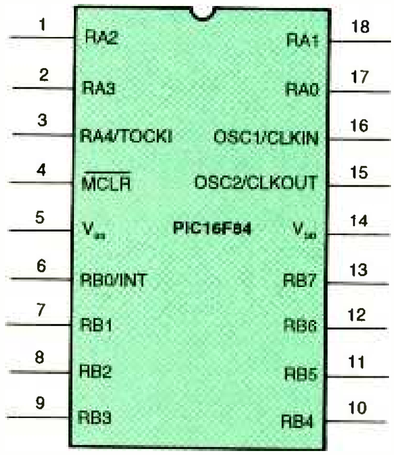


Fig. 1. PIC 16F84 Specification Sheet

You will also need a PC (compatible) computer with a printer port and DOS 3.3 or higher to program and burn PIC microcontrollers.

PIC Microcontroller 16F84

There are dozens of PIC microcontrollers from Microchip Technology, Inc. (*www.microchip.com*) to choose from. I chose the PIC 16F84, because it is versatile, see Fig. 1. It has 1K of on-board programming space and can be re-programmed 1000 times. Memory retention of a program, if you decide to keep it, is 40 years.

The chip has 13 I/O pins. Each pin may be configured as an input or output pin or changed on the fly as a program is running. A pin may source 20 mA maximum or sink 25 mA maximum.

PICBasic Compiler

Out of the two compilers, this month we will look at the PICBasic compiler. The PICBasic compiler is the less expensive of the two compilers with a retail price of $99.95. In addition, you will also need the EPIC programming board and software. The EPIC retails for $59.95. However, if you purchase the PICBasic compiler and EPIC programmer at the same time, the cost is $149.95. The reason we need to look at the compilers separately is that each compiler handles I/O a little differently and to do both at once will be confusing.

The first thing you need to do is to load the software on your computer's hard drive according to the instructions given with the software. To complete the instructions we are going to assume the software, both the PICBasic compiler and EPIC programming software, are saved to a directory called PBasic on your computer's hard drive.

First Basic Program

Now, we are ready to write our first program. To write programs, you need a word processor or text editor. Any word processor that can save a text file as a standard ASCII or DOS text file will suffice. Windows users can use the Notepad program. DOS users can use the Edit program.

I usually drop down from Windows into a DOS level when I write for the PICBasic compiler by opening an MS-DOS prompt window. Once in the MS-DOS window, move into the PBasic directory. Use the command "cd\PBasic" at the command line. In this example, I will be using the free EDIT program package with Windows to write the program. Start EDIT by typing "EDIT" at the command prompt. Enter the program from Listing 1 into your word processor—exactly as it is written. Use the Save function under the File menu. Name the file wink.bas.

Remember, if you are using a different word processor, it is important to save the program as an ASCII text or MS-DOS text file. The compiler (next step) requires the text file (basic source code) in a DOS or ASCII file format.

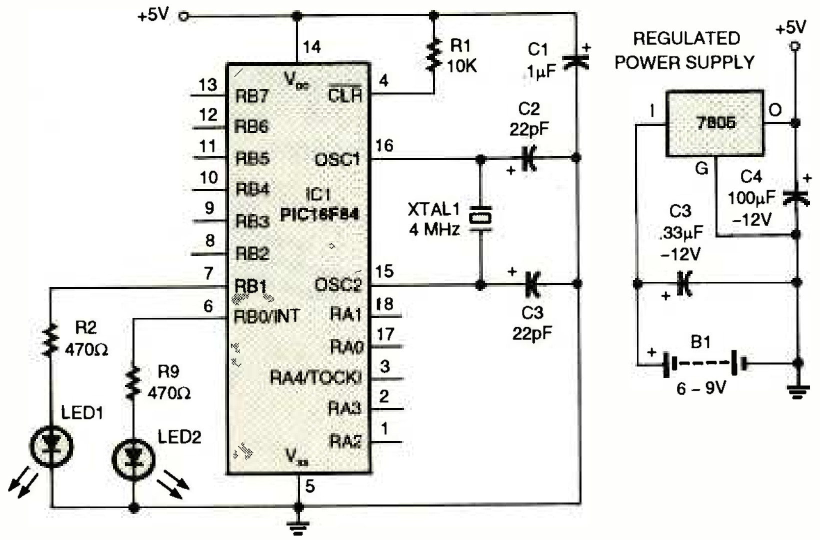


Fig. 2. The schematic above can be used to construct the PIC-controlled wink-circuit.

DOS and ASCII text files do not save any special formatting and print codes that are unique to individual word processors.

Compile

The PICBasic compiler must be run from DOS or from a MS-DOS Prompt Window within Windows. Run the PICBasic compiler from the "PBasic" directory, type this command, pbc –p16f84 wink.bas at the DOS prompt and hit the enter key. The "–p16f84" portion of the command informs the compiler to compile the program for the 16f84 microcontroller.

The compiler displays an initialization copyright message and begins processing the basic source code. If the basic source code is without errors, it will create two additional files (wink.asm—assembler source code file and wink.hex—Machine Language file). If the compiler finds any errors, a list of errors with their line numbers will be displayed. Use the line numbers in the error message to locate the line number(s) in the wink.bas text file where the error(s) occurred. The errors need to be corrected before the compiler can compile the source code correctly. The most common errors are with basic language syntax and usage.

Programming The PIC Chip

To load our program into the PIC chip, we must connect the EPIC programming carrier board to the computer. The EPIC board connects to the printer port.

If your computer has only one printer port, disconnect the printer, if one is connected, and attach the EPIC programming board using a six-foot DB25 cable.

When connecting the programming board to the computer, make sure there are no PIC microcontrollers installed on to the board. If you have an AC adapter for the EPIC programmer board, plug it into the board. If not, attach two fresh nine-volt batteries. Connect the "Batt ON" jumper to apply power. The programming board must be connected to the printer port with power applied to the programming board before starting the software. If not, the software will not see the programming board connected to the printer port and give the error message "EPIC programmer Not Connected."

The EPIC Programming Board Software

There are two versions of the EPIC software; EPIC.exe for DOS and EPICWIN.exe for Windows. The Windows software is 32-bit; it may be used with WIN95, WIN98 and WINDOWS NT, *but not* WIN3.X. It has been my experience that Windows often likes to retain control of the printer (LPT1) port. If this is the case with your computer, the Windows EPIC program may not function properly and you may be forced to use the DOS-level program. If you receive an error message "EPIC Programmer Not Connected" when you start the EPIC windows program, you have the option of either troubleshooting the problem or using the EPIC DOS program.

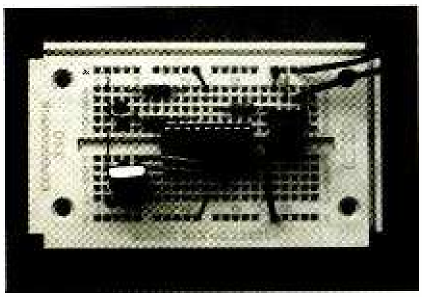
Using EPIC DOS Version

At the DOS prompt inside the "PBasic" directory, type "epic" and hit enter to start the DOS version of the EPIC software. Use the mouse to click on the OPEN button or press ALT-O on your keyboard. Select the wink.hex file. When the hex file loads, you will see a list of numbers in the window on the left. This is the machine code of your program. On the right-hand side of the screen are configuration switches that we need to check before we program the PIC chip.

Let's go through the configuration switches one by one.

