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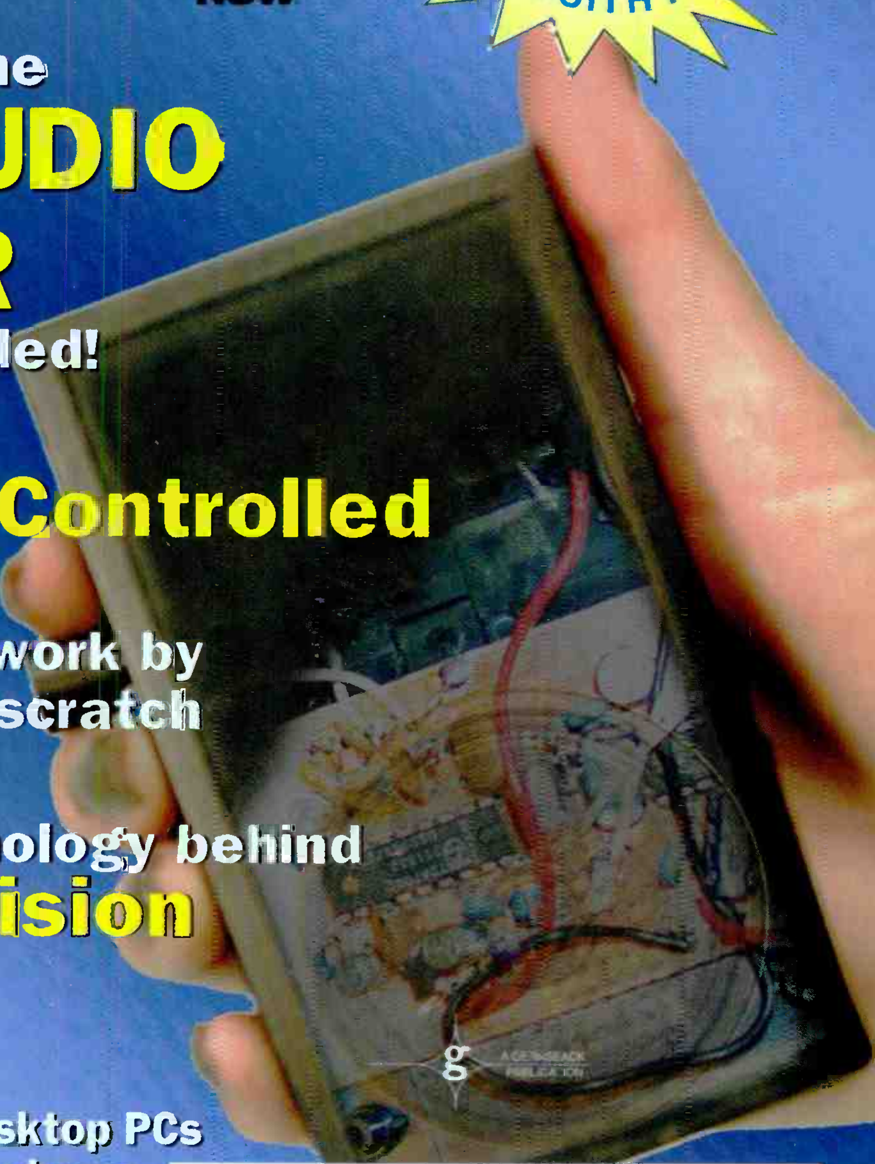

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Electronics Now · October 2000, Vol. 1, No. 10 · Popular Electronics®

Poptronics®

THE MAGAZINE FOR THE HANDS-ON ELECTRONICS ACTIVIST!

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How many times have you missed a favorite television program because you just couldn't get to a screen? Perhaps you were in the kitchen or garage or working outside. You couldn't (or didn't want to) stop what you were doing, but the task was mindless enough to make television a welcome distraction. Now you no longer need to worry that you set the VCR properly. This small, battery-powered receiver can fit in a shirt pocket with the right case. By changing a few select components, you can tune in different TV or FM-radio bands. What better way to pass the afternoon than listening to soap operas while weeding the garden?—Anthony J. Caristi

37 LOOKING AHEAD TO DTV: PART 2

The first part of this technological look behind the scenes of the digital-television standard took the video and audio signals, digitized them, compressed them, and squeezed them down to a fraction of their original size. This month, we chop them up, pack them together, and send them out over the airwaves to appear soon on a digital television near you.—Geophrey McComis

45 GETTING INSIDE AN NCO

Numerically-controlled oscillators are usually "unsung heroes" when it comes to generating an accurate waveform over a wide frequency range. Not only do we tell you all about how NCOs are designed, you get your hands dirty by building an actual NCO from discrete parts—a learning experience much more valuable than buying a single-chip device off the shelf.—Tom Napier

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"Top-end" CD Player, mood lights, handheld GPS system, flat-screen monitor, digital-audio jukebox, wireless GyroMouse, emergency batteries, multi-channel speaker system, TV/VCR combination, Internet privacy software.

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Editorial

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Whose Copyright Is It, Anyway?

I recently received an interesting e-mail from a Chris Rupert, who said: "From the August 2000 editorial comment, I gather that you have no objection to people taking copyrighted music, converting it to .MP3 format, and making it available free of charge to anyone on the Internet. I can only assume, then, that you wouldn't mind if I scanned an entire issue of **Poptronics** and put it on the Internet for all to enjoy."

I thought about that for a while. Not only was it a response to Gary Shapiro's guest editorial, it was probably a reaction to that day's news concerning the court-ordered shutdown of *Napster*—a event that will likely be "old news" by the time you read this.

In my response, I pointed out that our guest editor was expressing his frustration with how the copyright holders are, by holding back technology, preventing wide dissemination of public-domain content. Two hundred years ago, the American Founding Fathers established the ability to copyright a work for the purposes of enriching society (the "We the people" part of the US Constitution). The idea is that *all* created works of art—music, pictures, books, etc.—will become part of the "public domain," but that the original creator has the chance to profit from his/her work. In that way, the creation of artistic works is encouraged; artists are able to earn compensation for their effort; and everyone benefits in the long term.

For all of the bad taint that the .MP3 format had garnered over the "ripping" of copyrighted CD-audio tracks, there is also a "good" aspect to it. Many "garage bands" and individual musicians who aren't signed with a record label have distributed their original compositions and performances over the Internet using the .MP3 format. Whether they are "good" or "bad" in terms of their song-writing and/or playing ability, their contributions have enriched society. They shouldn't be lumped together with the "rippers" and get banned outright.

Our society is in the throes of working out these issues right now. The various sides are just seen in black and white, while the various shades of gray are being ignored. If history is any sort of teacher, the balance between access and protection will eventually sort itself out. That process, however, is not automatic; as the old saying goes, "If good does nothing, evil wins every time."

In part of his response to my reply, Mr. Rupert agreed with my clarification of Mr. Shapiro's position, but pointed out that "There is definitely a 'copyright holders are selfish and greedy' under- (over-) tone to the article." He's got a point. The original concept of copyright was meant to protect the *creators* of the works. Nowadays, it seems that the copyright holders—at least those in the news who are most vocal about stolen copyrights—usually have little, if anything, to do with creativity.

Mr. Rupert further pointed out: "Sites like *mp3.com* are the wave of the future. This site actually pays the artist by the download, bypassing the recording industry behemoth entirely (perhaps this is why record companies are so up in arms over the new format). Any artist can upload his music here; and if people like it, they download it. If not, they move on. This is a great opportunity for the musician to ply his trade without being in debt to record companies or having to be subject to their brand of creativity.

"I do not fear the new technology; in fact, it's quite the opposite. I'm currently working on a CD of my own, and can't wait to upload my music in .MP3 format to sites like *mp3.com* potentially reaching a wider audience than I could have imagined only a few years ago."

I know how he feels about reaching an audience, since I co-authored one science-fiction novel and have another in the works.The Internet has provided the opportunity and means to distribute such material.

Thanks for the correspondence, Chris. Not only did you make some very good observations on this complex issue, you helped save us all from what might have been a dull and boring editorial!

Joseph Suda
Managing Editor

GIZMO®

Superlative Super-Audio CD Player

Marantz makes its Super-Audio CD debut with the *Reference Series SA-1* SACD player ($7500). It uses Direct Stream Digital (DSD) technology and has a sampling rate of 2.822 MHz (compared to the 44.1 kHz sampling rate of conventional CDs). The SACD format can deliver both frequency response—from DC to over 100 kHz—and dynamic range that are greater than 120 dB, resulting in clear, detailed, realistic music reproduction.

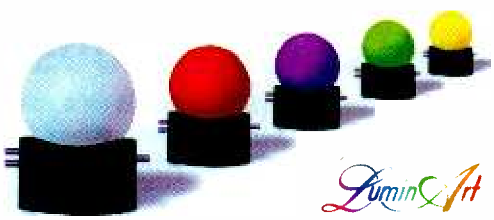
Boasting audiophile-grade design and construction, the SA-1 uses premium optics and digital decoding circuitry for exceptional data-retrieval accuracy and resolution. It also is said to provide excellent playback quality from standard CDs. The player provides a full complement of CD program and play functions.

Interior components were selected for maximum sonic purity, and copper shielding is used extensively to block unwanted EMI and RFI. The SA-1's heavy-duty chassis—with aluminum alloy top, side, and front panels, copper-plated double-layer steel bottom plate, and shock-absorbing feet—damps unwanted internal vibrations, as well as reducing mechanically induced jitter.

Marantz America, 440 Medinah Road, Roselle, IL 60172-2330; 630-307-3100; *www.marantzamerica.com*.

CIRCLE 50 ON FREE INFORMATION CARD

In the Mood



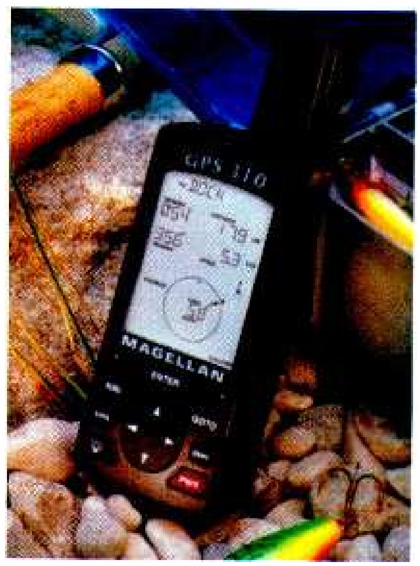
At first glance, it might look like a high-tech light fixture—a milky white globe resting atop a sculpted black base. But twist the knobs protruding from that base, and the *LuminArt* (about $190) changes color. One knob lets you dial in any color of the spectrum, and another lets you vary the color's intensity—from blush pink to fiery red, for instance.

Based on new age color theory and the psychodynamics of color, the design of the LuminArt reflects the mood and personality of the user. Meant to serve as an interactive focal point and to make a design statement, the color-changing light sculpture allows you to define the atmosphere and set the mood in any room.

LuminArt, 518 Edens Lane, Northfield, IL 60093; 847-441-3260; *www.luminart.net*.

CIRCLE 51 ON FREE INFORMATION CARD

Portable Navigator



Find your way, without finding yourself in the red, with the *GPS 310* handheld satellite navigator, which carries a suggested retail price of $119.99. Its data-output capabilities make it compatible with most popular PC navigation software, and it comes with a coupon for a free data cable. On land or offshore, the GPS 310 can be used as a primary navigational tool or as a backup. Its "navigation" screen displays your speed, the direction in which you are traveling, and the distance remaining to your destination.

The device stores up to 100 of your favorite locations and one reversible route with up to ten legs. The rocker keypad and dedicated GO TO, MARK, MENU, and NAV buttons make it easy to save, name, and return to landmarks. The "position" screen displays location information in latitude/longitude or Universal Transverse Mercator (UTM) Map Coordinate System coordinates and also displays satellite status, including elevations. The 12-channel receiver is waterproof—in fact, it floats. Two AA batteries provide power for up to 20 hours.

Magellan Corp., 960 Overland Court, San Dimas, CA 91773; 909-394-5000; *www.magellangps.com*.

CIRCLE 52 ON FREE INFORMATION CARD

Low-Cost 17-Inch TFT Monitor

Prices continue to drop on flat-screen TFT monitors. The *SyncMaster 770TFT* lists at $1454. The monitor presents the equivalent viewing area of a traditional 19-inch CRT display. It offers a 160-degree viewing angle, Sun Micro and SGI compatibility, and affordable options for USB and multimedia stereo speakers. The unit is only 2.5-inches thick and 8 inches at its base. The monitor draws 40 watts and comes with a three-year parts and labor warranty.

Samsung Electronics America, Inc., 105 Challenger Road, Ridgefield Park, NJ 07660-0511; 800-SAMSUNG; *www.samsungmonitor.com*.

CIRCLE 53 ON FREE INFORMATION CARD

Digital Music Deck

What may be the world's first home-networked digital appliance—the Turtle Beach *AudioTron*—was recently introduced. The device transmits and receives data via standard in-wall phone lines and is able to organize and play an unlimited number of digital music files stored on the owner's personal computer or found on the Internet.

In the process, the PC becomes a huge music jukebox, delivering music to any room in which the AudioTron resides. Although no definite release date or pricing had been announced by the time this was written, the AudioTron is expected to be available well before the holiday season.

Voyetra Turtle Beach, Inc., 5 Odell Plaza, Yonkers, NY 10701; 800-233-9377 or 914-966-0600; *www.AudioTron.net*.

CIRCLE 54 ON FREE INFORMATION CARD

Wireless GyroMouse

This wireless, motion-sensing pointing device, the *GyroMouse Pro* ($99), is based on a solid-state gyroscope sensor that precisely controls the cursor on the screen by detecting natural, ordinary hand motions. Advanced radio-control technology gives users the freedom to roam around the room with no required line-of-sight to their computers. It should be great for presentations, classrooms, and everyday computer use.

Gyration, 12930 Saratoga Ave., Building C, Saratoga, CA 95070; 800-316-5432 or 408-255-3016; *www.gyration.com*.

CIRCLE 55 ON FREE INFORMATION CARD

Roadside Assistance

Keep your portable GPS navigator—or other roadside-assistance or automatic mayday system—in good working order even under harsh conditions with *Pulses Plus* lithium batteries. Most emergency roadside assistance devices are powered by the vehicle's main battery. In an accident or in extremely cold weather, the car's battery can be disabled, leaving the driver stranded. A Pulses Plus battery, engineered to withstand extreme temperatures, can serve either as backup or as the primary power source.

Pulses Plus batteries are specifically designed to deliver the high voltage, high capacity, and lower self-discharge required by GPS- and RFID-based systems. Combining lithium-thionyl-chloride chemistry, a hermetically sealed hybrid-layer capacitor (HLC), and bobbin-type construction, the batteries are said to deliver greater performance and safety compared to spiral-wound batteries. Pulses Plus batteries come in a variety of configurations, including cylindrical cells and battery packs, and are available in sizes and capacity ranges to meet virtually any requirement. For information on prices, contact the company, go to their Web site or check your local store.

Tadiran, 2 Seaview Boulevard., Port Washington, NY 11050; 800-537-1368; *www.tadiranbat.com*.

CIRCLE 56 ON FREE INFORMATION CARD

Gizmo is published by Gernsback Publications, Inc., 275 G Marcus Blvd., Hauppauge, NY 11788. Senior Writers: Christopher Scott and Teri Scaduto.

Big Sound, Small Package

The *System T 70* delivers high-performance sound from an ultra-compact home-theater system that's priced just under $1000. The system includes center, left and right front, and surround speakers, as well as a 125-watt powered subwoofer. The five satellite speakers are all two-way suspension designs in tiny enclosures whose size and MDF construction make them acoustically inert.

Due to their rigid enclosures and tiny baffles, the small front speakers, T70 LR, are said to deliver both unusually natural sound and excellent imaging. A proprietary one-inch silk-dome tweeter provides a smooth, extended frequency response.

The center-channel speaker, T 70 C, features an adjustable tilting base that lets you aim the speaker up or down to attain maximum performance. It uses the same tweeter and two of the same woofers as the T 70 LRs, ensuring that all three front speakers will have the same tonal balance.

The TriVector design of the T 70 SR surround speakers uses a single forward-facing woofer/midrange to deliver a direct, easily localized sound pattern, coupled with two phase-compensated side-firing tweeters that produce a diffuse sound field. That combination allows the T 70 SR to be placed almost anywhere in the room.

A special feature of the acoustic-suspension subwoofer, T 70 PBM, is its 125-watt, custom-built, discrete component amplifier that is precisely matched to its 10-inch driver. The powered bass module offers signal-sensing auto-turnoff, an absolute-phase (polarity) switch, controls for level and crossover frequency, and high- and low-level inputs and through-puts for easy connection to home-theater electronics.