Device: Sets the device type. Set it for 8X.
ROM Size (K): Sets memory size. Choose 1.
OSC: Sets oscillator type. Choose XT for crystal.
Watchdog Timer: Choose On.
Code Protect: Choose Off.
Power Up Timer Enable: Choose High.

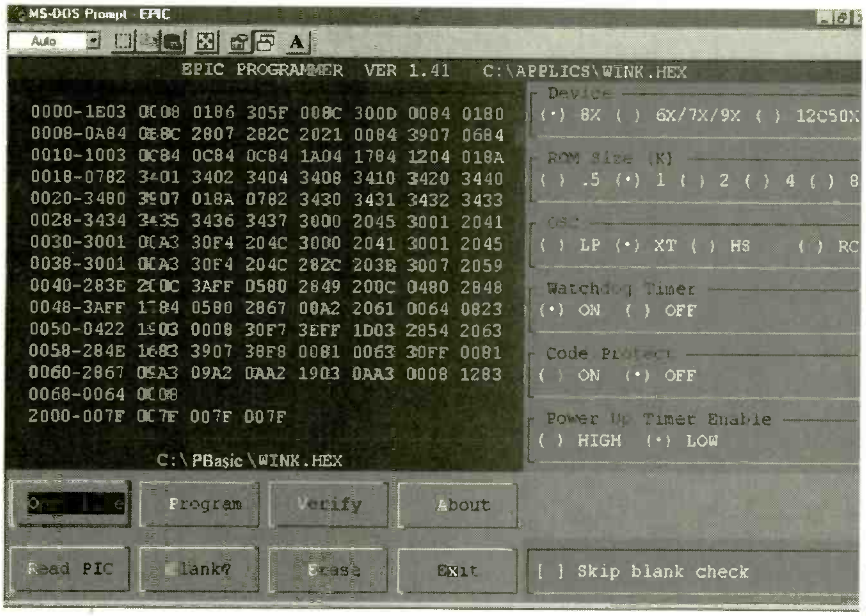
After the configuration switches are



The entire circuit can be assembled on a small prototyping solderless breadboard for testing.

LISTING 1

```
LOOP:  HIGH 0      ' TURN ON LED CONNECTED TO PIN RB0
       Low 1       ' Turn off LED connected to pin RB1
       Pause 500   ' Delay for .5 seconds
       LOW 0       ' TURN OFF LED CONNECTED TO PIN RB0
       HIGH 1      ' TURN ON LED CONNECTED TO PIN RB1
       Pause 500   ' Delay for .5 seconds
       Goto loop   ' Go back to loop and blink & wink LED's forever
       End
```



EPIC Program with wink.hex loaded and ready to be programmed into the PIC16F84.

set, insert the PIC 16F84 microcontroller into the open socket on the EPIC programming board. Click on Program or press ALT-P to program the microcontroller. The EPIC program first looks at the microcontroller chip to see if it is blank. If the chip is blank, the EPIC program installs your program into the microcontroller. If the microcontroller is not blank, you are given the options to cancel the operation or overwrite the existing program with the new program. The machine language code lines are highlighted as the PIC is programmed. When it is finished, the microcontroller is programmed and ready to run.

SOURCE INFORMATION

PIC-LED-02
PIC EXPERIMENTORS KIT
$25.50
Consists of:
(1) PIC16F84, (1) 4-MHz crystal *($1.50), (2) 22-pF caps *($0.10 ea.), (1) 10K ¼-watt resistor *($0.05), 7805 voltage regulator *($0.90), (1) solderless breadboard, 2.1-inch x 3.6-inch, 270 tie points *($8.95), (8) 470-ohm resistors *($0.05 ea.), (1) 10K-ohm resistor *($0.05), (8) Subminiature LEDs *($0.25 ea.), (1) push-button switch, booklet with tutorial on binary number system, logic and I/O of ports A & B.

Available from Images SI Inc., 39 Seneca Loop, Staten Island NY, 10314; 718-698-8305; fax 718-982-6145; *www.imagesco.com.*

*Items marked can be ordered separately.

Testing The PIC Microcontroller

The schematic, shown in Fig. 2, illustrates how few components are needed to get your microcontroller up and running. Primarily, you need a pull-up resistor on PIN 4 (MCLR), a 4-MHz crystal with two (22-pF) capacitors, and a 5-volt power supply.

The two LEDs and two current limiting resistors connected in series with the LEDs are the output. It allows us to see that the microcontroller and program are functioning. I assembled the components on a solderless breadboard.

WINK

Apply power to the circuit. The LEDs connected to the PIC microcontroller will alternately turn on and off. Wink... wink... Now you know how easy it is to program these microcontrollers and get them up and running.

As you gain experience, using the compiler and programmer will become second nature. You won't even consider them as steps anymore. The real challenge will be in writing the best PIC basic programs possible, and that is as it should be. P

mailto: serviceclinic@gernsback.com

SAM GOLDWASSER

TROUBLESHOOTING INTERMITTENT PROBLEMS

Everyone dreads equipment that is temperamental—working or not working depending on its mood. Behavior of faulty electronics may appear to be totally random, but, in most cases, there will be some correlation with physical, environmental, or external interference. Troubleshooting such problems is a primary cause of hair loss in engineers and technicians. Careful observation and perhaps a bit of detective work will ultimately allow a repair to be successful. Using a methodical and patient approach, it should be possible to identify the cause of trouble and repair misbehaving equipment.

If you need your fix of FAQs, then set your browser to www.repairfaq.org. *Sam Goldwasser's Web site offers a near-infinite database of technical info—electronic repair from soup to nuts.*

Haywire Electronics

Some electronic units seem to have personalities of their own. Here are just a few examples of intermittent problems found in household electronics:

- A computer monitor that erratically loses one of its primary colors (red, green, or blue)
- TV reception that turns to slow and then returns to normal apparently at random
- A car radio or tape deck that misbehaves on rough roads
- A TV that turns itself on at maximum volume in the middle of the night
- A CD player that is prone to aborting or skipping at random times
- A microwave oven that blows its main fuse once every 10 days
- A TV that exhibits annoying herringbone patterns at certain times of day

This article deals mostly with TVs and monitors since they appear to be most prone to these sorts of problems. This is partially due to the higher power levels and associated heat generation inside of them, and partially due to the cost pressures that result in manufacturing quality control problems. Other equipment like VCRs and CD players also may suffer from intermittent behavior, but it is usually not due to bad soldering (though there are exceptions). The faults are often due to mechanical problems or dirty or worn internal position-sensing switch contacts.

Manufacturing Defects

Low cost no-name (or unknown name) computer monitors tend to be particularly prone to bad solder connections. However, so are many models of name brand TVs, including those from RCA/GE/Proscan and Sony. We'll touch on these at the end of this article.

Any intermittent problems with monitors that cause random sudden changes in the picture brightness, color, size, or position are often a result of bad connections. Strategically placed bad connections can also cause parts to blow. For example, a bad connection to the SCR anode in a phase-controlled power supply can result in all the current passing through the startup resistor, blowing it as well as other components. I had a TV like this—the real problem was a bad solder joint at a pin on the flyback. Thus, erratic problems, especially where they are power or deflection related, should not be ignored!

Bad solder joints are very common in TVs and monitors due both to poor quality manufacturing as well as to deterioration of the solder bond after numerous thermal cycles and components running at high temperature. Without knowing anything about the circuitry, it is usually possible to cure these problems by locating all bad solder connections and cleaning and reseating internal connectors. The term *cold solder joint* strictly refers to a solder connection that was either not heated enough during manufacturing, was cooled too quickly, or where part pins were moved before the solder had a chance to solidify. A similar situation can develop over time with thermal cycling where parts are not properly fastened and are essentially being held in by the solder alone. Both situations are most common with the pins of large components like transformers, power transistors and power resistors, and large connectors. The pins of the components have a large thermal mass and may not get hot enough during manufacturing. Also, they are relatively massive and may flex the connection due to vibration or thermal expansion and contraction.

Why Can't TV Manufacturers Learn To Solder Properly?

I can think of several potential reasons—all are solvable, but at higher manufacturing cost.

- Mass of large component leads (like shields) does not get adequately heated during manufacture leading to latent cold solder joints. While they may look OK, the solder never actually "wetted" the heavy pins and, therefore, did not form a good mechanical or electrical bond.
- Thermal cycles and differential thermal coefficients of circuit boards, traces, and solder. While it is not easy to do anything about the material properties, using plated through-holes or a similar mechanical via would greatly increase the surface area of the joint and prevent the formation of cracks.
- Vibration. This is also directly related to single-sided circuit boards without plated through-holes to strengthen the joints.
- Lack of adequate mechanical support (single-sided circuit boards without plated through-holes or vias).

I believe that the single most significant improvement would be by using plated through-holes, but this would add to the cost. Apparently, the consumer is not willing to pay more for better quality and reliability! Some designs have used rivlets—mechanical vias instead of plated ones. While this is good in principle, the execution has often been flawed where cold solder joints resulted between the rivlets and the circuit board traces due to lack of adequate process control.

The Sony and RCA/GE tuner shield problem is interesting, because this could have been solved years ago at essentially no additional cost as other manufacturers—and their own repair procedures—have proven.

Attacking Intermittents

First, determine whether the problem is internal or external. The most common external causes would be electro-magnetic interference, either through the air or via the power line. We'll discuss these at another time. Suffice it to say, changing the location or electrical power source will usually help to narrow it down.

If internal, it may be physical, heat related, or mode related. Gentle whacking (yes, whacking is an acceptable diagnostic technique but don't go for the 12 pound hammer!), pressing, flexing, cable wiggling, etc., can and should be used in an attempt to confirm at least that there is a physical cause inside the unit. Doing these tests just as the problem comes or goes is the best time as whatever is marginal will be most marginal then.

If the problem appears or disappears, or does both, over a period of time after the equipment is turned on, then temperature is almost certainly a factor as the circuit board and components expand.

The most common physical problems are bad (cold) solder joints, connectors that need to be cleaned and reseated, and bad cables or cable connections. Perhaps surprisingly, though components may fail internally and result inerratic behavior, this is probably lower on the list of likely causes than those listed above. Some exceptions would be mechanical relays in audio power amplifiers, phone equipment, and elsewhere; hybrid power amplifiers; and other power devices.

The whacking, etc., can be done without taking the cover off the equipment and may or may not reveal anything. In either case, you will have to go inside. If there is an effect, then you will know that the problem IS inside, and further tests will be needed to identify the specific cause.

Once the cover is off, there still may be quite a challenge to find the specific solder connection or contact that needs attention. Knowing something about how the actual circuit area relates to the symptoms will help narrow it down. For example, if there is a loss of vertical-deflection in a TV or computer monitor, the most likely areas to attack will be the vertical-deflection output stage and its power-supply feed.

For popular consumer electronic equipment, intermittent problems are often present in many (or even most) samples of a particular model over the course of its life. Therefore, checking a tech-tips database or asking on the USENET newsgroup *sci.electronics.repair* may reveal a common cause and an easy solution ("resolder the flyback pins"). There is a list of tech-tips databases at my Web site, *www.repairfaq.org*.

Assuming these don't help (or you consider letting someone else solve your problem to be cheating), a detailed visual inspection is the next step. This may be all it takes. With the unit unplugged (and after confirming that power-supply capacitors are discharged!), remove the cover.

Start with the pins on devices like power transistors, transformers, and large or high-current connectors. These are most likely to cause marginal solder connections to break apart due to thermal and physical stress. Hairline cracks at solder joints are primary causes of intermittent faults, especially in TVs and monitors with their power supply, deflection, and video circuitry that may run hot.

Make the inspection under a bright light. If your close-up vision isn't perfect, use a good magnifier—there may be hairline cracks and their visibility may be obscured by reflections from the solder joint. Use a pointed stick (not something metal if possible) to gently prod any suspicious looking pins to see if they move. Look for discolored patches on the circuit board. Such discoloration isn't in itself a problem unless it is severe. It does indicate that hot components live there or nearby and bad solder joints are very likely.

Check for tan or brown glue on the top and bottom of the circuit boards. A rigid adhesive may be used to attach various components, but some varieties decompose and become conductive with heat and age. Some very weird problems have been linked to decayed glue! So, carefully scraping it away and replacing it with non-acidic RTV Silicone or similar adhesive may be prudent. However, I don't know how to tell which type is a problem. Check for loose or damaged cables (particularly in user-serviced equipment like PCs!).

Remove, inspect, clean (if necessary), and reseat all internal connectors. Even if they don't seem to be in an area of the circuitry that is relevant, they could be feeding a power or control signal. Check for discolored or fatigued contacts as well as physical damage to the wires and improperly made crimps. If any components (like transistors or SIMM memory modules) plug in, do the same for them.

Where a problem is found, don't assume there is only one! In many cases, bad solder connections or bad crimps are caused by poor manufacturing process control and will be repeated in many locations. So, correct what was found and then continue to inspect the entire unit. Sometimes, manufacturing is so poor that resoldering the entire board is the only solution with any chance of long-term success. An example of this was given in a previous ServiceClinic sidebar, "GE TV With 'Rivlets'"—intermittent by design!

If a suspicious area is located, it may be possible to use an ohmmeter between selected pins to determine if a connection is intermittent. To increase the chance of detecting a momentary change in resistance that may be too brief to register on a meter, connect the input of an amplified speaker (or audio amp and speaker) in parallel with the meter probes.

Taking A Closer Look

If none of the previous checks produces a breakthrough, the next step is to power up the equipment. **WARNING! Depending on the particular equipment, lethal voltages or other hazards may exist.** Make sure you understand and follow the safety guidelines published in prior Service Clinic articles and at my Web site!

Using an insulated stick, start gently prodding likely areas of the circuitry in an attempt to make the problem come and go. If you are successful, don't assume the journey is over! Pressing at a corner of the board may have an effect at the opposite side. In fact, you may find that pressing anywhere appears to have about the same effect. It may take some very, very light tapping, flexing, etc., to locate the culprit. Until a physical cause is actually located (e.g., a visibly cracked solder joint where the pin can be seen to move!), don't assume you're home free even if the problem appears to clear up. In fact, it is very common for an intermittent problem to go away as soon as troubleshooting begins, not to reappear for several days or more—but it will reappear!

Once a particularly sensitive area is located, use a stick thin enough to just touch a single pin at a time. Sometimes, a probe with a pointed metal tip, insulated for all but the last 1⁄16-inch or so, will be useful as it can get into the area between the pin and solder pad where cracks may have developed but are not visible. The metal tip will bridge the gap causing a change in behavior.

If the cause is heat related, no amount of prodding (or cursing) will make the problem occur with the cover off. In this case, a heat gun (or blow dryer) may be needed to carefully warm up selected areas of the circuitry in an effort to identify the culprit. A blower with no heat may be used for cooling, or "circuit chiller" or "cold spray" may be used for more aggressive spot cooling. However, simply removing the cover may have altered something physical. For example, one of the cabinet screws may be too long and is shorting out something—this may be either from improper prior reassembly after repair or a manufacturing or design defect.