Atlantic Technology, 343 Vanderbilt Ave., Norwood, MA 02062; 781-762-6300; *www.atlantictechnology.com*.

CIRCLE 57 ON FREE INFORMATION CARD

TV/VCR COMBIPLAYER

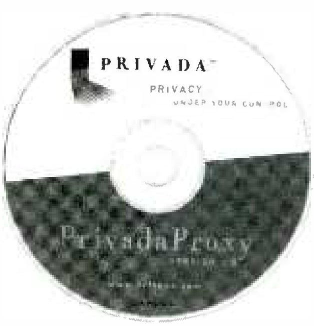
We can't imagine our kitchen without a TV/VCR—it allows everyone to peacefully coexist in the same room, kids happily watching a video while we cook or pay bills. The 20-inch *PV-C2080* ($399.95) adds a few convenience features that our old combiplayer didn't have. Its four-head, hi-fi VCR is equipped with VCR Plus+ for easy programming.

And the set offers a feature called Wireless Audio that uses a built-in FM transmitter to send the audio signal from the set to the tuner of a separate sound system or portable stereo. If you tune it to an unused FM station, your seven-year-old can use a headphone portable and watch *Pokemon*, for instance, without disturbing his older siblings' homework sessions or subjecting you to the sound of the "Poké Rap" while you're prepping dinner. Place the PV-C2080 in a bedroom that's also home to a bookshelf stereo, and you can listen to "home-theater" sound. For quiet bedroom listening, transmit the TV dialog to your bedside clock radio.

Panasonic USA, One Panasonic Way, Secaucus, NJ 07094-2999; 800-211-PANA; *www. panasonic.com*.

CIRCLE 58 ON FREE INFORMATION CARD

Secure Privacy on the Web



Consumers take control of their online identity through *Privada Proxy*, a suite of fully-private Web-surfing and e-mail services for anyone concerned about privacy protection. The upgraded 2.0 version allows users to manage "cookies" or block, unblock and delete them as they wish.

The software certifies the identity of the sender, while protecting that person's identity and personal information from everyone—including Privada. The cost is $4 per month for both *Privada Web* and *Privada Messaging*.

Privada, 3099 N. First St., Second Floor, San Jose, CA 95134; 877-PRIVADA or 408-577-1820; *www.privada.com*.

CIRCLE 59 ON FREE INFORMATION CARD

NET WATCH

JOE BLACK

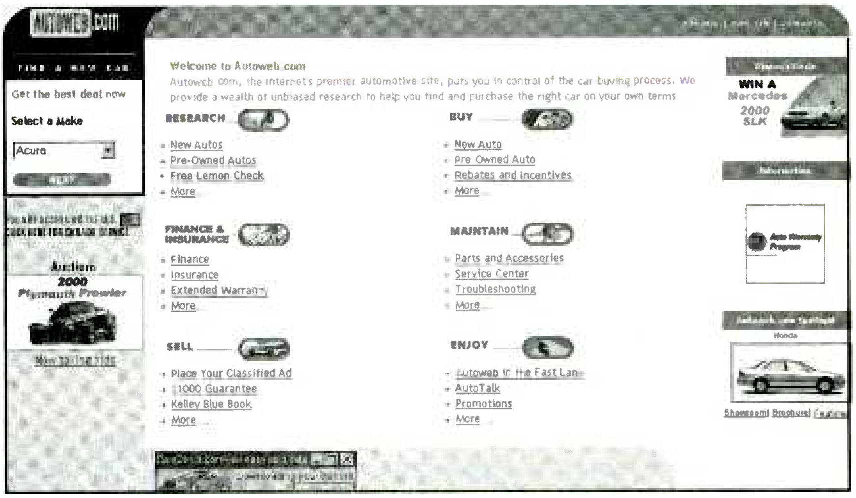
mailto: netwatch@gernsback.com

So You Want to Buy a New Car!

Buying a new car is an experience! Rarely is it a good experience. For no matter how well we shop; no matter how hard we bargain; no matter how much we compare; when all is said and done, we are never sure that we got the right car at the right price. Often, the only observations we can make when we look back on the experience is how long it took, how many dealerships we visited, and how much it cost.

I'm not in the market for a new car right now, but I knew that somewhere on the Internet, I would find an easier way to shop—and I did. I've visited at least ten sites that offer a way to buy a new car—"at the lowest price." Now, I can't confirm that you will actually get the lowest price, but I can tell you where to shop and what you will find there. I've taken the three most interesting Web sites—most interesting to me, of course—and tried them out.

Here is a brief report on what I found. I believe that they *will* save you money. I believe that they *will* save you time. I believe that when you finish shopping and finally buy that car, you will be a lot happier, more relaxed, and you will have a little more money in your bank account.



Autoweb has a clean page design where you're just a click away from any type of information that you'd need when researching and buying a car.

AUTOWEB.COM

I was only interested in buying a new—not "pre-owned"—car, so I only checked out the areas labeled "Research," "Buy," and "Finance & Insurance." Since I already had decided on a make and model, I went directly to the "Free Lemon Check" to make sure that my choice was not there. Then it was on to "Buy New Auto," "Rebates and Incentives," "Finance," "Insurance," and finally "Extended Warranty." When I was done, I was ready to buy. As I said before, I was not really looking for a new car, but I sure thought that this was one place to check the next time I was in the market.

NEWCARSLOWEST PRICE.COM

Here, the claim at the top of the opening page is "Buy or Lease Any New Car or Truck at the Absolute LOWEST Price, by Phone or Online, Delivered to Your Door." Sounds great to me. Of course, I really needed to have some idea of what I wanted to buy before I started, and I do have some—not a lot—quibbles with myself about shopping for cars at a dealership, deciding on the make and model, and then going home and going online to buy. Nevertheless, the dollars I save are mine, so I wouldn't feel too badly about it.

Maybe what the car manufacturers need to do is to set up display rooms in every city so you can look, compare, and perhaps even test

HOT SITES

Automall
www.automall.com

Autoweb
www.autoweb.com

New Cars, Lowest Price
www.newcarslowestprice.com

The award for "slickest-looking Web-page interface" of our three sites would have to go to New Cars, Lowest Price. Just grab that shift lever and grind your gears through everything that they have to offer. If you want to speak to a human, just be careful not to use that cell phone while driving!

drive, and then go home to shop on your computer screen. Although I'm sure that the independently-owned dealerships would *love* to see that!

Again, I did not actually buy a car from this site, so I can't tell you anything about the Absolute Lowest Price or the Money-Back Guarantee, but this sure is a place to look.

AUTOMALL.COM

This was the last stop on my shopping tour. The major difference here is that after you go through the selection process, your quote comes from a dealer in your local area. The dealership is probably where you will go for warranty repairs, if needed, and that, right now, is probably a good thing. One of the problems that comes to my mind in buying a car over the Internet is whom do I take it to during the warranty? Sure, the dealer gets paid for warranty work, but will he give an Internet buyer the same service as one of his regular customers? A thought to ponder.

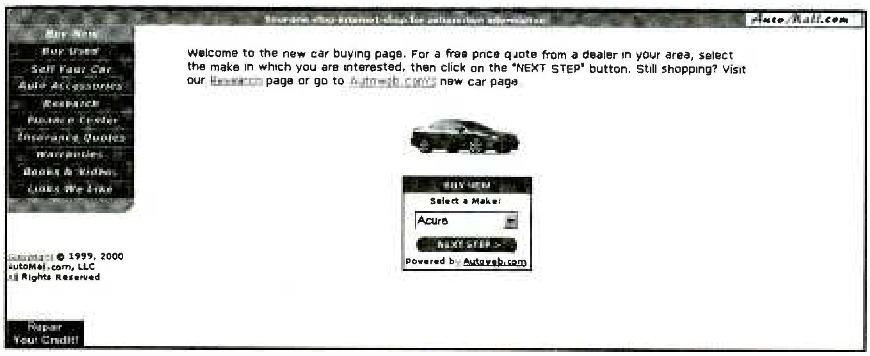
DRIVE IT ON HOME

There are a lot more new car sites out there. Go to your favorite search engine and look for "Buy New Car." Remember to specify "search for the exact phrase" or you are going to get more than you bargained for. The three sites that we have covered here, however, are complete and comprehensive. They appear to deliver what they claim, are easy to navigate, and provide lots of illustrations and help. One of them, *automall.com*, even makes it possible to complete your deal by telephone if you need the reassurance of a human being.

As I said at the beginning, I have not personally used any of these services. If you have any experience with any of them or with any of the many others not mentioned here, send your comments to me at *netwatch@gernsback.com*. Let me know about any other sites that you like or prefer and tell me why.

While we're on the subject of cars, I've been told that there are some Web sites that will arrange to have your car painted and turned into a mobile billboard, but I have not been able to find any of them. If you have heard of such a site, let me know. I understand that a mobile billboard can be paid as much as $400 a month for the service, and that sounds a lot like a free new car to me.

Till next time.



Auto Mall might not have the fanciest (read: slowest-downloading) graphics on the Internet, but at least your car comes from a local dealership—an important consideration for any possible warranty work down the road.

REID GOLDSBOROUGH

mailto: digitaldomain@gernsback.com

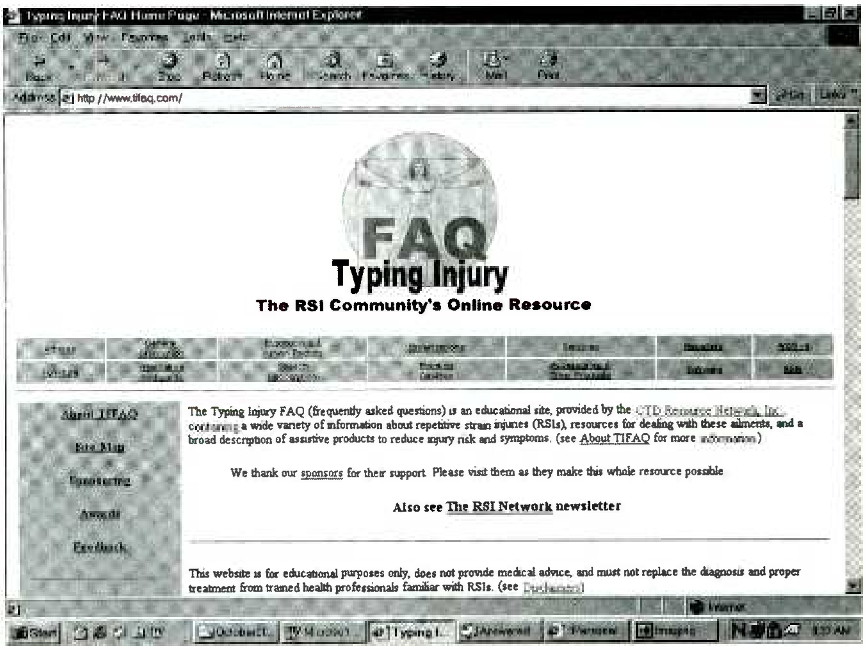
Health Risks of PCs and The Power of Web Computing

Unless one happens to drop on your head while you're walking on the sidewalk, personal computers can't kill you. Nevertheless, they can hurt you badly. Every year nearly two million people suffer work-related musculoskeletal disorders, including repetitive-strain injury caused by computer use, according to the U.S. Occupational Safety and Health Administration (OSHA). From spending long hours evaluating hardware, software, and Web sites, reading online publications, exchanging e-mail, and participating in online discussions, I've experienced my own fair share of computer-related maladies.

OSHA may have flip-flopped recently on whether employers are responsible for the ergonomic health of PC-using employees who work in home offices—first ruling they were, and then backing off. Nevertheless, the fact remains that if you spend any amount of time with a PC, regardless of where you work (or play), it behooves you to give some thought to how you do so.

"You don't want to find yourself in a situation where you can't get yourself dressed, feed yourself, or hug your children," says Deborah Quilter, author of *The Repetitive Strain Injury Recovery Book*. Good equipment helps, but according to the advice of experts and my own experience, your work habits are as important.

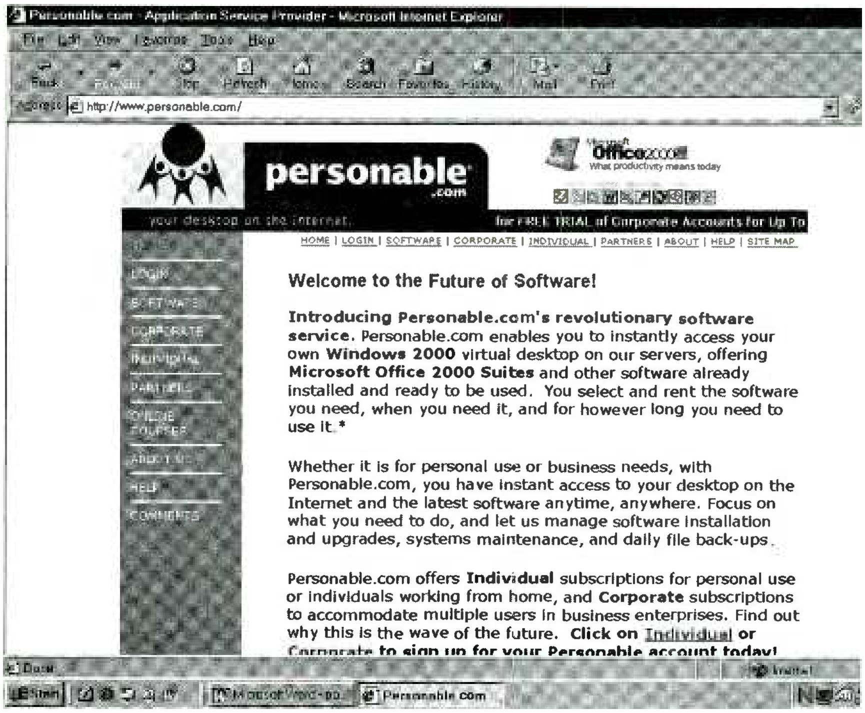
Many people use ergonomic keyboards such as Microsoft's Natural Keyboard, but they're no panacea. A study a few years ago by *CTD-News*, a publication about cumulative trauma disorders, concluded that ergonomic keyboards don't decrease the risk of wrist and other injuries at all, though ergonomic-keyboard manufacturers point to other studies that contradict this. More important than what keyboard you use is how you use it. The cardinal rule is: *Keep your wrists straight*. For years, I've used a keyboard-wrist support to prevent my wrists from bending upward when typing. Even so, four years ago I developed the beginnings of tendinitis in my left wrist from mousing around too much.



The Web contains much helpful information on Repetitive Strain Injury and other computer-related afflictions

I saw an orthopedic-hand specialist, and I tested about a dozen ergonomic mice, trackballs, and keyboard-trackball combinations. What eventually solved this problem was simply putting three paperback books in front of a regular mouse, again to prevent upward wrist bending, and doing wrist exercises every time I went to the gym.

About a year later, I developed a painful case of thoracic-outlet syndrome in my right shoulder, which was caused by holding my left arm higher than my right at the computer. I solved this by having a custom three-inch-high keyboard wrist support built at a local lumber-supply shop, which helps keep my right and left shoulders in balance, and by paying closer attention to my posture.



Sites like Personable let you "rent" major applications for a monthly fee to use over the Web.

Some experts, including Quilter, feel that the best thing you can do for your health around computers is to stop using them, though this of course is impractical for most people. At the least, take frequent breaks and heed grandma's advice: Posture counts. Always sit up straight with your shoulders and head back, your feet flat on the floor or a footrest, and your forearms parallel to the floor.

Mice cause the most injuries, says Quilter. You can reduce mousing by using the keyboard shortcuts included with most programs or a macro program such as the free TypeItIn, at *www.wavget.com/typeitin.html*, or the commercial QuicKeys, at *www.quickeys.com*. Speech-recognition software, though improving, still hasn't progressed to the point where it can efficiently eliminate mousing and typing for most users.

While sitting, you need to protect your assets too. Ergonomic chairs that are adjustable in multiple ways help prevent back problems, but I still regularly bruise the discs in my lower back from sitting too long. What works best for me in preventing this is remembering to take breaks and stretch, keeping my stomach and back muscles strong through exercise, and having my back massaged at the end of the day.

Eyes are another area at risk when computing. There has never been any conclusive evidence that radiation from computer monitors leads to health problems. However, staring at a computer screen can cause eyestrain and, because it's a type of close work, can worsen nearsightedness. My own glasses have grown considerably thicker since I bought my first PC nearly 15 years ago. Experts say your most eye-friendly moves are to stay a foot-and-a-half away from the monitor, minimize screen glare by positioning external lighting to the side, and to rest periodically.