The hardest intermittent problems to locate are those that occur infrequently and for only a short time with no chance of making a measurement. There are fancy and expensive recording analyzers for just such occasions (but you can buy a nice car for what one of these costs!). However, there may be no need for such extravagance. If you have an oscilloscope and camcorder or video camera/VCR, you probably have all you need.

For a TV or monitor, point the camera at the CRT and the scope screen so that they are both in the picture and record on a six-hour tape. Then, when your event takes place, you have a permanent record! That old video camera will be perfectly adequate. It doesn't need a 100× digitally stabilized enhanced reprocessed zoom or 1/10,000th second shutter. It doesn't even need to be color! Sure, this won't capture the 1-ns glitch. For the occasional flash in the picture, it is more than adequate to eliminate a video-signal line as the source of the problem.

Don't rush this process. It may take several diagnostic sessions to finally resolve the problem. Even if you find and fix one or more cracked solder joints, it may be worth waiting a few days to reinstall those ten shields that had to be removed in order to access the underside of the main board! However, do replace the cover so that the internal temperature will be similar to normal during extended operation.

Now the question comes up: How can the recurrence of intermittent faults be prevented? For cracked solder joints, in addition to using proper soldering techniques for repair, it should be possible to add some "reinforcements" in the form of bare wire wrapped around the pin and extending out to the circuit board trace or even to an adjacent component pin. This will be better than just using more solder. For the CTC175 etc. cases discussed below, there is also special "elastic" solder that supposedly should be used. But, there are mixed reviews on whether this really helps.

Some equipment may also benefit from a small amount of additional cooling. A small fan can be added to draw air out of the cabinet. This will improve reliability since most components are happier being cool, but it will also reduce the extent of the thermal cycles reducing the likelihood of bad solder joints developing in the future.

RCA/GE/Proscan And Sony TVs

Classic examples of an intermittent problem present in an entire product line are the RCA/GE/Proscan TV chassis starting with CTC175 and running at least through CTC187, possibly beyond. A very large percentage of these TVs have cracked solder joints in the area of the tuner/controller resulting in erratic picture and sound. If not corrected, this eventually results in bad data being written into the EPROM that stores the TV's parameters causing a total failure to turn on. Until recently, Thomson Electronics was covering at least part of the repair costs. There may also be at least one class action lawsuit pending in regards to this problem.

Some Sony TVs suffered from a similar set of bad solder joints, usually in the tuner or IF (metal) boxes. The most common location for the problem for many of these was one pin of a coil inside the IF box that always seemed to lack adequate solder. Much more information on the RCA/GE/Proscan and Sony solder problems and solutions can be found on my Web site. Other makes and models of TVs have similar problems with solder joints, but not to the extent of these.

Wrapup

That's all for now. Intermittent faults have been present since the days of the cat's whisker radio and will be with us until something replaces electronics in the high-tech world. Until then, we will have to deal with bad soldering and other similar problems. However, in most cases, they will yield to a systematic approach of inspection and testing. I welcome comments and suggestions in regard to this and previous Service Clinics (via e-mail to sam@repairfaq.org, please—I am not able to reply to snail mail, sorry). ■

DIGITAL DOMAIN

(continued from page 20)

legitimate products. Even so, MLM participants, called "distributors," typically make money less by selling products than by enticing other people to sell products. Distributors earn commissions of the sales of their recruits, and their recruits' recruits, and so on, with everybody scrambling to work their way up the pyramid where the big money supposedly is.

MLM has a bad reputation for good reason. The hype surrounding MLM is in direct proportion to its penchant for taking people for a ride. Most people wind up losing money on the cost of inventory, "educational" products, and travel, says Edwards. On the other hand, you can indeed use your personal computer and the Internet to help you make money from home, either full time or on the side, and many people do. Various statistics indicate that about one-third of Americans have a home office and that about one-quarter of these offices are used to support home-business activities.

Some do succeed at MLM, and if you want to explore it as a moneymaking opportunity, recommendations from friends or colleagues are best, says Edwards. Find a company selling products you find useful. Check out the company with the Federal Trade Commission and the Better Business Bureau. Your best bets for making money with the help of your PC are more mainstream pursuits, such as Web site creation, computer consulting, computer repair, and technical writing, says Edwards. He provides more tips at his Web site, at *www.homeworks.com*. Another good site, which offers particularly good advice about technology for those working in either home or small offices, is Smalloffice.com, at *www.smalloffice.com*. You may not get rich quick doing it the right way, but you won't lose your shirt either.

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COMPUTERS AND THE ECONOMY

Perhaps the days of a cashless society are still beyond our grasp, but over the past five years, more people are participating in trade over the Internet. Although society-at-large may not yet be cash-free, the Web has proven that money does not have to physically change hands in order to make profits. The so-called Information Revolution has produced new profit-yielding opportunities and careers for folks the world over. Cyberspace may be a cashless society bustling with trade, but it is still a far cry from utopia. ■

THE MPX 2000

(continued from page 44)

cures the hum, the problem is either a poorly filtered DC supply or RF induced hum. There is filtering built into the MPX 2000 so a pretty poor DC supply will be tolerated, but this is still not recommended. If improving the power-supply filtering does not help, the hum is most likely RF induced. In this case, you may have to experiment with antenna placement, grounding, and RF chokes in the power leads. A metal case is helpful sometimes, as it provides some shielding and grounding via its self-capacitance.

Final Words On FM Transmission. It is important to remember that the FM band is strictly governed by federal regulations in the US. Likewise, the use of transmitters also must follow certain guidelines. In keeping with Part 15 FCC requirements, the radiated field must be kept below 250 mV per meter at 3 meters (about ten feet) from the transmitter. The use of a six-inch whip antenna is recommended. If the receiver is close to the MPX 2000, no antenna at all will be needed. Sufficient signal will radiate from the PC board itself to be detectable, if a plastic case is used for packaging. In practice, this 250 μV per meter at 3-meter limit will permit good reception at 50 to 500 feet from the transmitter, depending on the receiver sensitivity and its antenna system. DO NOT connect any more length of antenna than you need, or you may invite an FCC citation. ■

BASIC CIRCUITRY

mailto: basiccircuitry@gernsback.com

CHARLES D. RAKES

Current-Monitoring Circuits

Greetings to all Circuiteers! This visit we're going to look at several AC current-monitoring circuits, including one designed for robot use. Making DC current measurements is usually an easy task. Most often it's as easy as breaking the circuit and inserting a DC current meter. Fortunately, in today's electronic world, most solid-state circuits operate at relatively low voltages, but that's not always the case when working with AC circuits. In fact, AC-operated equipment is often powered by 120 volts.

AC Or DC? That Is The Question.

Most DC current-measuring circuits monitor the voltage drop across a low-value internal resistor that is placed in series with the DC supply and load. There is always a slight power loss due to the voltage drop across the meter's internal resistor. AC current can be measured in a similar manner, as shown in Fig. 1. A sampling resistor is connected in series with the AC power source and the load. The voltage drop across the resistor can be monitored and converted into a current reading by simply using Ohm's law, I=E/R.