Computers are great, when they're not a pain in the neck, the back, the wrists, the eyes... Check out the Typing Injury FAQ, at *www.tifaq.com*, and Harvard RSI Action, at *www.rsi.deas.harvard.edu*, for more tips.

COMPUTING FROM THE WEB

What's old is new again. In the old days of computers, you used a "dumb terminal" and rented processing time with a big mainframe computer. Today, you can once again use a computer with minimal processing power and run programs that reside elsewhere. Only today, you access these programs, called Web apps, through the Internet.

It works this way: Instead of installing computer applications or programs onto the hard disk of your computer, you log onto a Web site and use apps that are installed there, which are password protected. You access some Web apps through your Web browser and others through a custom interface. You can print and sometimes save data to your own hard drive, but the bulk of the processing occurs at a distant server.

The benefits are that you outsource the chore of software maintenance to others and that you can access your apps and data with any computer connected to the Internet. The drawbacks are that if you're not connected, you're not computing; and that even when you are connected, unless you have a fast connection you'll incur a sizable speed penalty.

POINT AND CLICK

Excite Planner
planner.excite.com

Harvard RSI Action
www.rsi.deas.harvard.edu

NetLedger
www.netledger.com

NetStudio
www.netstudio.com

Personable
www.personable.com

Quicken TurboTax for the Web
www.turbotax.com

QuicKeys
www.quickeys.com

SmartOnline
www.smartonline.com

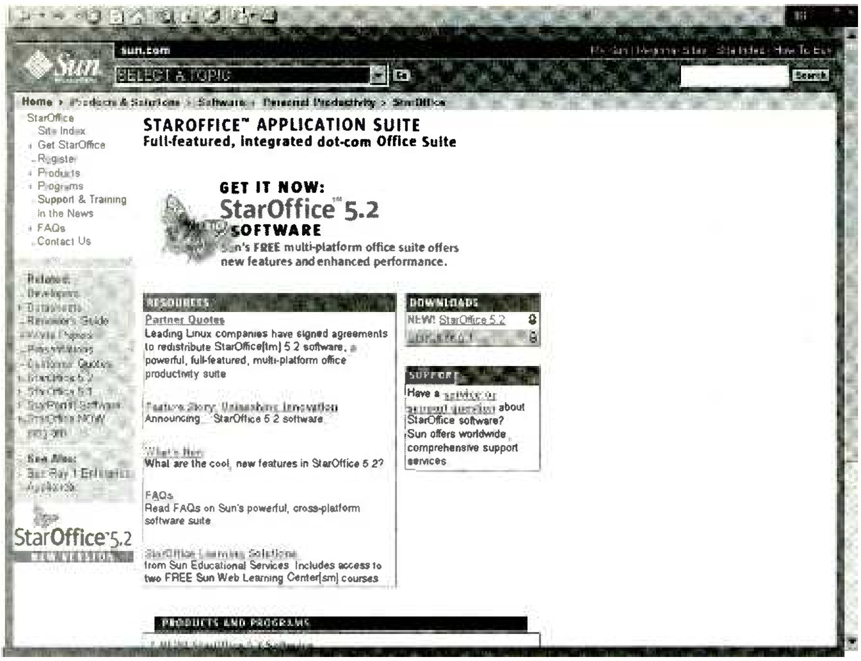
StarOffice
www.sun.com/staroffice

Thinter
www.thinter.net

TypeItIn
www.wavget.com/typeitin.html

Typing Injury FAQ
www.tifaq.com

X:Drive
www.xdrive.com



Instead of renting or leasing Web-based applications, full-featured office suites like StarOffice *from Sun Microsystems install on your local hard drive. Not only does that result in a more responsive application, the price is right...free!* StarOffice *has another advantage over Microsoft* Office*—it's available for different operating systems such as Solaris and Linux.*

The biggest players in the software industry are getting involved, including Microsoft. Bill Gates says the reason he recently quit his post as Microsoft's chief executive officer was to spend more time developing the Web versions of Microsoft's products. (Many analysts, however, believe that another, perhaps overriding, reason was Gates' desire to influence the U.S. Justice Department as it weighs penalties against the software behemoth for abusing its alleged monopoly power.)

Today many Web apps are free, though larger or specialized apps can require fees. The first Web apps were e-mail programs such as Hotmail. Some of the handiest Web apps today are those that help manage your personal information, whether you're a home or business user.

Excite Planner, at *planner.excite.com*, is the best Web app of this kind that I've found. It tracks your schedule, contacts, to-do items, and notes and also synchronizes with Microsoft Outlook and the Palm hand-held devices. SmartOnline.com, at *www.smartonline. com*, is more business oriented. It not only lets you create a calendar and to-do list, but also provides business letters, legal forms, business and marketing plan generators, and an incorporation guide.

Other Web apps are more focused, performing just a single task. X:Drive, at *www.xdrive.com*, is the best site providing off-site storage, which is convenient for sharing documents or backing up a few files. X:Drive distinguishes itself by letting you use an interface familiar to you, whether it's Windows Explorer or a third-party utility such as Mijenix's *PowerDesk*. NetStudio.com, at *www.netstudio.com*, helps you create Web graphics such as buttons, headings, banners, and photos. Quicken TurboTax for the Web, at *www.turbotax.com*, provides forms and help for completing your income taxes. Filling out a 1040EZ is free. A more complex return costs $9.95, and a state return costs another $9.95. NetLedger, at *www.netledger.com*, lets you and your coworkers work on the company's books from any location.

Office suites such as Microsoft *Office* are beginning to become available on the Web as well, through "application-service pro-viders." But don't expect Microsoft to give away its cash cow for free. It derives more than one-third of its income from Microsoft *Office*, according to analysts. At Person-able.com (*www.personable.com*), you can rent Microsoft *Office* for fees ranging from $9.95 to $24.95 per month, plus access and usage fees charged by the site itself.

Sun Microsystems is Microsoft's main competition in online office apps. Its *StarOffice* suite is available as a free download at *www.sun.com/staroffice*. You can also run it as a Web app for $30 per month at the application service provider Thinter.net, at *www.thinter.net*.

Office suites are complex programs, so don't expect stellar performance over the Web. Microsoft *Office* was agonizingly slow over a 56K modem, particularly with *Word* tables and *Excel* worksheets. I also tested it over a cable modem, and though the speed increased considerably, the going was still slower than normal. Still, Web productivity apps are worth considering for individuals with older hardware or limited hard-disk space, casual users who need a program for a short time, newer or smaller companies who want to use industrial-strength applications without committing significant financial or personnel resources, and larger companies seeking stable and predictable software costs.

Thus far, Web apps have been more popular with individuals than companies, though more companies are expected to embrace them in the future. Application service providers such as Digex are attracting millions of dollars in investments from big names such as Compaq and Microsoft. **P**

TED NEEDLEMAN

mailto: computerbits@gernsback.com

Real Networks, Real Quick

With more than a dozen PCs generally residing in my house, there's always something on one PC that someone in the house needs on another system. These PCs are distributed across three floors, and from one side of the house to another. Obviously, my household is a prime candidate for networking, and indeed, we've been playing with networks of one kind or another for years.

The most recent networks that we've installed here have revolved around the telephone wiring that resides within the walls. Back in the beginning of the year, I detailed an Intel AnyPoint phone-line network. This network ran at 1-Megabit per second or about a tenth as fast as the slower of the two Ethernet wired networking protocols—10BASE-T and 100-BASE-T. In the interim, Intel and other vendors, such as 3Com, have come out with home phone-line networks based on the updated Version 2 specifications. These newer networks run at 10Mbit/sec, or just about the same speed as 10BASE-T Ethernet. The HPA 2 phone-line networking equipment is backward compatible with the slower 1-Mbit/sec adapters, though mixing them together on the same network generally slows things down. We had one of the faster phone-line networks running here for a while, as well.

The truth is, home phone-line networks are really good for sharing data, peripherals like printers, and even an Internet connection, but for head-to-head multiplayer first-person shooters, like *Rouge Spear*, the faster the network the better the game play. With three teenage boys, I'd rather they get their

Two different 10/100BASE-T Networks "in a box." The 3Com HomeConnect kit on the left has a 5-port hub, while the LinkSys kit, on the right, offers a switch, rather than a hub.

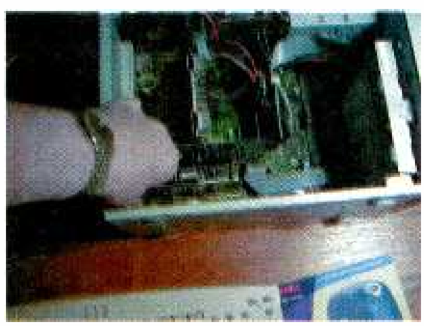
aggression out at the keyboard, than in a place where it might get them, and others, into trouble. That's probably not a politically-correct attitude, but as long as I keep track of how they react to computer games and feel comfortable with it, I don't believe that *Quake* and other games of this sort really have much of an effect on well-adjusted kids. If I think things are getting a bit out of hand, the PCs get turned off; and it's then time to read a book or watch something less exciting on TV.

CRANK UP THE BITRATE

That being said, I've recently succumbed to 100BASE-T network fever. Actually, it's been the wiring, rather than anything else, that's kept me from installing "real" Ethernet here. Getting a network up and running, especially if you are running Windows-98, is pretty much the same whether you're running it on Category 5 unshielded twisted pair Ethernet cable or the phone-line cabling in your walls (which, by they way, is very similar, though not identical to, Category 5 Ethernet cable.)

"Fast Ethernet," or 100BASE-T, runs at 100-Megabits per second, and with the right network cards and hub can run in full-duplex mode, transmitting and receiving at the same time for a whopping 200-Mbit/sec throughput. What I decided to do, until I can find someone in the area who can pull the cabling through the walls at a reasonable cost, was just to run the Ethernet cabling along the walls near the baseboards.

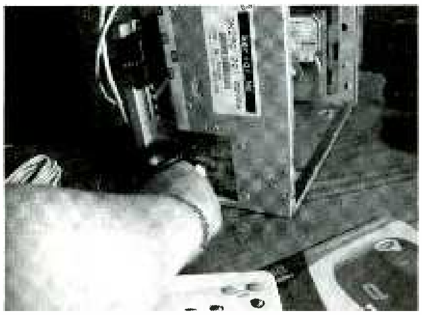
We used a variety of Ethernet kits here to set up the network. There are lots of vendors currently marketing 10/100BASE-T Ethernet kits for home and small-office use. While the equipment included in these kits is intended to run at 100-BASE-T speeds, they are also backwards compatible with 10BASE-T adapters and hubs, should you already have some of this equipment in your home or office. Two of the kits that we used are 3Com's HomeConnect Ethernet kit and LinkSys' Fast Ethernet Switch kit. Each kit comes with two network-interface cards that go in a PCI slot on your PC, 25 cables (also called Ethernet patch cords), and either a hub or a switch.



Each PC needs to have a network interface card (NIC) installed.

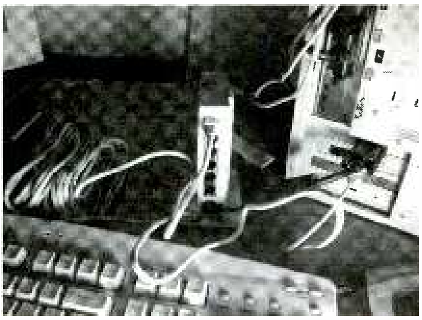
WEAVING AN ETHERNET WEB

When setting up an Ethernet network, each PC receives a network interface card, or NIC. Physically installing a NIC into a PC is just like installing any other adapter card; if you've ever up-graded your sound or video card, you're already an expert in this part of the operation. Laptops can be connected to an Ethernet network through an adapter that uses either a USB port or a PCMCIA card slot. A cord is then run from each networked PC to a central hub. Plug-ging the cords between NIC and hub is no more difficult than plugging a telephone into a wall jack.



When the NIC is installed, plug in an Ethernet patch cable.

The 3Com HomeConnect kit offers a 5-port hub, so you can plug up to 5 patch cords from network workstations into it. The hub allows each PC to connect up to the other PCs on the network. The LinkSys kit uses a switch, rather than a hub. Both are similar, but a switch actually lets a specific PC workstation "take over" the network and transmit at full speed. When it is finished, a different workstation can "grab" the network. This allows each workstation to run at the full speed and bandwidth of the network, but all of the other network users need to wait their turn. A hub lets everyone simultaneously access the network. If a lot of users do this at the same time, the whole network slows down somewhat. Therefore, in choosing between a hub and switch, you need to think of what kinds of applications will run over the network. Switches work very well when you have orderly access to a network, while hubs generally are a better choice when you can't predict network load. Neither type is



The other end of the patch cable needs to be plugged into the Ethernet hub.

necessarily more or less expensive than the other. The 3Com kit costs about $180, while the LinkSys kit will set you back about $120.

THE SOFTWARE SIDE

Once the cards are installed, setting up the actual network is just a few minutes work at each PC. Actually, with the 3Com kit, the Microsoft HomeClick! networking software is installed before the hardware. After the drivers are installed, the software tells you to shut off the PC, install the NIC, and restart your computer. When you do, the software finishes the install. With the LinkSys kit, you install the NIC first. When Windows98 finds the new device on boot, you install the network drivers. The 3Com software and kit are a little easier, especially for absolute networking novices. Nevertheless, neither kit should give the average **Poptronics** reader much difficulty.

During the install, you will be asked to give the PC that you're working on a unique name. However, you have to remember to give the same workgroup name on every machine. When you're finished, reboot. You should see each PC in your network when you double-click on the Network Neighborhood icon.

WATCH THAT CORD!

You can also chain hubs or switches together, if you have more PCs on a network than there are ports on the hub/switch. We've actually installed three separate 100BASE-T networks in the house, one on each level, and when we need to link them, we temporarily run a 50-foot, 75-foot, or 100-foot patch cord between the hubs that form the center of the network on each floor. It's neither pretty nor elegant, but it does work.

One day, we'll probably have the cables in the walls. Nevertheless, having "tasted" 100BASE-T, I doubt that we'll ever go back to networking with anything slower. **P**

VENDOR INFORMATION

3Com Corp.
800-NET-3COM
www.3com.com

Linksys
17401 Armstrong Ave.
Irvine, CA 92614
949-261-1288
www.linksys.com

"When I said that we were dealing with 'limited memory,' I wasn't talking about the computer, I was talking about you!"

TED NEEDLEMAN

mailto: peakcomputing@gernsback.com

Easy Additional Ports

One of the side effects of the wide popularity of PCs is that there is a tremendous selection of peripherals and accessories that you can attach to your computer. Unfortunately, while it's easy to just plug in a Dymo printer to print out electronic postage from *e-Stamps* or *Stamps.com*, you still have to move your computer to access the serial port on the rear panel. Some vendors, including Compaq, eMachines, and Hewlett Packard, have moved several ports to the front panel, making it easier to attach accessories and peripherals. The large majority of computer vendors, how-ever, have not.

Another device for which you might need to move or add expansion ports is a laptop. A port replicator, which moves all of the laptop's ports to a convenient "breakout" box, is a convenient accessory when you switch between mobile and desktop use. Not all laptops, however, provide the special connector or custom-tailored cable-collection unit.

Finally, with printers, scanners, digital cameras, PDAs, and a myriad of other devices all using USB connectors, you've probably already run out of USB ports. You could just add a USB hub, but there is a better solution.

Regardless of whether you just want to move I/O port connectors to a more accessible and convenient location or need to add some ports that your PC or laptop did not originally include, there are several low-cost and easy-to-use devices that perform exactly that function—PortStation from Xircom and Belkin Components' BusStation.

The 10BASE-T Ethernet module can stack right on top of Belkin's 7-port BusStation.

RACK 'EM UP

Both of these are modular devices that plug into one of your PC's USB ports and allow you to assemble your own combination of ports. The Belkin BusStation builds vertically, pretty much as high as you need to go to gain the specific ports that you require. Our test unit was assembled from a 7-port USB hub and a 10BASE-T Ethernet module. Belkin also provides a variety of different modules, so you can use only those that meet your immediate requirements while still being able to add additional modules at any time in the future. In addition to the 7-port USB hub that we used, which is actually four modules high, Belkin also offers a single module with four USB ports. On the multiple-height module such as the one we received for testing, you can actually pop out individual modules from the four-high backplane and insert other modules of your choice. We decided that we could live without one of the seven USB ports that our initial configuration had and substituted the 10BASE-T Ethernet module for the top USB port, lowering our "tower" from five modules to four modules high.