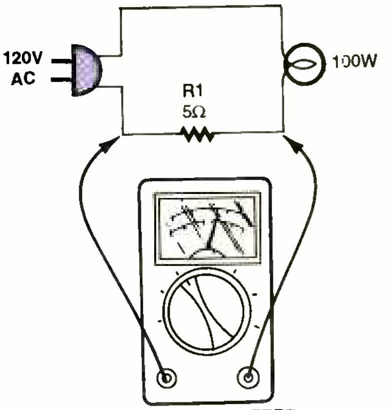

Fig. 1. Here is a simple circuit used for monitoring current. A sampling resistor is connected in series with both the power source and load.

The voltage drop across the 5-ohm resistor can easily be converted into a current value. The meter connected across the 5-ohm resistor will indicate a voltage of about 4.15 volts. The current through the 5-ohm resistor is easily found by dividing the voltage (4.15) by the resistance (5 ohms), producing a current of about .83-amps. A typical 100-watt bulb draws about .83 amps at 120 volts AC, indicating that our answer is on the money. One of the negatives in using this system of measuring current is the power loss in the 5-ohm sampling resistor, which is about 3.44 watts (P = EI).

Equipment Failure

Our main objective in measuring the current flow in an AC circuit is to give out an alarm when the current ceases to flow. This information can be extremely important when a circuit or piece of equipment fails. Several examples come to mind, such as an exhaust fan pulling flammable fumes from an area where a motor failure could end in a fire or explosion or an electrical heater used to keep pipes from freezing. An alarm here could save money and headaches. With a bit of head scratching, I'll bet you can come up with even better uses for AC-monitoring circuits.

A Better Way

A much better and efficient way to monitor AC current flow is to insert a current transformer in series with the power source and load. A simple example is shown in Fig. 2. Here we've taken a 6-volt, 3-amp power transformer and placed the secondary winding in series with our power source and with a 100-watt light bulb. The transformer's 120-volt primary is now the current transformer's output. This AC output can be connected to the coil of an AC relay to send an alarm when the relay drops out. This method can be used in applications

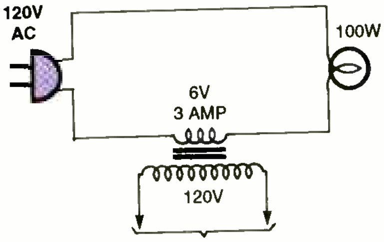

Fig. 2. A current transformer can be used to monitor current flow within a circuit. The 6-volt, 3-amp power transformer used above is ideal for low-current circuits.

where the circuit current is low and where the voltage drop across the 6-volt winding is not a problem.

An Even Better Way

A much better current transformer can be made (see the examples in Fig. 3 and Fig. 4). The current transformer in Fig. 3 is wound on an Amidon Associates,

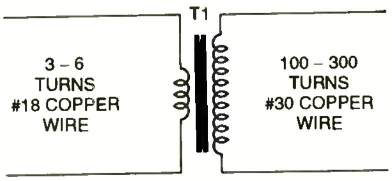

Fig. 3. Using hand-wound coils, you can make a variety of current-sensing transformers. Patience and practice are needed to wind over 200 turns of copper wire on a secondary coil.

PARTS LIST FOR AMIDON CURRENT TRANSFORMER (FIG. 3)

AMIDON part # EA-77-375 core and bobbin can both be ordered through Amidon Associates, Inc., 2216 East Gladwick, St., Dominguez Hills, CA 90220; *www.amidoncorp.com*.

Number 18 or larger enamel-covered copper wire

Number 30 enamel-covered copper wire

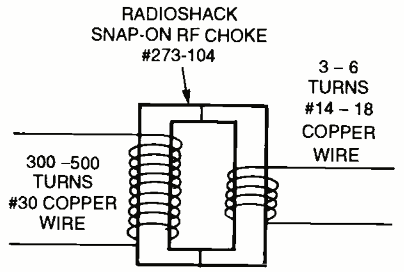

Fig. 4. Using an RF-choke form, one can hand-wind an E-core transformer. This type of transformer is more efficient at lower frequencies.

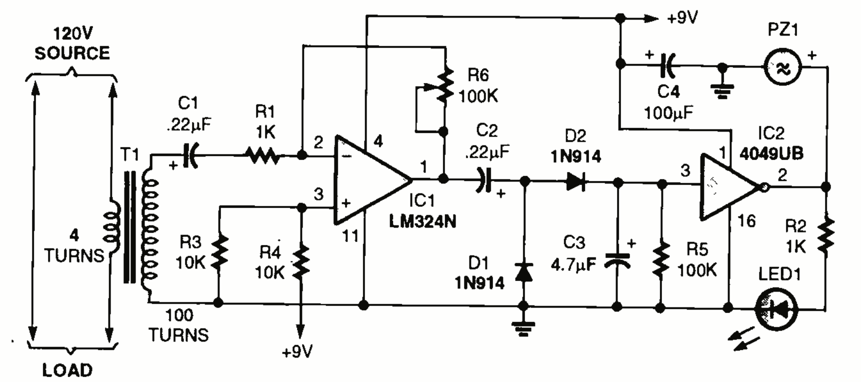

Fig. 5. Here is the schematic for an alarm circuit that incorporates light and sound. An op-amp and buffer are used for signal monitoring.

PARTS LIST FOR MONITORING-CIRCUIT WITH A/V ALERTS (FIG. 5)

SEMICONDUCTORS
IC1—LM324N quad op-amp IC
IC2—4049UB inverting buffer IC
D1, D2—1N914 silicon diode
LED1—LED (any type or color)
Pz1—Piezo sounder.

RESISTORS
(All resistors are ¼-watt, 5% units.)
R1, R2—1000-ohm
R3, R4—10,000-ohm
R5—100,000-ohm
R6—100,000 ohm-potentiometer

CAPACITORS
C1, C2—.22-µF, ceramic-disc
C3—4.7-µF, 25-WVDC electrolytic
C4—100-µF, 25-WVDC electrolytic

ADDITIONAL PARTS AND MATERIALS
Current transformer (see text)
IC sockets, perfboard, etc.

Inc. “E” bobbin and core. These run about $3.50 for the bobbin and two cores.

The two windings are wound on the plastic bobbin and placed in the center leg of the two “E” cores. The current-sensing winding that is connected in series with the power source and load has from three to six turns of number 18 or larger copper wire. The secondary winding can be 100 turns and up of number 30 enamel-covered copper wire. The number of turns needed on the secondary depends on the primary current and the output voltage required by the monitoring-alarm circuit. Low current levels of less than 1 amp to around 3 amps require about 300 turns on the secondary and less turns for higher current levels.

The current transformer in Fig. 4 is wound on a RadioShack snap-on RF choke form. The RF choke is made up of two identical U-shaped ferrite cores. Wind three to six turns of number 14 to 18 enamel-covered copper wire on one of the “U” cores and 300 to 500 turns of number 30 enamel-covered copper wire on the other core.

More turns are required on the secondary of these cores than is required for the same output voltage produced by the “E” cores. The “E” cores are more efficient at lower frequencies. If the RadioShack cores are used, be sure to place a single layer of electrical tape over the winding area. The core's edges are sharp and could cause a break or short in the winding.

Light And Sound

The circuit shown in Fig. 5 is an AC current-monitoring circuit, complete with an audible and light alarm output. Either of the two previous current transformers may be used in this circuit. Adjusting the op-amp's gain with R6 can compensate for the difference in the transformer's output voltage. The circuit is suitable for monitoring AC current levels from less than 1 amp to over 5 amps.

One op-amp of a LM324N quad op-amp package is connected in a variable-gain voltage-amplifier circuit. The gain may be varied from less than one to about 100.

The amplifier's output is connected to a DC rectifier circuit made up of D1, D2, C2, and C3. The positive DC output signal is coupled to the input of an inverting buffer IC, one of six buffers in a 4049UB IC. Current flowing in the primary of the current transformer supplies a continuous AC output voltage at the secondary and a positive voltage at the input of the 4049UB buffer. Since the IC buffer is an inverter, the output is low and neither the LED nor piezo sounder is activated.

A failure of current flow in the load circuit allows the positive voltage across C3 to discharge through R5 to near ground level taking the input of the inverter IC low. The output of the 4049UB goes from a low to a high, lighting the LED and sounding the alarm.

The op-amp's gain should be adjusted to produce a minimum of 7 volts DC at the input (pin #3) of the 4049UB, when the load current is at its lowest operating level. This will keep the alarm

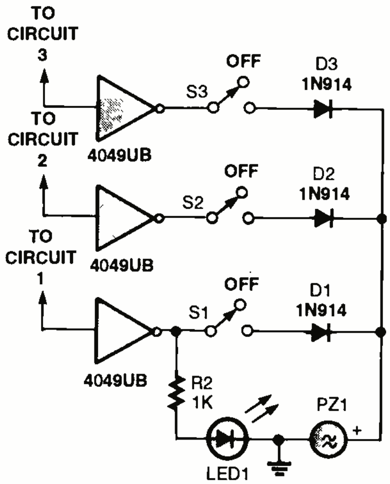

Fig. 6. Multiple occurrences of the circuit shown in Fig. 5 can be linked together using the schematic above. Several sensors can be used to form a complex alarm network.

PARTS LIST FOR ADDING ADDITIONAL STAGES (FIG. 6)

PZ1—Piezo sounder
S1—Single-pole, single-throw switch
D1—1N914 silicon diode.

from going off when the load is operating at its lowest current level.

Additional current-monitoring stages may be added by following the scheme shown in Fig. 6. The output of the 4049UB inverter, pin #2, connects to a single-pole, single-throw switch and on through a 1N914 diode to a common alarm buss with a piezo sounder as the audible alarm. The LED remains connected to the IC's output to indicate which alarm has been activated.

A Transistor-Based Alarm Circuit

Our next current-alarm circuit, see Fig. 7, takes a slightly different design approach to accomplish similar results. The circuit's only active component is a general-purpose NPN 2N3904 transistor. Current levels from about 1–10 amps can be monitored with this circuit. Either of the current transformers in Fig. 3 and Fig. 4 may be used. The circuit operation is also very simple.

With no current flowing in the current transformer's primary, the voltage output of the secondary is zero and the voltage across C1 is also zero. Q1 remains off, allowing LED1 to light. If S1 is closed, the positive voltage at the collector of Q1 will pass through D1 and R4, turning on Q2 and sounding the alarm. Normally, when current is flowing in the transformer's primary, the AC output voltage at the secondary is rectified by D1. This positive voltage charges C1 and turns Q1 on. The voltage at Q1's collector is near ground level, the LED remains dark, and no positive voltage is fed to the output buss. An interruption of the load current allows Q1 to turn off and send a positive voltage to the buss—turning on Q2 and sounding the alarm. Any number of current-monitoring circuits may be added to the alarm circuit. Connect each output through a switch and a diode to the output buss, as shown in Fig. 7.

Either monitoring circuit can be connected to a control relay or to an optoisolator for other output applications. A high-powered sounder could be added this way to give out a more positive and far-reaching alarm. Also, the output could be coupled to an automatic shutdown circuit as a safety feature. In any case, there are many applications where a current-alarm system can save money, improve safety, and reduce down time.

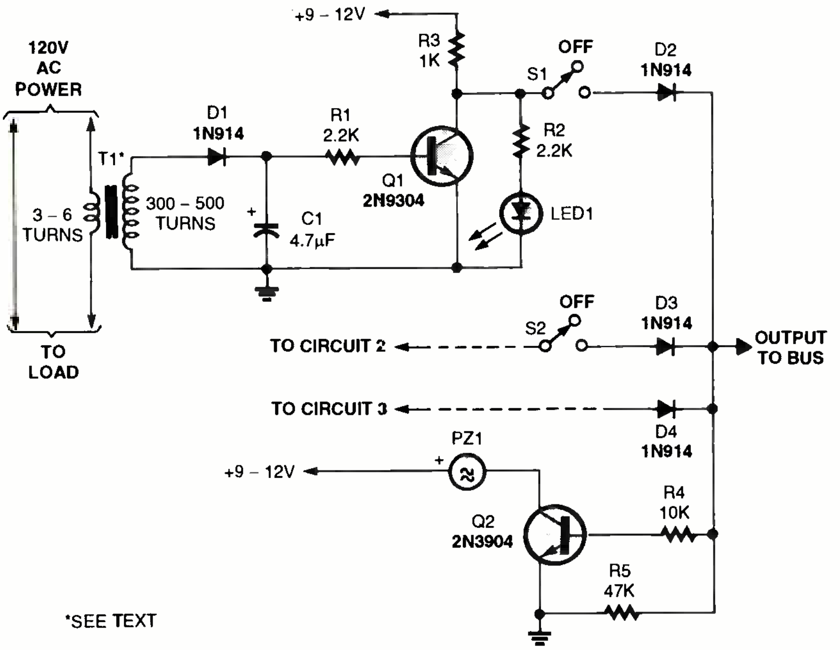

Fig. 7. Sometimes it is nice to create a circuit without ICs. Above is an alarm circuit that uses transistors as the only active components.

PARTS LIST FOR THE TRANSISTOR-BASED ALARM (FIG. 7)

SEMICONDUCTORS

Q1, Q2—2N3904 NPN general-purpose transistor
D1-D4—1N914 silicon diode
LED1—LED, any type or color

RESISTORS

(All resistors are ¼-watt, 5% units.)
R1, R2—2200-ohm
R3—1000-ohm
R4, R5—10,000-ohm

ADDITIONAL PARTS AND MATERIALS

S1, S2—Single-pole, single-throw switch
PZ1—Piezo sounder
Current transformer, see text

Robot-Turning Zone

Our last entry this visit is a dual-current-sensing circuit that's designed to give directional output signals to a roving robot. The circuit in Fig. 8 is an updated version of the steering system for a three-wheel hound dog that I helped a young friend build for a Science Fair project over thirty years ago. The original circuit used transistors and a DC steering motor with a built-in gearing system that turned at about 5 rpm. The hound dog would follow the signal from a wire placed on the floor and travel around over the wire no matter where it went.

The secret to the dog's good nose was the 5-kHz current flowing in the wire. The output of an audio generator fed through a speaker-output transformer to the closed wire loop did the trick.

The updated version of the robot-steering circuit replaced the transistors with a single LM324N quad op-amp IC. We'll look at the "left" steering circuit since both the left and right are identical. First, let's look at the pick-up coils. L1 and L2 are coils wound on a round piece of ferrite-rod material, measuring ¼-inch diameter by 2 inches in length. The exact size isn't all that important. The ferrite rods can be salvaged from either an old TV or from just about any old transistor radio. About any ferrite rod material will work. Wind between 200 and 500 turns of #30 enamel-covered copper wire in a jumble fashion on each rod. The two coils are placed on a platform with the robot's front steering wheel (see drawings in Fig. 9 A and B). The steering motor is attached to the robot's main body, and its shaft is connected to the steering wheel platform.