A serial module is also available. Note also that both the Ethernet and an available SCSI module can plug into either a USB port on your PC or on one of the Belkin hubs. The SCSI adapter provides a transfer speed of up to 1.2 megabits per second, but comes only with driver software for the Mac. The Ethernet adapter, on the other hand, comes only with driver software for Windows95 or Windows98. The base USB hub comes with a small AC-power supply, and all of the remaining adapters draw their power through the USB connection into which they are plugged.

The Ethernet (or other add-on) module plugs into a USB port on the BusStation's rear panel.

You can also pop out one of the USB ports and put an add-on module into the BusStation stack.

Several of the individual modules targeted for the Macintosh come with a selection of colored sleeves, which let you match your iMac's case for a coordinated look. These modules include USB ports, a serial port, and the SCSI module.

Belkin has priced the BusStation very affordably. Our 7-port USB hub lists for $99, and a 4-port USB hub is only $59; about the same price as a 4-port USB hub without the BusStation's expandability. The 10BASE-T Ethernet module lists at $69, while the serial module is a bit more expensive at $79.

SIMILAR CONCEPT, DIFFERENT DIRECTION

Xircom's PortStation is similar to the BusStation, at least in concept; the execution's a bit different. With the PortStation, the different modules mount between a set of snap-on/snap off end caps. You can string on the exact configuration of modules you need for your particular application, or just order one of the "Starter" kits, which come in different configurations. We tested two different "Starter" configurations—the $139 "USB Hub Starter Kit"—which provides you with two end caps, an AC-power supply, and a 7-port USB hub module—and the $229 "Office Communications Starter Kit." This kit has the end caps and power supply, and parallel, serial, PS/2, and 10BASE-T Ethernet modules. It makes a perfect replacement for a laptop port replicator, which is how we generally use it.

The third packaged "Starter" kit is the "Connection Starter Kit," which is almost identical to the "Office Communications" kit but substitutes a 4-port USB hub for the 10BASE-T Ethernet modules and is priced a bit less at $189.

At the moment, Xircom also offers slightly more options in modules—such as a 56Kbps modem—than Belkin does. In the works for the PortStation series are ADSL and cable-modem modules, as well as modules for home networking.

GREAT, BUT NOT QUITE PERFECT

Both of these products are really nice. The Xircom PortStation fits a bit more easily into a laptop carry case, which makes it a perfect accompaniment on the road. Belkin's BusStation is easy to stand right next to a tower PC, though the PortStation fits on top of most towers or sideways if you have a lot of modules in your configuration.

Keep in mind, however, that while adding an Ethernet module to either the Belkin or Xircom device makes it really easy to attach a PC or notebook to a network running at the 10BASE-T rate of 10 megabits per second, that's the best that you can get from this approach. That's not really a limitation of the Belkin or Xircom hardware. Both could easily manufacture a module with 100BASE-T (100 megabits per second) capability. In fact, Xircom provides that speed in a PC Card network adapter. However, remember that attaching these hubs to your PC or notebook via a USB port is the reason for the limits to the ultimate speed of any device connected to any of the ports in the module. The USB interface itself is currently limited to a maximum speed of 12 megabits per second, so attaching a 100BASE-T Ethernet adapter doesn't make much sense. If you really need 100BASE-T capability, bite the bullet and install a NIC (network-interface card) in one of your PC's PCI slots or laptop's PCMCIA slots.

Xircom's RealPort is similar to the BusStation, but expands horizontally between the snap-on/snap-off end caps.

Another limitation, at least on the PC side, is that not all versions of Windows provide the same degree of support for USB. Windows95 only implemented USB support in OSR2.1, the last service release that was not made available to retail purchasers. Even in that release, USB support, while present, didn't always work well. To be sure that either device works properly, you'll need to be running Windows98 or Windows 2000.

If you are, either vendor's product makes a terrific addition to your computer table. Moreover, neither adapter is overly expensive. P

VENDOR INFORMATION

Belkin Components
501 West Walnut St.
Compton, CA 90220
800-2-BELKIN
www.belkin.com

Xircom
2300 Corporate Center Dr.
Thousand Oaks, CA 91320
805-376-9300
www.Xircom.com

CD ROM based resources for learning and designing

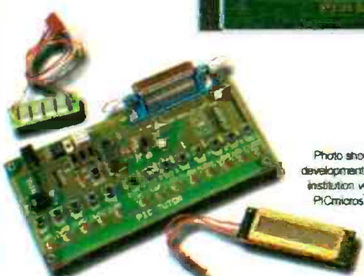


Photo shows PICmicro development kit supplied with institution versions of C for PICmicros and PICtutor

The internationally renowned series of CD ROMs from Matrix Multimedia has been designed to both improve your circuit design skills and to also provide you with sets of tools to actually help you design the circuits themselves.

matrix multimedia

Electronic Circuits and Components provides an introduction to the principles and application of the most common types of electronic components and how they are used to form complete circuits. Sections on the disc include: fundamental electronic theory, active components, passive components, analogue circuits and digital circuits.

The Parts Gallery has been designed to overcome the problem of component and symbol recognition. The CD will help students to recognize common electronic components and their corresponding symbols in circuit diagrams. Quizzes are included.

Digital Electronics details the principles and practice of digital electronics, including logic gates, combinational and sequential logic circuits, clocks, counters, shift registers, and displays. The CD ROM also provides an introduction to microprocessor based systems.

Analog Electronics is a complete learning resource for this most difficult subject. The CD ROM includes the usual wealth of virtual laboratories as well as an electronic circuit simulator with over 50 pre-designed analog circuits which gives you the ultimate learning tool. The CD provides comprehensive coverage of analog fundamentals, transistor circuit design, op-amps, filters, oscillators, and other analog systems.

Electronic Projects is just that: a series of ten projects for students to build with all support information. The CD is designed to provide a set of projects which will complement students' work on the other 3 CDs in the Electronics Education Series. Each project on the CD is supplied with schematic diagrams, circuit and PCB layout files, component lists and comprehensive circuit explanations.

PICtutor and C for PICmicro microcontrollers both contain complete sets of tutorials for programming the PICmicro series of microcontrollers in assembly language and C respectively. Both CD ROMs contain programs that allow you to convert your code into hex and then download it (via printer port) into a PIC16F84. The accompanying development board provides an unrivaled platform for learning about PIC microcontrollers and for further development work.

Digital Works is a highly interactive scalable digital logic simulator designed to allow electronics and computer science students to build complex digital logic circuits incorporating circuit macros, 4000 and 74 series logic.

CADPACK includes software for schematic capture, circuit simulation, and PCB design and is capable of producing industrial quality schematics and circuit board layouts. CADPACK includes unique circuit design and animation/simulation that will help your students understand the basic operation of many circuits.

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LETTERS

mailto: letters@gernsback.com

Call Alert Alert!

There were several mistakes in my "Call Alert" article (**Poptronics**, July 2000). Two connecting dots were left out of the schematic diagram when Fig. 1 was redrawn for publication. On IC5, pins 4 and 14 should be connected together; and the line from J2 to the center contact on RY1 should connect to the line going to R2 and BR1.

The Parts List has three errors as well: R10 should be 68 ohms as shown in Fig. 1, not 680 ohms. Additionally, I forgot to include C13; it is 0.1 µF. Again, this is shown in Fig. 1. What's more, I got the transistors mixed up a bit. Transistors Q1 and Q4 should be 2N4401 or 2N3904. Transistors Q2 and Q3 are MPSA-06; several people told me that the MPSA-56 units won't work as a substitute.

Finally, the typesetters left out one important keystroke in the instructions for programming the security codes as detailed on page 47, column 2. When you pick up the telephone handset (ignoring the dial tone), you should press the "#" (pound key) before dialing 1-2-3-4-5 to set location 1 with a security code of 2-3-4-5. The "#" alerts the unit that it should pay attention to the programming instructions that you are dialing.

RAYMOND C. BUCK III

[Speaking of telephones, we just discovered another small but aggravating problem with Mr. Buck's article. It seems that in the time between editing the article and publishing it, a new area code for Phoenix—623—was implemented; ATC Electronics was part of that area-code switch. The new number (with area code) is 623-516-2926.—Editor.]

And Then The ScatCat Came Back

A few errors crept into the "ScatCat" article (**Poptronics**, August 2000) during editing and redrawing for publication. In Fig. 1, the ground connection on IC3 should be labeled as pin 7. Ground connections should also be made to pins 4 and 12 of DISP1. I had indicated the wrong pins in my original submission; a leftover from an earlier version with a different display. Since we're on the subject of ground connections, the unused inputs of IC2—pins 8–11—should be tied to ground as well; floating inputs on CMOS is a no-no. I indicated that on my original schematic, but it was not redrawn that way.

The terminals and terminal identifications that are shown on Fig. 8, the photographs, and mentioned several times in the text were omitted from Fig. 1, so it may be difficult to correlate the two. A cardinal rule of good tech writing is, "Maintain consistency." Removing them from one figure and not the other gives an additional level of confusion, i.e., "muddies the waters."

Some component references were changed on Figs. 1 and 2, but weren't changed in the text. On page 36, second column, four lines from the bottom, change R1 and R2 to R8 and R9; TR1 should be included with other solid-state relay components. On page 38, third column, eight lines from the top, change IC1 to IC10. On page 32, first column, 11 lines from the bottom, change R1 to R3 (my goof).

The wire connection shown between VDC(-) and SENS(-) in Fig. 8 is not on the Control Module as shown; it will have to be added externally.

I'd also like to point out a particular sentence (page 36, first column, four lines down) that was added by the editorial staff. An engineering colleague read it and laughed so hard, beer came out of his nose. I still can't convince him that I did not write the sentence. I may need a notarized statement to that effect.

I do not expect editorial infallibility. Having been through this process a few times, I know I make as many mistakes as anyone; sometimes more. Even the *New York Times* lets one slip through occasionally. I do, however, expect an article to be better after editing; not worse.

The author accepts no responsibility for grammatical errors or for muddied or muddled explanations. In spite of all this, it is still a potentially fun project!

RUSSELL SHUMAKER

KEEP IN TOUCH

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Hauppauge, NY 11788

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And don't forget to visit our Web site: *www.gernsback.com.*

Converting Inverters to Inverting Converters

In the August 2000 issue of **Poptronics**, "Basic Circuitry" has an error.on page 62. The article shows a "DC Power Converter," which should operate just fine as a DC converter. However, the caption below Fig. 6 states that this circuit can be used to "... operate AC devices from a 12-volt car battery."

The device being describes is a "power inverter," which transforms DC voltage (usually 12-volt car power) into an AC output (again, usually 120 volts). I just wanted to point this out, as a reader attempting to power an AC product off this circuit may be curious why it will not work (incorrectly suspecting an error in their assembly).

ALLEN T. MAHURIN
via e-mail

(Continued on page 23)

Prototype

Mirror of the Future

Sandia researcher Tammy Henson examines a new thin-film, ultralight piezoelectric material that may be the future of space telescopes and surveillance satellites. (Photo by Randy Montoya).

Shown here is the highly curved piezoelectric thin-film mirror inside a vacuum tube at the University of Kentucky.

A whole new approach to space mirrors is being developed by researchers at Sandia National Laboratories and the University of Kentucky (UK). Made out of a "smart" material that changes shape when struck by electrons fired by a computer-controlled electron gun, this thin-film ultralight deployable mirror may be the future of space telescopes and surveillance satellites.

"Unlike the Hubble and the upcoming NASA Next Generation Space Telescope (NGST), which use the traditional polished glass mirror approach, this is a light-weight thin film that could be folded up and carried on a small booster rocket and opened to its full diameter in orbit," says Tammy Henson, principal investigator. "The electron gun would then be used to correct the shape of the film mirror to its desired form to within 10 millionths of an inch that is the required accuracy for optical-quality imaging applications."

How It Works

During their initial research, the Sandia and UK researchers are using the piezoelectric material polyvinylidene fluoride because it is inexpensive, readily available, and exhibits the necessary properties. However, for actual space applications where the climate is very hostile, piezoelectric polyimide thin-film material looks very promising.

The flexible nature of the piezoelectric mirror material means it will become misshapen once it is deployed in space. It will need to be reshaped with the electron gun.

Laser optical sensors measure the shape of the mirror surface. This information goes into the control algorithm programmed into the computer, which is connected to the gun. The algorithm determines the excitation profile necessary to change the mirror surface to its desired shape using electron gun excitation. Since the initial mirror shape will be very different from the desired shape, the mirror figure sensing method must have both large dynamic range and high resolution.

The gun fires electrons into different areas of the mirror to make the surface change its shape in either a more convex or concave direction. The new shape remains fixed for several hours to days. Then the beam is reactivated to add or remove the charge to make small corrections to the mirror surface shape.

"An electron gun is the same device that draws a picture on your television screen," team member Jim Redmond says. "To reshape the film-mirror, the gun distributes a surface charge at a very high resolution."

Lightweight and Easy to Launch

The light-weight, deployable, and large-aperture aspects of the new mirror approach are what make it attractive for space telescopes and surveillance satellites. The extremely flexible piezoelectric material can be folded into a small package. When released, it deploys very close to its original state. The material weighs less than one kilogram per square meter of mirror area compared to 15 kilograms per square meter for the NGST and 250 kilograms per square meter for the solid glass Hubble mirror. The NGST, tentatively scheduled for launch in 20008, may use a mirror constructed from thin glass segments on a composite structure, or even beryllium segments, folded to fit into a launch vehicle.

"The next step for NASA after the NGST will be larger mirrors—possibly as large as 20 to 30 meters in diameter—to allow for collection of light from the dimmest and smallest of sources," says Redmond. "It would be nearly impossible to do this with traditional materials because of the expense and the size limitations of launch vehicles. The new technology would allow extremely large mirrors to be launched from small boosters, saving millions of dollars per launch."

This technology, still in its early stages, has already captured the interest of NASA officials and the community involved in remote-sensing work.

"NASA strategic plans call for giant telescopes many meters across, and it's clear we can't launch large rigid ones," says John Maher, NGST project scientist. "Hence we will be making a large, flexible primary mirror that will have to be adjusted after launch. One way to improve the performance is to use a small, carefully controlled thin-film mirror located at an image of the primary mirror to correct its error, and such a device might even be useful for NGST. Another way is to make the primary mirror itself adjustable with an electron beam, but this probably will not be ready in time for NGST."

Sandia/University of Kentucky Partnership

A partnership was formed between Redmond's adaptive structures group, Henson's satellite imaging group, and the university. Under funding from Sandia's Laboratory Directed Research and Development (LDRD) program, the researchers have made significant progress in the critical areas of mirror-figure sensing, control algorithm development, electron gun actuation, and space-implementation assessments.

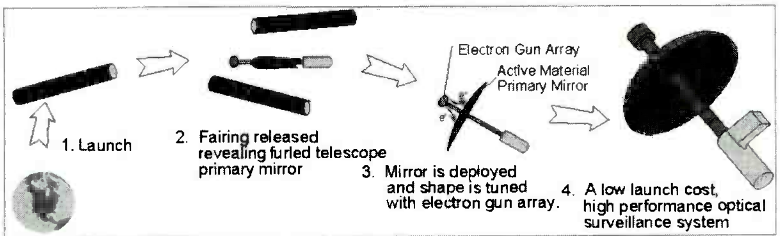
Using electron-gun excitation of piezoelectric materials was the brainchild of UK researcher John Main.

"Main was developing electron gun technology and was interested in pursuing it for space telescope applications," Redmond says. "The electron gun eliminates the wires and electrodes used in other 'smart structure' approaches that add to the system's complexity."

Main and Ph.D. student Jeff Martin are pursuing research on the electron gun, while Redmond is developing precision shape-control algorithms for the piezoelectric mirror. Henson is developing optical concepts and mirror-figure-sensing systems for the project.

Henson says that besides being lightweight and relatively inexpensive to launch, the thin-skin deployable mirror has the advantage of being able to be "launched on demand."

"The mirror could be fabricated and deployed in a matter of months—as compared to many years with the Hubble telescope," she says. PT



This diagram illustrates the deployment sequence for a large-aperture electron-gun controlled thin-film mirror.

Dangers of Compression

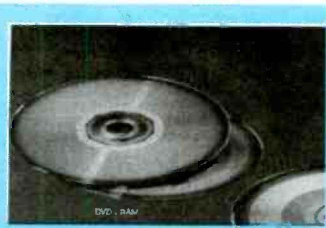
A picture's worth a thousand words, but when it comes to digital medical images, one of those words should be "caution." That's the message from researchers at the University of Florida (UF), who have found that even mildly compressing angiograms for delivery over telephone or computer lines can lead to diagnostic errors. At issue is the increasingly common practice of storing medical images such as angiograms, X-ray films and CT or magnetic resonance scans on compact discs and other portable media. Because the images contain so much data, storing them or sending them electronically requires mathematically manipulating them to shrink their size.

"Data compression helps with costs and with speed of transmission—that's the upside," said Dr. Richard Kerensky, an associate professor of medicine in the division of cardiovascular medicine at UF's College of Medicine and medical director of the cardiac catheterization laboratory at Shands at UF Medical Center. "The downside is you might start to degrade the image the more you compress it. As you change it, you lose information and add artifacts that weren't present on the original image."

Kerensky and his colleagues published findings from one of three related studies involving an international team of scientists in the April issue of the *Journal of the American College of Cardiology* (ACC). The goal of the researchers is to set guidelines for cardiologists to follow; after all, most experts agree it's just a matter of time before digital imaging completely replaces film or videotape. The recommendations will be added to the Digital Imaging and Communications Standard for Medicine, which the international cardiology community, led by the ACC, established to standardize the digital file format and image exchange medium for angiography. The trio of studies arrived at the same conclusion: Image quality was progressively lost with increasing compres-

➤ Rewritable DVDs—Next Generation

The French electronics company, MPO Media/HI-SPACE, in partnership with CEA/LETI, France's Laboratory for Electronics, Technology, and Instrumentation, recently developed a new generation of dual-layer rewritable DVD discs with a capacity of 8.5 gigabytes, equal to that of pre-recorded discs. This capacity was obtained with optical components that were also used in the current generation of DVDs (lasers emitting red light at 650 nm), allowing full compatibility with existing DVD Video and DVD-ROM drives.



A new generation of dual-layer rewritable DVD discs with a capacity of 8.5 gigabytes on a single side has been developed. This technology reads the second layer through the first, semi-transparent layer.

Prerecorded optical DVD discs for video and software can, thanks to their dual-layer technology, hold 8.5 gigabytes on a single side. This technology reads the second layer through the first, semi-transparent layer. For recordable discs, the two layers are therefore quickly accessed from the same side without having to be turned over.

These rewritable DVDs offer a playing time of more than three hours, as well as direct digital writing and rewriting, a very high-definition image (high-speed MPEG-2), high-fidelity sound (Dolby AC-3), and the absence of wear. As well as having Internet or CD/DVD-ROM-type interactive functions. they may replace the traditional VHS video cassette.

This technology is the result of a research and development partnership within the framework of the European Eureka Remod program, launched in 1996. It was a combined French/German effort with both government and industry support. PT

sion. In the UF study, 100 different angiograms were compressed at varying degrees. Researchers evaluated observers' ability to detect subtle diagnostic features in the angiograms and discovered slight changes were introduced when the images were reduced 10:1. At 16:1, clinicians interpreting the images began to make mistakes; they were less likely to detect common diagnostic features, including arterial narrowings or calcifications and the presence of stents, wire coils designed to prevent arteries from closing. The studies focused on a compression method originally developed for still photography—JPEG (Joint Photographic Experts Group).

Based on the latest findings, the standards committee has decided not to permit JPEG compression for original image recording and archiving, and it most likely will prohibit data compression for network transfer. Other compression approaches are under development that may someday yield better performance. But for now, "we couldn't take that risk," Kerensky said. "You can never be sure if a surgeon or another doctor might not see some subtle characteristic that they really need to see." PT

Dramatic Differences

Tiny nanoclusters of metallic gold, which are assemblies containing between 20 and 40 gold atoms encapsulated by a common biomolecule, can display distinctly chiral properties—they exist in distinct right-handed and left-handed variations. The chiral nature of the clusters dramatically affects the ways in which they absorb polarized light.

This optical effect had been predicted theoretically to occur in metal nanostructures, but Georgia Institute of Technology researchers were the first to measure it in a special class of clusters they formulated. Their research was published in the March 30th issue of the *Journal of Physical Chemistry*.

"When clusters are prepared in this way, we see that the conduction electrons in the gold circulate in such a way as to have the unique optical effect of preferring one direction of circularly polarized light over the other direction," explains Dr. Robert L. Whetten, professor in the School of Physics and the School of Chemistry and Biochemistry. "The effect was enormous, which was unexpected."

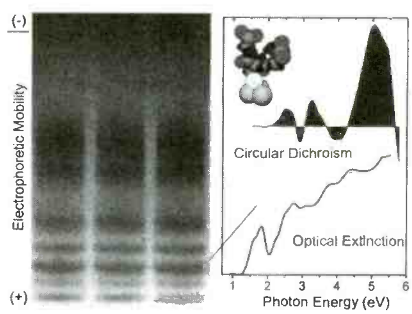
The gold nanoclusters are believed to be the smallest ever prepared. Dr. T. Gregory Schaaff, a former graduate student in Whetten's lab and now a staff scientist at Oak Ridge National Laboratory, attached glutathione—a common sulfur-containing tripeptide—to individual gold atoms to form a gold-glutathione polymer in which the gold atoms make no direct contact with one another. The decomposition of this polymer yields the gold clusters, which have glutathione molecules adsorbed to their surface so as to physically limit the number of metal atoms that could join together in each cluster.

While measuring the properties of the clusters, Schaaff noted dramatic differences in the way the smallest clusters absorbed polarized light in the visible and near-infrared spectra. In one cluster, this circular dichroism effect exceeded 300 parts per million (ppm) in the yellow-green region, while in another cluster, the effect exceeded 1000 ppm in the red and near infra-red.

These optical measurements suggest that the clusters have a helical structure that Whetten compared to the stripes on a candy cane or a barber-shop pole.

"We had to double-check our instruments and repeat the measurements a number of times because the effect was enormous," he says.

Using gel electrophoresis to separate the clusters by weight, Schaaff found that certain cluster sizes dominated, with 28-atom assemblies—slightly less than one nanometer across—being the most common. The chiral properties



Experimental results reveal that tiny clusters of gold can have distinctly chiral optical properties. This figure shows electrophoretic separation of gold: glutathione cluster compounds, left; the circular dichroism effect observed, upper right; and optical extinction of the third separated band, lower right.

varied by size of the cluster, and therefore were only observed clearly when the clusters were separated by weight. Only clusters with 40 or fewer atoms displayed the intense optical properties.

Whetten believes the effect is related to the high level of confinement created in the conduction electrons by formation of the small clusters, though research has not yet confirmed that. A helical geometrical pattern or "tiling" of the glutathione adsorption sites (gold-sulfur bonds) could also affect the circulation of the conduction electrons. PT

Gene Construction Software

Designed for biologists, the Gene Construction Kit 2 (GCK2) from Textco, Inc. is an innovative tool for DNA manipulation, cloning design, and illustration that is now available for Windows operating systems. GCK2 provides a way to manipulate DNA sequences with an intuitive graphical interface that presents and assembles the many steps needed in most cloning projects in a natural and logical fashion. (See figure below.)

GCK2 allows the user to automatically monitor DNA fragment ends during cutting and pasting; define thickness, pattern, shape, direction, and color for each DNA segment; and examine predicted gel patterns. Its unique chronography feature tracks the history of any given DNA segment and maintains alternative views. The program can display any generation (view) for any segment of DNA in a construct—even multiple generations in the same construct.

Ideal for planning and tracking complex construction projects, it allows users to view the construct either as a text sequence or graphically. Restriction sites can be marked using one or more completely editable and expandable enzyme lists. It provides the option of listing DNA with either protein sequence or with restriction enzyme or other sites, or both.

The program can create color illustrations containing multiple constructs, gels, sequence listings, free text, legends, and other graphics. Its file-searching module offers sophisticated database-like capabilities. Further information can be found at Textco's Web site: *www.textco.com*. PT

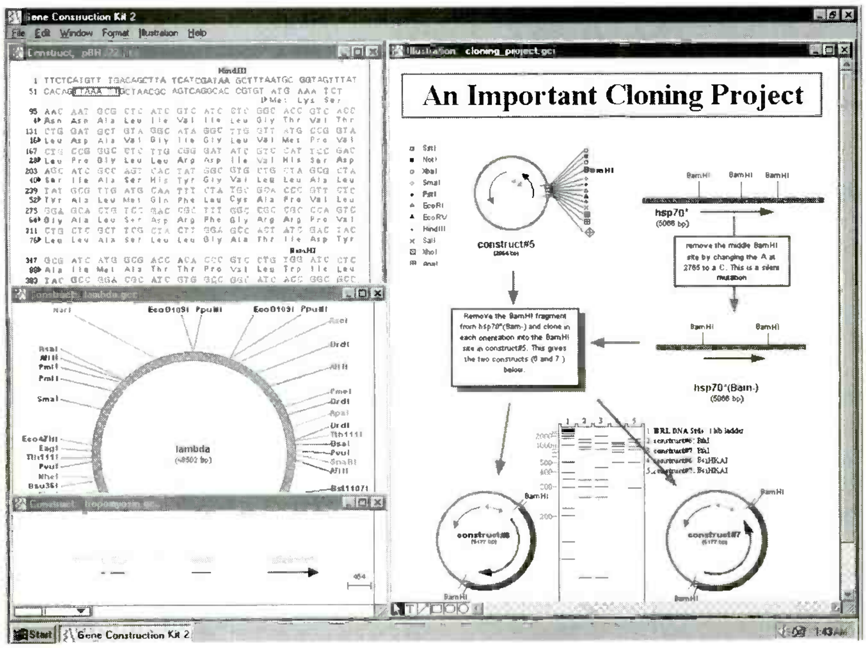
Color Me Green

Green chemistry is a philosophy of constantly searching for ways to do things better and cleaner. Paul Anastas, Industrial Chemistry Branch Chief of the Environmental Protection Agency (EPA), first coined the phrase "green chemistry" back in 1992. It is defined as "the invention, design, and application of chemical products and processes to reduce or eliminate the use and generation of hazardous substances." Over the past several years, international efforts in green chemistry have greatly increased in hopes of combating today's most pressing environmental problems, such as air and water pollution, global warming, and ozone depletion. Los Alamos National Laboratory, a member of the International Union of Pure and Applied Chemistry and management organization for the Green Chemistry Institute, has been working with industry and other research institutions worldwide to help solve these and many other problems.

Los Alamos' collaborative efforts in green chemistry already have made tremendous impacts on several industrial sectors. One example is the development of dense-phase carbon dioxide, a multi-award winning recyclable solvent that cleans everything from plutonium pits to semiconductor wafers to clothes.

Another Los Alamos success story is the Advanced Recovery and Integrated Extraction System, or ARIES, which allows workers to separate plutonium from other weapon components during dismantlement. As part of the plutonium recovery process, workers use hydrogen instead of nitric acid to convert the nuclear pit into plutonium oxide, completely eliminating hazardous aqueous waste streams.

Most recently, Los Alamos and Motorola announced the development of a fuel cell for cellular phones that lasts the lifetime of the phone and runs on methanol. PT



"Strength of material report indicates that the material wood is inappropriate."

mailto: q&a@gernsback.com

De-whiskering NiCd Batteries

Q *Do you know of a circuit that will "blow" the "whiskers" off NiCd cells? Will this cure cells that have developed a memory? I have a student who wants to fix his cell-phone battery and save the environment in the process.—T. N., Dublin, GA*

A Nickel-cadmium batteries are poisonous, so anything that keeps you from having to throw one away is good for the environment. When a NiCd battery does fail, it should be taken to a battery dealer for recycling rather than thrown out in trash.

"Whiskers" and "memory" are two different problems. Whiskers are small filaments of conductive material that form inside the cell and short it out. If a cell conducts heavily during charging but won't keep a charge, it probably has "whiskers."

To get rid of them, you can "zap" the cell as follows. Charge a large (3200-µF) capacitor to about 12 volts, and then apply it to across the cell (positive to positive, negative to negative). The resulting surge of current will often clear the whiskers. You can tell that the cell is fixed by charging it for a few minutes and checking it with a voltmeter; you should see 1.2 volts or higher, rather than 0 volts.

In a battery where the cells are connected in series, I've had better results using a different tactic. The usual symptom is that the battery works but its voltage is low; for example, a 7.2-volt battery gives about 6 volts when partly discharged and peaks at 7 volts (not 8.4) when fully charged. In that case, it's lost one of its six 1.2-volt cells. To restore it, you might try charging with heavy current (maybe 1 to 2 amps) for a few seconds. This is easy to do with a lab-type power supply, where you can watch the voltage to see if you're getting results. Caution: Some batteries contain fuses that will blow if you charge with more than 1 amp.

Neither of these techniques makes the battery as good as new, but you can get a few more weeks of operation out of what would otherwise be a piece of toxic waste.

"Memory" is a different—and controversial—phenomenon. Supposedly, if you repeatedly charge a NiCd battery, then discharge it only slightly before recharging it again, it will "learn" that it's only being used for a shallow cycle, and its capacity will diminish. The cure is to discharge it thoroughly (down to 80% of the rated voltage and no lower, or some of the cells might reverse-charge the others). Then charge it again, and it's as good as new.

Manufacturers deny that there is such a thing as NiCd memory. It's fairly clear, though, that if a cell undergoes a lot of charging and not much discharging, its voltage will decrease slightly. A good discharge and recharge cycle will restore it.

A Better Function Generator?

Q *In your March column, you recommended the ICL8038 function-generator chip. Sure, it works, but it requires dual high-voltage (>5 volts) power supplies, uses lots of power, runs hot, and gives a poor sinewave. Why not use the Maxim MAX038, which works up to 20 MHz?—R. K., Portland, OR*

A The ICL8038 mainly was the chip used in the articles to which I gave reference. The MAX038 does have some advantages, and as you pointed out in your letter, its data sheet is online at *www.maxim-ic.com*. Like the ICL8038, this chip generates sine-, triangle-, and squarewaves. Unlike the ICL8038, it operates from +5- and –5-volt supplies and covers a wide frequency range with low distortion. You can buy it in small quantities directly from Maxim as well as other mail-order suppliers such as Digi-Key.

Don't Forget The Nanofarad

Q *Further to your item on "What's a 5M6 resistor?" in the April column, the European notation for a capacitor of 0.0027 µF is 2n7 and for a 4.7-µF electrolytic, 47 (4u7).—N. L. L., Patras, Greece*

A Thanks. For those who tuned in late, we were explaining that "4.7 kilohms" is abbreviated "4k7" on European schematic diagrams; likewise 4.7 megohms would be "4M7" and 4.7 ohms (4.7) is often written 4R7.

The capacitance units used in America are microfarads (µF) and picofarads (pF, formerly F), where 1 F = 1,000,000 pF. In between is the nanofarad (nF), seldom used in America but widely used elsewhere; 1 nF = 1000 pF = 0.001 uF. And as you note, 2.7 nF is written 2n7 on European schematics.

As one who has studied the Greek language, I balk at writing "u" for "µ"; everybody knows that µ (mu) is the Greek letter M. But if we're using m for "milli" we need a different abbreviation for "micro," and if µ is not on the keyboard, we have to type "u."

Wrong Answer To Scanner Question?

Q *The letter from T. R. B. in your March column was interesting, as was the answer. He needed to build a 16-volt, 900-mA power supply for a scanner whose original power supply had failed.*

What you overlooked was the cause of the original power-transformer failure. Most small power transformers are designed to burn out (rather than heat up and start a fire) when overloaded.

I suspect that both his original power supply and the one he built were overloaded by some fault in the scanner, such as a leaky capacitor. He should measure the current drain when the voltage starts dropping. Chances are that it will be more than the 900-mA rating of the original unit.—Bob O'Brien, Los Angeles, CA

A You're right, of course; thanks for your comments.

Ferrite Rod and RF Transformers

Q *Where can I find a 24-inch-long ferrite rod to make an AM radio antenna? Also, where can I buy RF and IF transformers?—G. K., New York, NY*

A These and other hard-to-find radio parts are available from Ocean State Electronics, P.O. Box 1458, Westerley, RI 02891; 401-596-3080, *www.oselec tronics.com*. However, their longest ferrite rod measures 7½ inches. I've actually never seen a 24-inch rod and don't know if they were ever made; you might try a wire loop antenna instead.

Grafftech Transmitter

Q *I am looking for a schematic of an FM-broadcast-band transmitter called Grafftech FM 3000, which dates from the mid-1970s. It appears to have been built from a kit.—J. M. (jsmullin@sprint.ca), Toronto, Canada*

A An extensive Internet search didn't turn up any information on Grafftech, so we're publishing your e-mail address in the hope that a reader can help. If this was a pirate-radio transmitter, designed to be used illegally, the maker may have operated in secrecy.