Now back to the circuitry. The circuit is designed so the robot will follow a wire placed on the floor. When it is traveling in a straight line, the wire will

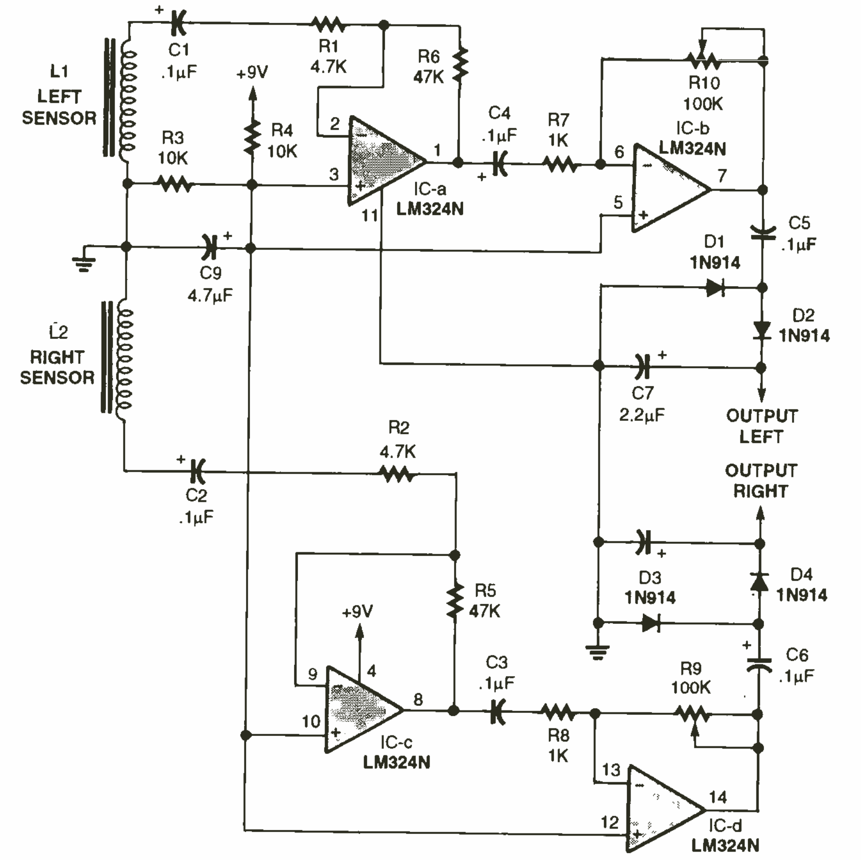

Fig. 8. Here is a circuit designed for steering a roving robot. Two pick-up coils are used as sensors that detect current flowing in copper wire.

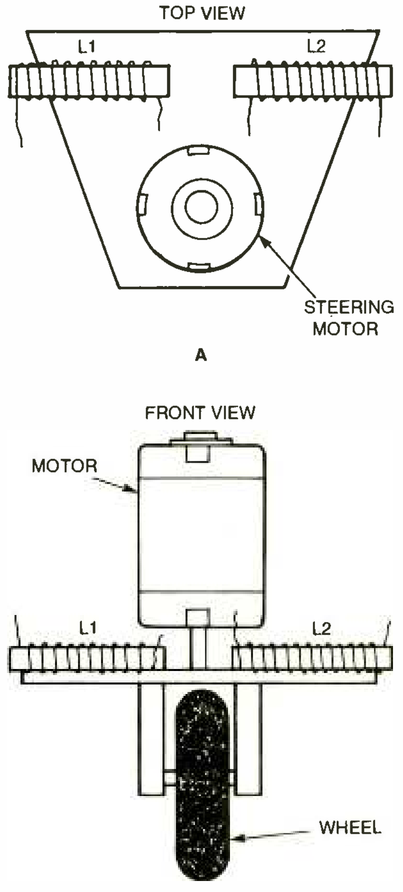

Fig. 9. A DC motor is used in conjunction with the monitoring circuit from Fig. 8 in order to control the robot's movement. The two sensing pick-ups are placed on either side of the front wheel.

PARTS LIST FOR THE ROBOT-STEERING CIRCUIT (FIG. 8)

SEMICONDUCTORS
IC1—LM324N quad op-amp IC
D1–D4—1N914 silicon diode

RESISTORS
(All resistors are ¼-watt, 5% units.)
R1, R2—4700-ohm
R3, R4—10,000-ohm
R5, R6—47,000-ohm
R7, R8—1000-ohm
R9, R10—100,000-ohm pot.

CAPACITORS
C1–C6—.1-µF, ceramic disc
C7, C8—2.2-µF, 25-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS
Current transformer (see text)

be centered between each pick-up coil. If the robot starts to head off track towards the right, the left pick-up coil will begin to receive a stronger signal. The circuitry then sends a positive voltage to the motor steering circuit to turn the robot back in line with the wire.

The circuit operation is simple. Amplifiers A and B amplify the audio-tone signal picked up by the coil. The amplified signal is fed to a positive DC rectifier circuit, which supplies the steering motor with a correcting signal. The gain pots, R10 and R9, allow the circuit to be adjusted so little or no DC output occurs from either the left or right circuit when the tracking wire is centered between both coils.

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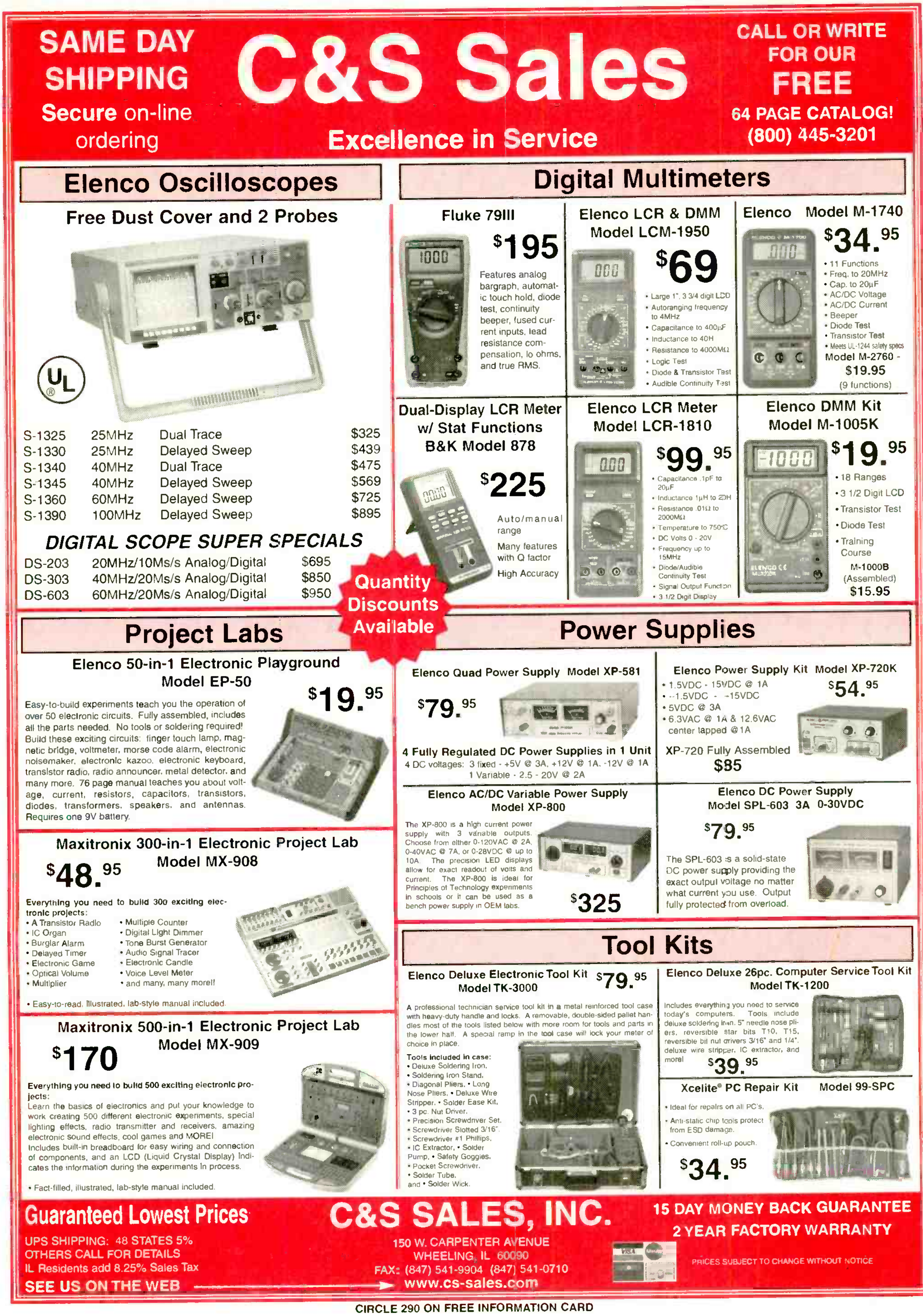