Loop Antennas

Q *Thank you for answering, in your February column, my question about loop antennas for direction finding. However, I'm actually looking for something more. I'm familiar with the* ARRL Handbook, *but need a design for a medium-wave or long-wave direction-finding antenna, not a VHF one. The loops that I'm interested in were used on planes such as Pan American Clippers. They operated between 200 kHz and 500 kHz.—V. K. (vklein@micro.com), Kansas City, MO*

A Another reader, Ken Robbins, W1KNI, wrote in to say that some information about such antennas can be found in *The Low and Medium Frequency Radio Scrap Book*, by Ken Cornell, W2IMB, published in the 1970s. You might want to track this book down. The best way is to get your public library to look for it via interlibrary loan.

We're publishing your e-mail address so that any other readers who have information can write to you directly.

C And C++ For Microcontrollers

Q *Can you suggest a good microcontroller that takes C or C++ and a project to build that will teach me the basics?—M.S.O., Jamaica Plain, MA*

A C compilers are available for a wide range of microcontrollers; the maker of each chip can tell you what's available for it. C++ is used only on the largest microcontroller systems.

One book that gives you the details of microcontroller programming in C is *C Programming for Embedded Systems*, by Kirk Zurell, published by R&D Books, Lawrence, KS 66046 (available through any bookstore). The book, priced at $29.95, comes with a working copy of the Byte Craft C compiler for the Motorola MC68705J1A. That's a real bargain.

Nevertheless, a word to the wise: Don't skip assembly language, or you won't have a good mental picture of how a microcontroller works.

Philips Scope Manual Found

Q *I just noticed the inquiry in the June 2000 column from a reader in Miami needing a manual for a Philips PM3305 oscilloscope. The Test and Measurement Division of Philips was acquired by Fluke a few years ago. Manuals for the PM3305, a good model number by the way, are still available from Fluke. Your reader can call*

HOW TO GET INFORMATION ABOUT ELECTRONICS

On the Internet: See our Web site at *www.gemsback.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.elec tronics.repair, sci.electronics.components, sci.electronics.design*, and *rec.radio.ama teur.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.motoro la.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.

Copies of past articles: Copies of past articles in **Electronics Now, Popular Electronics** (post 1995 only) and **Poptronics** are available from our Claggk, Inc., Reprint Department, P.O Box 12162, Hauppauge, NY 11788; Tel: 631-592-6721.

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, PO Box 549, Tooele, UT 84074.

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.

888-99-FLUKE (888-993-5853) for more information.—Colin Plastow, Fluke Corporation.

A Thanks! The mailing address is Fluke Corporation, PO Box 9090, Everett, WA 98206 USA; in Europe, PO Box 1186, Eindhoven, The Netherlands.

LED Flasher Progress Report

The LED flasher described in Fig. 9 of our July column successfully flashed a red LED for ten weeks using a single N cell (smaller than an AA cell). Has anyone been able to improve on it yet? Please write and let me know your results.

Transformer Safety Note

In last month's column, we said that you can always use a transformer on a lower *voltage than it was designed for. That's true as long as it's* not *also working at a substantially lower frequency. You can generally swap 50- and 60-Hz transformers without any trouble, but if you apply 50- or 60-Hz power to a 400-Hz transformer (common in military-surplus equipment), it will saturate and conduct heavily. That's one reason that you should always do your testing with a light bulb in series with the primary.*

If a transformer is labeled "120 volts" but conducts far too heavily on 120 volts, 60 Hz, it's probably a 400-Hz transformer. Either that or it's shorted.

Writing To Q&A

As always, we welcome your questions. The most interesting ones are answered in print. Please be sure to:

(1) include plenty of background information (we'll shorten your letter for publication);

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

(3) type your letter if possible, or write very neatly; and

(4) if you are asking about a circuit, include a complete diagram.

Questions can be sent to Q&A, **Poptronics** Magazine, 275 G Marcus Blvd., Hauppauge, NY 11788, or e-mailed to *q&a@gernsback.com*, but please do not expect an immediate reply in these pages (because of our backlog) and please don't send graphics files larger than 100K. Due to the volume of mail, we regret that we cannot give personal replies.

LETTERS

(continued from page 16)

[Chalk that one up to an overworked editor on deadline whose "fat fingers" were aiming for the "D" key but landed on the "A" key instead. As the old saying goes, "close" only counts in horseshoes, hand grenades, and nuclear weapons!—Editor.]

Less Than Useful Source Code

I would like to point out significant errors in the programs published in the article "LCDs for PCs" by Michael Chan in the March issue of **Poptronics**. In spite of the statements in the remarks, the Basic code in Listing 1 does not turn off the LEDs. Much more significantly, the code in Listing 2 contains (twice) GOSUB 600, although there is no line 600. Moreover, both listings are in an archaic format, either GW Basic or BasicA, rather than the QBasic format used with all recent Windows systems; line numbers are not required (nor recommended), and procedures are defined in separate named subroutines or functions. The QBasic format makes the listings much easier to read and would help avoid the errors that occurred.

By the way, I searched your Web site and could find no source for the code for either of the Chan articles there.

ED GRENS
via e-mail

[We have e-mailed the author for clarification and have yet to receive a response. If any reader has a solution to this, we'd love to print it.

The reason that you couldn't find the code on our FTP site is because it's not posted there; it's printed in the article. If you go to the author's Web site listed in the article, you'll find a page with the exact same information, errors and all—admittedly not very helpful.—Editor.]

Fixing Lester's Crosley

Lester Haugsdal asked about repairing his 1920 Crosley radio ("Letters," August 2000 **Poptronics**). The triode-receiving tube in the radio is more than likely an "O1A." This is a 5-volt DC filament tube drawing 250 mA. I would suggest that Lester find a 20-ohm wire-wound potentiometer that is rated at 5 watts or more to place in the filament line. In the old "regen" and "trf" (tuned-radio-frequency) receivers of this vintage, the filament voltage was changed in order to control the volume of the receiver. That also decreased the gain at the same time.

Best of luck restoring your radio.

L. PIPPEL
via e-mail

You Mean You Don't Have One?

I like your new magazine. As for things to make, I would like to suggest four projects: a 220-volt inverter; a buzzer that will foil those very loud sub-woofers; a simple fuel cell; and since all light and matter are vibrations, a replicator as seen on *Star Trek*.

AL PURCELL
Cleveland, OH

[Those first three projects sound way too difficult to do. However, I'm surprised that you don't have a replication unit; I thought everyone has them. The manufacturer sent me a unit on 30-day approval. The price was $700, so I replicated a $1000 bill and sent it to them—keeping the original, of course. The only oddity I noticed was when they sent me my change, all three $100 bills had the exact same serial numbers...

For those who don't recognize the story I'm referencing, read the collection of "Venus Equilateral" short stories written by George O. Smith back in the 1940s. The trial story that takes place in a Buffalo, NY courtroom is particularly priceless!—Editor.]

Looking For Articles On...

I would love to see an article on modems that covers things like how it verifies dial tones and busy signals and responds to sent tones. Also, many of us hobbyists educate ourselves by using magazines as textbooks. "Basic Circuitry" is a great idea. Please don't make it too simple, but do progress into more complicated functions.

RANDY HEISSERMAN
Boulder, CO

Haves and Needs

I have a Conar Oscilloscope model 225 for which I would like the schematics and any other information. Any help is much appreciated.

FRANK CLAY
5746 Springfield Ave.
Bokeelia, FL 33922-3401
fcclay@netzero.net
941-283-1533

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The four analyzers in the SureTest family are Models 61-150, 61-151, 61-152, and 61-156. The basic unit measures line voltage and voltage drop. Model 61-151, which is pictured here, also measures ground impedance and false grounds. The high-end model provides event recording, true RMS, and harmonics measurements, among other features. There are other SureTest analyzers as well: two Harmonic Circuit Analyzers and a 220VAC model. The more advanced models verify isolated grounds and dedicated circuits, in addition to measuring line-voltage drop, neutral-to-ground voltage, ground impedance, and the estimated load on the branch.

Left unidentified, excess voltage drop can lead to improper, erratic, or non-operating equipment; poor efficiency and wasted energy; and a heat buildup at the connection/splice—a possible fire hazard. Such a drop can be caused by high-resistance connections at wiring junctions or outlet terminals, possibly from poor splicing, corroded connections, or inadequate seating of wire in receptacles or switches.

These circuit analyzers can isolate such connection mistakes by testing receptacles in sequence along the branch circuit. In addition, the SureTest analyzers help find problem areas, which may require further investigation of some receptacles and/or of the branch circuit. Shorts, which cause the equipment on the circuit to be hot, are another area that can be tested with these analyzers. While other circuit testers identify this dangerous condition from the site of the receptacle itself, the SureTest circuit analyzers can identify a false ground from as far away as 15 feet.

The SureTest circuit analyzers range in price from $195 for the model 61-151 up to $675 for the high-end model.

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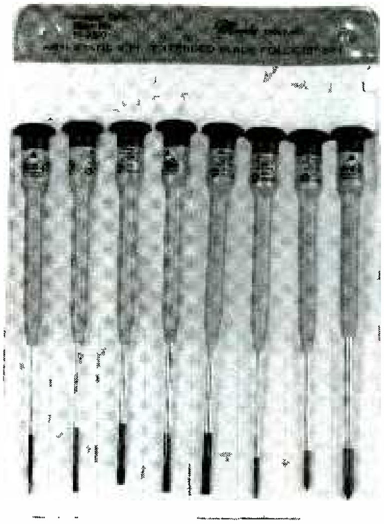

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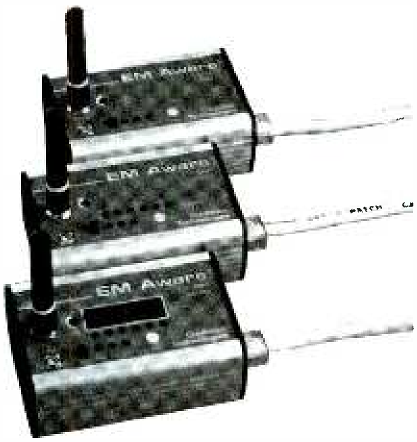

CIRCLE 62 ON FREE INFORMATION CARD

Prices for EM Aware range from $540 for the basic model (CTC032) to $931 for Model CTC034.

CREDENCE TECHNOLOGIES, INC.
3601-A Caldwell Dr.
Soquel, CA 95073
831-459-7488
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Audio-Interconnect Transformer

THE LATEST ADDITION TO THE ISO-MAX line of isolators, the *Model CO-2RR* is a plug-and-play device that eliminates annoying hum and buzz in audio systems. Simultaneously, it preserves the signal's audio spectrum. Aimed at professional as well as consumer applications, including home-theater and high-end-stereo, this audio-interconnect solution eliminates any ground loops in unbalanced interfaces and produces clear audio performance.

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Operating at –10dBV, the CO-2RR also provides 15 dB of "headroom" at 20 Hz. The CO-2RR's low-frequency response level is ruler flat to 10 Hz and extends well below 1 Hz. Housed in a heavy-gauge steel enclosure with a six-hole mounting base, the easy-to-mount stereo unit measures 2.60 × 2× 1.45 inches. Its input and output connectors consist of four high-quality gold-plated RCA/IHF jacks.

The ISO-MAX Model CO-2RR transformer lists for $169.95

JENSEN TRANSFORMERS
7135 Hayvenhurst Ave.
Van Nuys, CA 91406
818-374-5857
www.jensen-transformers.com

Fast 8-bit Microprocessor

THE *AB181E-20*, A Z180-COMPATIBLE microprocessor, uses a unique one-cycle architecture and a powerful instruction set that allows manufacturers to use their previous code development while increasing their ability to create new designs. Any clone device that uses the Z80 instruction set can be upgraded as well—not just Z180 devices. The AB181E-20 is 98% code compatible with all but four of the original Z180 instructions.

At minimum, the AB181E-20 gives a

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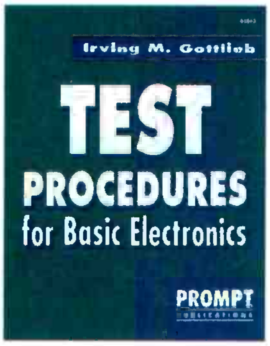
five-fold improvement over the Z180 microprocessor, in terms of the number of internal clock cycles and their execution times. These times are based on an internal clock frequency of 20MHz. The AB181E-20 uses a PLL to generate the internal clock, which runs at four times the external crystal frequency.

The AB181E-20 Microprocessor sells for $12.65 (U.S) in single quantities.

AB SEMICON
62 Victoria Way
Burgess Hill, West Sussex RH15 9LR
England
www.ab-semicom.com



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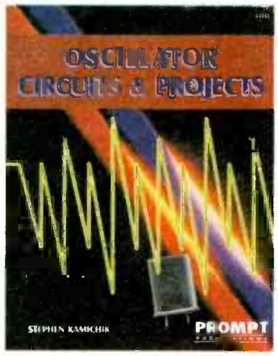

☐ Oscillator Circuits and Projects. #61111. -- $24.95
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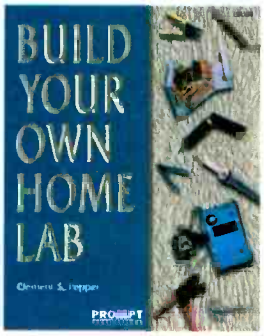

☐ Troubleshooting and Repair Guide to TV. #61146. -- $34.95
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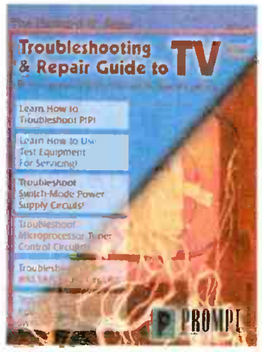
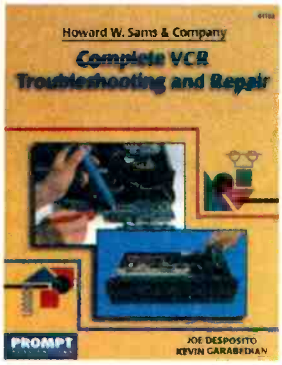
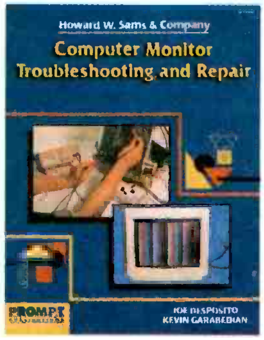




☐ Complete VCR Troubleshooting and Repair. #61102. -- $34.95
Though VCRs are complex, you don't need complex tools or test equipment to repair them. This book contains sound troubleshooting procedures that guide you through every task. *8 1/2 x 11", 184 pp, paperback.*



☐ Computer Monitor Troubleshooting and Repair. #61100. -- $34.95
This book can save you the money and hassle of computer monitor repair by showing you how to fix it yourself. Tools, test instruments, how to find and solve problems are all detailed.
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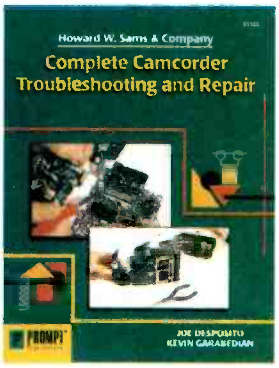
☐ Complete Camcorder Troubleshooting and Repair. #61105. -- $34.95
Learn everything you need to know about the upkeep and repair of video camcorders. Start by examining camcorder troubleshooting procedures, then move into more advanced repair techniques. *8 1/2 x 11", 208 pp, paperback*



☐ Joe Carr's Circuit Toolkit. #61181. -- $29.95
Easy-to-build, useful circuits from Carr's workbench to you. They will spark new ideas in your day-to-day use of circuits and help solve frustrating problems.
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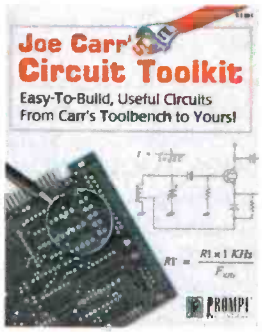
Contact Jim Surface.



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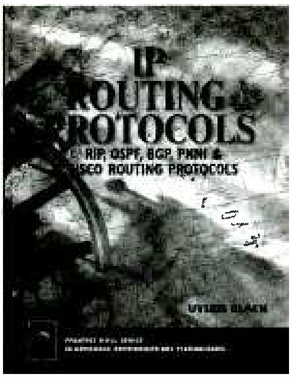
NEW LITERATURE

IP Routing Protocols

by Uyless Black
Prentice Hall
One Lake St.
Upper Saddle River, NJ 07458
800-282-0693
www.phptr.com
$48.99

According to the author, "The IP routing protocols are the sextant of the Internet. The chief use of the IP routing protocols is the same as the sextant: to discover routes, except these routes are through an Internet terrain."

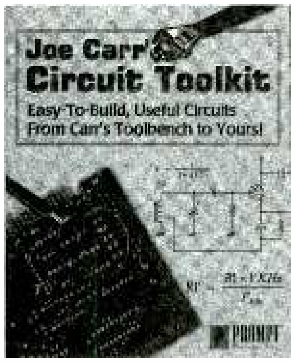


This complete guide examines the basics of how to build and manage networks with these routing protocols: RIP, OSPF, BGP, PNNI, and CISCO. Aimed at network professionals, this comprehensive book begins with a thorough tutorial on the fundamentals of route discovery, architecture, and operations. It proceeds to in-depth coverage of such subjects as interior gateway protocols, connecting internal networks to the Internet, and enterprise networking.

Joe Carr's Circuit Toolkit

by Joseph J. Carr
Prompt Publications
Sam's Technical Publishing
5436 W. 78th St.
Indianapolis, IN 46268
800-428-7267
www.samswebsite.com
$29.95

Former **Popular Electronics** columnist Joe Carr has compiled a collection of thought-provoking, easy-to-build circuits—useful for finding solutions to perplexing design problems. Basic circuit theory is presented in a readable text with helpful illustrations.

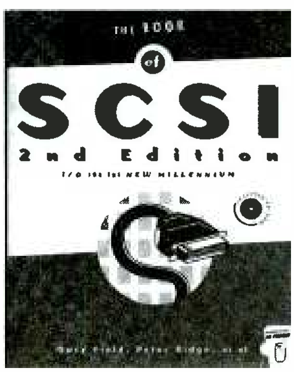


Circuit can be designed using simple division on a hand-held calculator. Designing active filters is usually very math intensive, but here Carr used the "nominal value" method instead. Among the circuits are RF and wideband amplifiers, RF hybrids and combiners, waveform generators, and active and notch filters.

The Book of SCSI, 2nd Edition

by Gary Field, Peter Ridge, et al
No Starch Press
555 De Haro St., Ste. 250
San Francisco, CA 94107
800-420-7240
www.nostarch.com
$49.95

SCSI (pronounced scuzzy, short for small computer system interface) is a hardware interface that allows fast com-



munication between devices connected to a computer. This newly updated edition explains the basics of installing and using SCSI, plus how to work with SCSI IDs, LUNs, and much more. There is also new and expanded coverage of SCSI 3 and device drivers.

Clear drawings, diagrams, troubleshooting tips and tricks, and a comprehensive index all make this an indispensable reference. For the first time, a CD-ROM with SCSI diagnostic tools and utilities and ASPI programming examples, as well as the complete searchable text, is bundled with the book.

Computer Communications Tools Catalog

from B&B Electronics Manufacturing Co.
707 Dayton Road
P.O. Box 1040
Ottawa, IL 61350
815-433-5100
www.bb-elec.com
Free

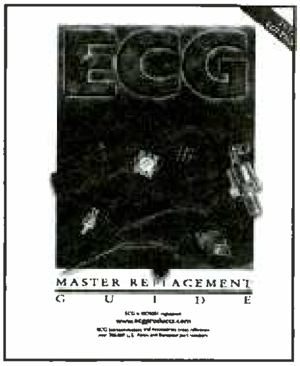
Designed for computer professionals and anyone else interested in tinkering with computers, this catalog features solutions to computer connection problems. New products include over 400 adapters to connect a CAN (Controller Area Net-work) bus to fiber-optic cable, converters that allow USB ports on new PCs to be used for legacy serial and parallel applications, and an optically isolated USB hub. There's a new section of Fail Safe and Redundancy products, including a Rogue Node Isolator that can automatically transfer data to a back-up line if needed.

In addition to computer products, there is technical information and books as well. Each product is accompanied by a color photo and full product description.

ECG Master Replacement Guide

from Philips ECG
1001 Snapps Ferry Road
Greeneville, TN 37744
800-526-9354
www.ecgproducts.com
Free

Featuring over 6000 additional cross-references and 81 new devices, including new product families, the 19th edition of this guide is a comprehensive source of replacement information. It has more than 306,000 crosses to U.S., Asian, and European part numbers. Expanded selector guides simplify choosing the best ECG replacement type for numbers that are not crossed, and there is a complete alphabetical index.

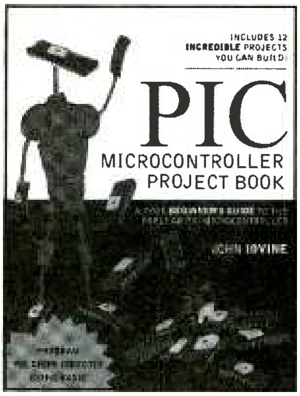


New products include power MOSFETs, TRIACs, resettable fuses, dual Schottky barrier rectifiers, and diodes. Each section provides technical information and drawings of the parts. The updated Philips ECG Instant Cross program (ET-2604W2.2) is also available on disk, with the semiconductor and relay database in one program.

PIC Microcontroller Project Book

by John Iovine
McGraw-Hill
2 Penn Plaza
New York, NY 10121
800-2MCGRAW
www.books.mcgraw-hill.com
$29.95

Bound to spur the imagination and inspire plans for using PICs in new products and

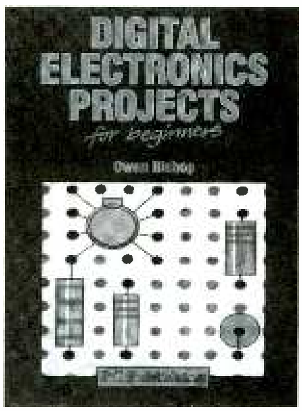


projects, this book answers the question: What can you do with PIC microcontrollers? Practically anything—from creating "photovore" robots that hunt light for their solar cells to making toasters announce "Your toast is ready!" These easy-to-use, low-cost, computers-in-a-chip let designers and hobbyists add intelligence and responsiveness to any electronic product or project—even faster than comparable Basic Stamps.

Hands-on directions are supplied for putting Microchip's RISC-based chips—with up to 8k of memory—to work. Starting with simple projects and experiments, this book progresses gradually into sophisticated programming techniques. The author John Iovine, our "Amazing Science" columnist, guides enthusiasts into such projects as synthesizing human speech, controlling DC and stepper motors, adding sensing abilities to robots, and building in decision-making neural and "fuzzy logic" functions.

Digital Electronic Projects for Beginners (PCP112)

by Owen Bishop
Electronic Technology Today, Inc.
P.O. Box 240
Massapequa Park, NY 11762-0240
$14.99 (includes S&H)



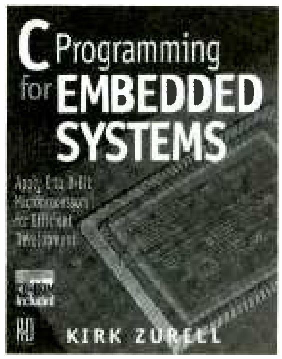
Suitable for the beginner, this book contains 12 digital electronics projects to build with the minimum of equipment. The projects range from instrumentation to home security, and there are some projects that are included just for fun. Except for one project, they are all battery powered, and all of them are completely safe for the beginner.

Each project has a circuit diagram, a drawing of the perfboard layout, and full construction details with instructions for testing the circuit at each stage. Each description ends with a list of the components required, all of which are widely available.

C Programming for Embedded Systems

by Kirk Zurell
R&D Books
6600 Silacci Way
Gilroy, CA 95020
800-500-6875 or 408-848-8294
www.rdbooks.com
$29.95

The majority of today's embedded systems rely on 8-bit microprocessors. Commonly used in autos and consumer products, 8-bit microcontrollers are increasingly used in the newest controller applications, such as USB peripherals and Net-enabled appliances. This book is ideal for the C programmers who want to transfer their skill to the embedded environment.



The author explains the architecture common to most 8-bit microcontrollers, introduces embedded-specific design regimens, and demonstrates the advantages of programming in C. He also guides readers through the development of a sample project, complete with source code, for a consumer product. The included CD-ROM contains a working C6805 Code Development System tailored for the Motorola MC68705J1A microcontroller, additional software, and test programs. P

"WATCH" TV WITH THIS FM/TV AUDIO RADIO RECEIVER

Keep up with your favorite television programs even if you can't watch the screen!

ANTHONY J. CARISTI

Do you, or perhaps someone you know, long to listen to a favorite TV program when you can't be near a TV set? Maybe you might like the satisfaction of constructing your very own FM radio instead and listening to your favorite radio station. If so, the *FM/TV Audio Receiver* presented here is just the project that you're looking for, whether for yourself or as a unique gift. This miniature, portable FM receiver fits into a pocket and can receive either the standard FM broadcast band (88–108 MHz) or the sound carrier from TV channels 2 through 6 (59.75–87.75 MHz).

This two-chip, superheterodyne FM receiver uses a unique method of receiving frequency-modulated broadcast signals: an intermediate frequency (IF) of only 70 kHz. That frequency is low enough to allow fixed-bandwidth-IF tuning using active-RC filters. Although that is interesting to a radio-design expert, it means no radio-frequency expertise is needed for the rest of us. What's more, there's no alignment to worry about for this project, and it's easy to build. The receiver is designed to drive a built-in loudspeaker; a headphone jack may be installed as an option. A common 9-volt transistor-radio battery powers the circuit. There is a fine-tuning control for accurate tuning to your favorite station as well; and an externally-adjustable volume control may be included as another option.

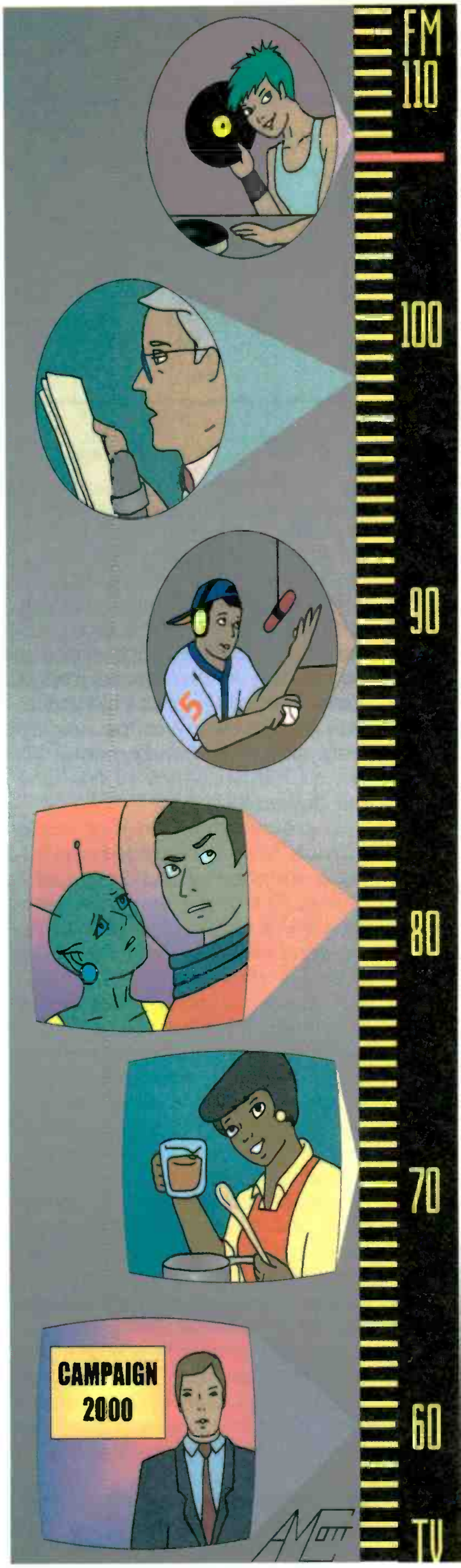
All of the difficult design parameters of the circuit are taken care of by a suitable printed-circuit layout. By following the easy construction details, you can build a properly operating TV-sound or FM receiver in just a couple of evenings.

How It Works. The FM/TV Audio Receiver is built around a TDA7000 FM-receiver chip (A block diagram of this chip is illustrated in Fig. 1.) Included in it are a mixer, local oscillator, IF amplifier, limiter, quadrature-FM demodulator, and muting control. All those subsystems tied together on a single slab of silicon makes the TDA-7000 a veritable "radio on a chip."

As mentioned previously, the use of a 70-kHz intermediate frequency instead of the more common 10.7 MHz is unique to the FM/TV Audio Receiver. The advantage of using such a low frequency is in eliminating the need for inductors and/or ceramic filters. Instead, the IF amplifier consists of on-chip op-amps that are configured as active filters using internal resistors and external capacitors for bandpass tuning.

Circuit Description. Since it is difficult to describe the various functions of the FM/TV Audio Receiver without referring to the actual circuit, let's "get our hands dirty" and dig right into the schematic diagram. Follow along with Fig. 2 during the following description.

The RF signal from a short wire antenna is coupled to pin 13 of IC1 through an LC network composed of C4, C5, and L1. This broadly tuned, antenna-bandpass filter circuit feeds the incoming signals directly into IC1's internal mixer.



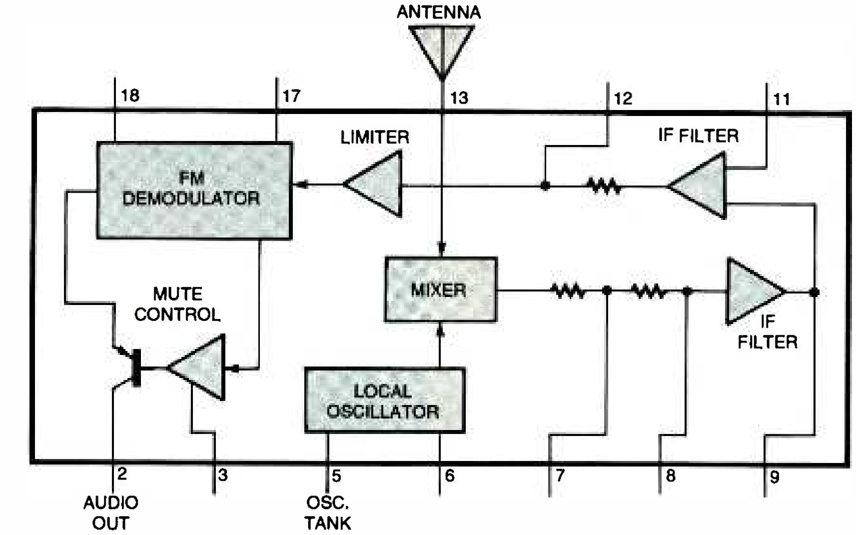


Fig. 1. The TDA7000 "radio-on-a-chip" from Philips is the heart of the FM/TV Audio Receiver. Everything needed for a radio receiver—except audio amplification—has been integrated into this 18-pin chip.

The frequency of the local oscillator determines which radio station will be received. Inductor L2, in conjunction with varactor diode D2, forms a parallel-resonant circuit that sets the frequency of the on-chip local oscillator. Potentiometer R3 adjusts this frequency to fine-tune the desired RF signal.

To prevent distortion that would normally occur with a wide-band FM-transmission signal and a receiver IF of only 70 kHz, the received signal deviation is compressed to ±15 kHz. This compression is accomplished by a built-in phase-locked loop that shifts the local-oscillator frequency in reverse proportion to the normal received-signal deviation, as produced by the frequency modulation of the transmitted carrier signal.

A quadrature FM demodulator is used to convert the frequency-modulated IF signal to audio. The monaural audio output appears at pin 2 of IC1; and it is sent to IC2, a low-power audio-amplifier chip that has sufficient power to drive a loudspeaker. Potentiometer R7 sets the volume level of SPKR1.

Power to operate the circuit is provided by a common 9-volt transistor-radio battery. Current draw is about 15 milliamps, which allows about 25 hours of use from a new alkaline battery.

Tuning Components. The FM/TV Audio Receiver is capable of receiving frequencies from 59.75 to 108 MHz, just not in one single band. The circuit is designed so that it may be constructed to receive the sound carrier of TV channels 2 through 4, channels 4 through 6, or the standard broadcast FM band. Table 1 illustrates the frequencies in question.

The tuning components for the antenna and local-oscillator tank circuits—L1, L2, C4, C5, and D2—will have different values for a standard FM receiver as opposed to a TV-station receiver. The component part numbers are specified in the Parts List. Choose only those parts specified in Table 2 for the frequency band of the receiver that you want to build.