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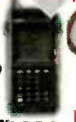

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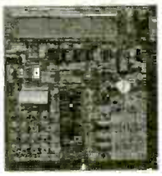

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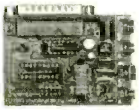

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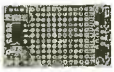

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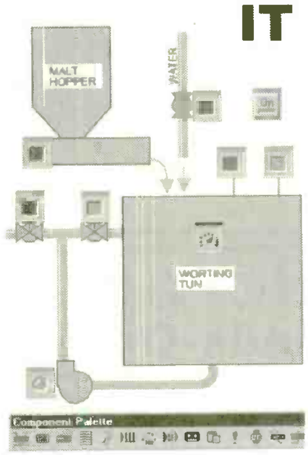

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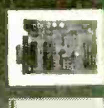

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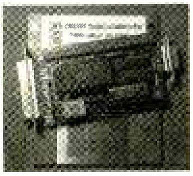

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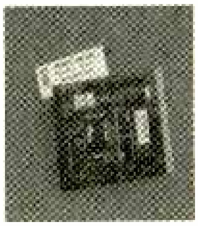

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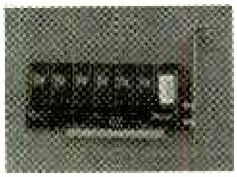

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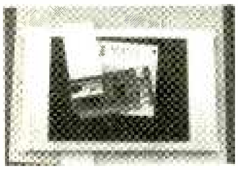

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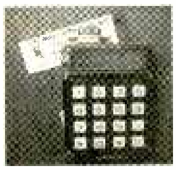

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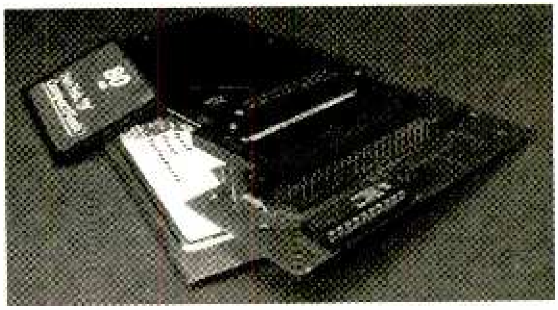

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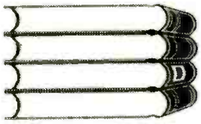

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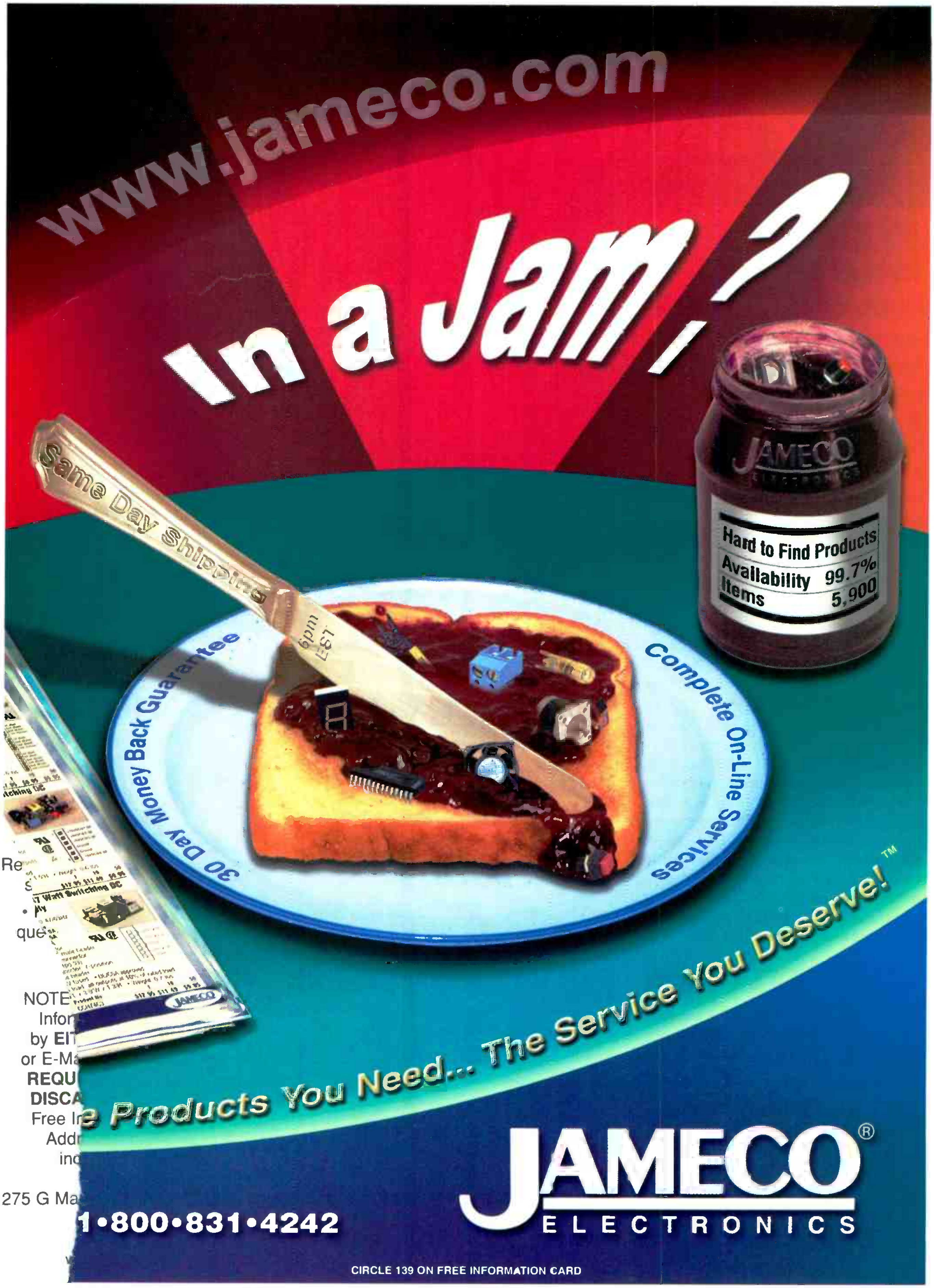

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