Construction. The FM/TV Audio Receiver is constructed on a small double-sided printed-circuit board measuring about 1¾ by 2¼ inches. Printed-circuit construction of this project is mandatory since it operates with very high gain in the VHF band. One side of the circuit board consists of a solid-copper ground plane in which the ungrounded component lead holes are manually cleared of copper. The opposite side of the board contains the printed circuitry, as in Fig. 3. If you do not wish to

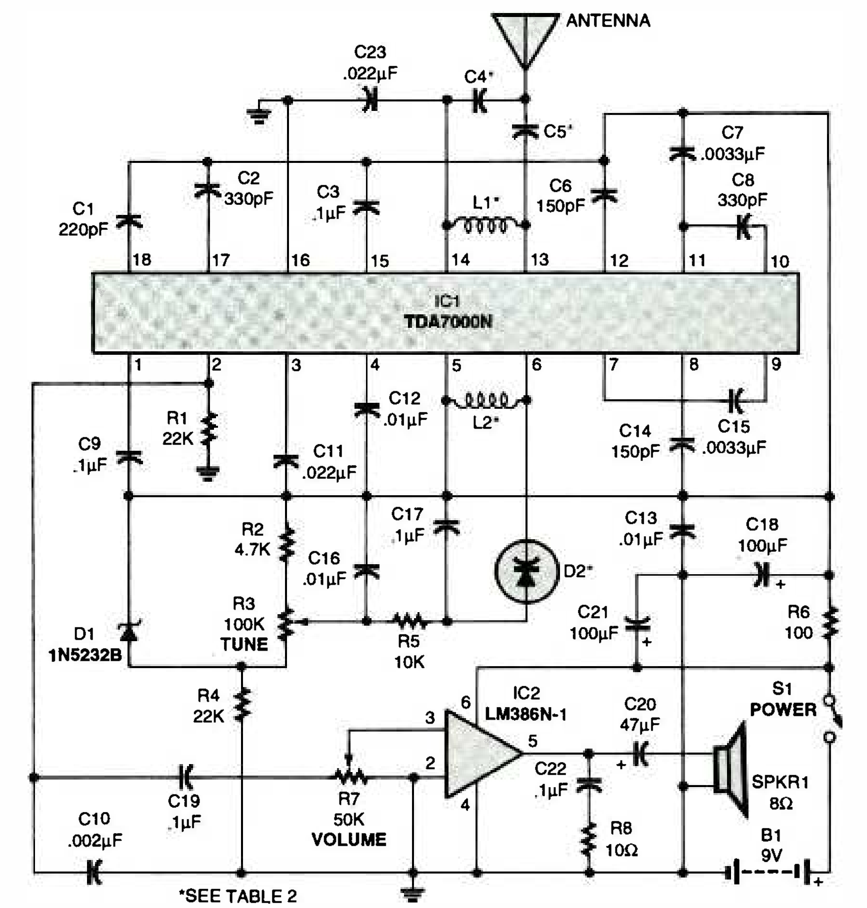


Fig. 2. If you replace a few select components, the FM/TV Audio Receiver can pick up FM radio or TV audio.

TABLE 1
FREQUENCIES OF TV AND FM BROADCAST STATIONS

TV Channel 2	59.75 MHz
TV Channel 3	65.75 MHz
TV Channel 4	71.75 MHz
TV Channel 5	81.75 MHz
TV Channel 6	87.75 MHz
FM broadcast	88–108 MHz

fabricate your own board, you may obtain one from the source given in the Parts List.

Although only one foil pattern is shown, the FM/TV Audio Receiver uses a double-sided board. The component side is simply a ground plane of unetched copper that covers the entire board. After etching the solder side of the board and drilling the component holes, you will need to clear the ground-plane copper away from the holes to prevent any accidental shorts to ground. One way to accomplish that is with a sharp 1/8- or 3/16-inch drill bit. By holding the drill bit in your hand and spinning it against each hole, a circular ring free of copper around each hole results. Be careful not to remove too much PC-board material or you'll enlarge the holes too much.

Do not clear copper from those holes in which the component leads connect to ground; we'll use the leads to make connections between both sides of the board. Using Fig. 4 as a guide, leave copper around the following pads:

- C10 and R1 that connect to each other *only*
- The C13 lead next to C12
- The R4 lead nearest the board edge
- R7's rightmost lead
- R8's rightmost lead
- C23's rightmost lead

If you feel ambitious, you can include the negative leads of C18, C21, B1, SPKR1, pin 16 of IC1, and pins 2 and 4 of IC2. Those additional leads were not connected to the ground plane in the author's prototype, but making the additional connections shouldn't cause too many problems other than added construction work.

After the ground-plane side of the board has been prepared, gently clean both surfaces of the printed-circuit board with steel wool and detergent to remove any possible oxidation or dirt. This procedure will provide a clean metal surface that is conducive to good solder joints. Rinse the board in cold water and dry thoroughly.

Use the parts-placement diagram in Fig. 4 as a guide when installing components. The first components that should be soldered in place are L1, L2, and D2. Those items are surface-mount components that are to be soldered on the solder side of the board. Figure 5 illustrates the terminal connections of D2. Note that only two of the three terminals are used.

The best way to install a surface-mounted component is to gently "tin" the copper pads on the board. Use solder braid to remove all of the excess solder, leaving a shiny, silver surface. Do not use excessive heat. Place the component in position directly over the pads and apply solder to one pad and terminal only. Inspect the position of the component. If it is correct, solder the remaining connection.

Insert all of the remaining components. If you want to use an external volume control, don't install R7 at this time. Pay strict attention to all polarized components such as the semiconductor and electrolytic capacitors. Any such part placed backwards in the circuit will render the receiver inoperative, and it may get damaged itself or damage other components when power is applied. Double-check before soldering those parts in place.

Note that to conserve "real estate" space on the board, the design places many parts vertically. However, component height should be considered to assure proper fit of the final assembly into the desired enclosure. Since this is a high-frequency circuit, the lead length of all com-

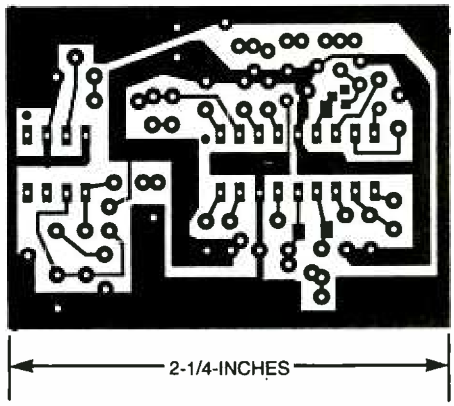


Fig. 3. The PC board for the FM/TV Audio Receiver is a double-sided board that any hobbyist can build; the component side is a solid ground plane.

ponents must be as short as practical. Be absolutely sure that no component wires touches the ground plane unless it is connected to ground on the opposite side of the board. Refer to Fig. 2 if in doubt.

When you install a grounded component, solder that component's grounded lead to the ground plane on the component side of the board after soldering it in place. See the list of components mentioned above.

A piece of flexible insulated wire about 20 inches long may be used as a temporary antenna for test. The final length will be determined later. Solder this temporary antenna wire in place as indicated in Fig. 4.

When you are finished soldering the parts in place, check the connections of all ungrounded components to be sure that there are no inadvertent short circuits to ground. If in doubt, use an ohmmeter. Carefully examine all of the solder joints; are they shiny and smooth? Check for short circuits between closely spaced copper conductors. Correct any problems now before proceeding.

When you are satisfied with your work, set the board aside.

TABLE 2
TUNING COMPONENTS FOR TV SOUND AND STANDARD FM BROADCAST RECEPTION

Frequency Band	L1	L2	C4	C5	D2
Standard FM	0.1 µH	0.083 µH	68 pF	47 pF	22 pF
TV channels 2, 3, 4	0.12 µH	0.12 µH	100 pF	68 pF	33 pF
TV channels 4, 5, 6	0.1 µH	0.083 µH	100 pF	68 pF	33 pF

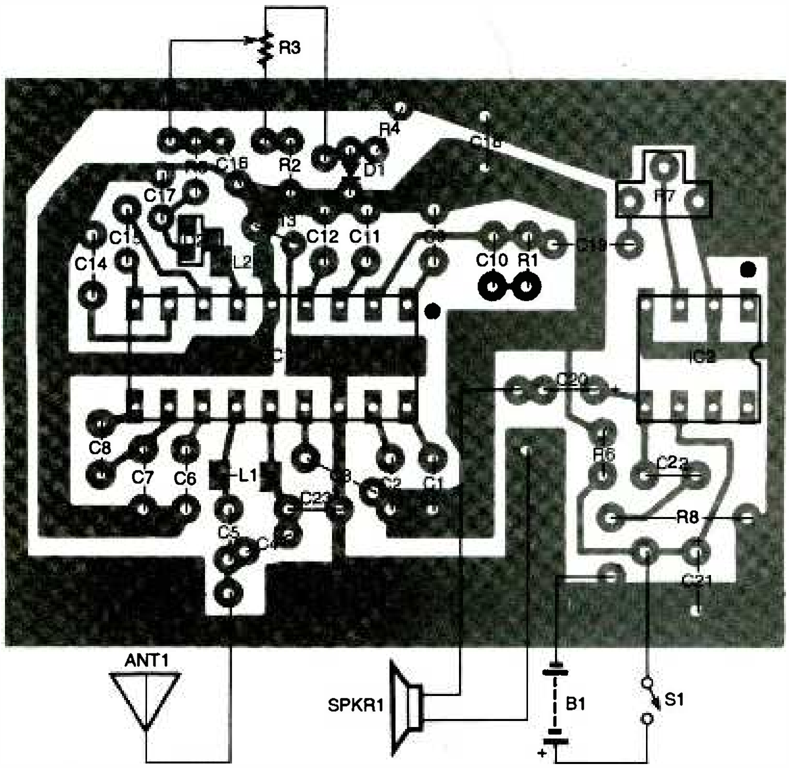


Fig. 4. Follow this parts-placement diagram when building the FM/TV Audio Receiver. You should clear away the ground-plane copper from the holes of any leads that are not grounded.

Cabinet Assembly. The small size of the board permits installation in a small enclosure that also houses the 9-volt battery, tuning potentiometer, loudspeaker, and on/off switch. The Parts List provides one such enclosure that has a built-in battery compartment; but any suitable plastic cabinet, obtained from parts suppliers such as RadioShack, may also be used.

The Parts List also suggests a miniature speaker that is capable of producing good quality audio when installed as directed. The audio-power amplifier used in the FM/TV Audio Receiver is capable of driving any 8-ohm speaker. You are certainly free to use a larger speaker—and larger enclosure to house it—if you so choose.

Choose a suitable location for the speaker. Drill a series of 1/16-inch diameter holes in a square pattern to form a grille in the front of the cabinet. Perfboard makes a nice template for that task. Construct a spacer from a piece of 1/16-inch-thick printed-circuit material, plastic, or aluminum to match the size and shape shown in Fig. 6. Glue the spacer to the inside of the cabinet with epoxy or other suitable adhesive; the result is an air gap between the speaker and grille. Once the adhesive has cured, the speaker may be glued in place in a similar manner.

Pick a spot for S1, R3, and R7 (if you want to use a panel-mounted volume control). The Parts List specifies a multi-turn tuning potentiometer for best resolution and performance. This unit is composed of two parts: the potentiometer itself and a shaft adapter that lets you attach a knob. An ordinary single-turn unit may be used if desired. Although the multi-turn potentiometer gives greater tuning resolution, it does not allow the attachment of a tuning dial. You can draw a simple dial for the single-turn potentiometer, but you'll sacrifice resolution for convenience.

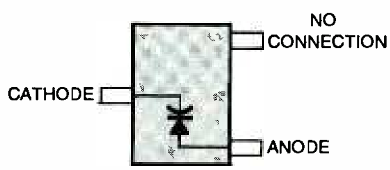


Fig. 5. Varactor diode D2, although a two-lead device, is housed in a three-lead package that makes it look like a surface-mount transistor.

Drill or cut out holes in the enclosure for those parts, taking note of the location of the printed circuit board and its components. One more hole, to be used for the antenna wire, must be drilled in the enclosure. This hole should be located near the antenna connection of the board as illustrated in Fig. 4.

If you wish, you may secure a small telescoping antenna to the side of the cabinet. The length of the antenna is not critical. For a ¼-wavelength antenna at the operating frequencies of the FM/TV Audio Receiver, you will need one that's about two to four feet, but the receiver will work with a shorter antenna.

When the cabinet has been properly assembled and wired in accordance with the schematic diagram, connect the battery clip to the circuit. Be sure to observe polarity of the battery clip wires. If in doubt, use a DC voltmeter and battery to verify polarity of the leads. Just because the battery-clip leads are red and black doesn't mean that the particular one you have is wired correctly!

Make the final connections to R3 and SPKR1 in accordance with Fig. 4. Be sure to wire R3 so that clockwise rotation causes the voltage at its wiper to decrease. This voltage drop will provide increasing received frequencies with clockwise rotation.

Before connecting B1 to the battery clip, check all wiring thoroughly to be sure that it is 100% correct. It is far easier to correct any problems at this time rather than later if you find that your receiver does not work.

Testing. Before applying power to the circuit, use an ohmmeter to measure the resistance across C21 to verify that there is no short circuit to ground on the power-supply line. Normal indication is 20,000 ohms or more. Turn S1 off and clip a fresh alkaline 9-volt battery onto the connector. Set the volume control halfway.

Turn the power on. Slowly rotate R3 until you hear audio. Note that IC1 has an automatic muting circuit; no sound will be heard until the circuit is tuned to a station. If you have chosen to build an FM-

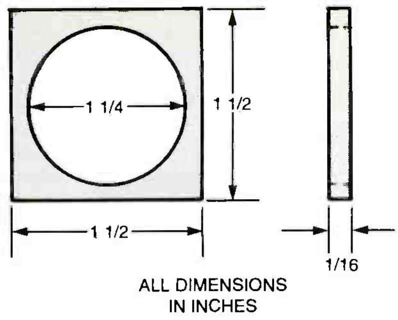


Fig. 6. This spacer will keep the speaker from touching the cabinet's grille.

band receiver, many radio stations will be heard. If you have built a TV receiver, only 2 stations, spaced far apart, may be picked up. Additionally, when the receiver is tuned past the video- or picture-carrier of a TV station, a hum or buzz will be heard. When the audio from a station is located, adjust the volume control as desired.

Once the identification of the received stations has been made, you will be able to determine the frequency range of your receiver by adjusting R3 over its entire range and noting what radio stations are heard. There are no other adjustments. The components specified in the Parts List and Table 1 should automatically tune your receiver to the desired frequency band.

At this time, you can experiment to determine the optimum antenna length. Generally, in strong signal areas, a short piece of wire will suffice. In remote areas, a longer antenna will provide better results.

If the receiver is working as described, the unit is ready for use. Otherwise, refer to the following hints to locate and correct any faults in the circuit.

Troubleshooting. If the loudspeaker is silent, set R7 halfway between its minimum and maximum rotation. Use a digital or analog voltmeter and check the voltage across B1 when the receiver is turned on; it should deliver at least eight volts to the circuit. Measure the current draw; normal indication is about 15 milliamps at low volume levels.

Try adjusting the tuning control over its entire range. The muting circuit of the receiver keeps the loudspeaker silent unless a radio station is tuned in.

Check all electrolytic capacitors, diodes, and ICs to be sure that they are properly oriented in the circuit. Check all other components for proper value. Verify that all of the specified grounded components are properly soldered to the top side (ground plane) of the board.

Placing a finger on pin 3 of IC2 should result in some buzz or hum in the speaker. If none is present, check C20 and the speaker connections. Try replacing IC2.

If the loudspeaker circuit is operational, measure the voltage at pin 2 of IC1. Normal indication is about 2 volts DC. Measure the voltage at pins 5, 13, and 14 of IC1. Normal indication is about 8 volts DC. Measure the voltage at pin 16 of IC1. Normal indication is zero volts. If incorrect voltages are encountered, disconnect power and visually inspect the wiring for opens, shorts, and bad solder connections. Check all components for proper values, especially L1 and L2.

A non-operational local oscillator can also cause an inoperative receiver. Thoroughly check L2, C17, R5, D1, and D2. Measure the voltage at the wiper of R3 to be sure that it varies when the tuning control is rotated.

With the FM/TV Audio Receiver at your side, you'll never miss another soap opera or episode of *Friends* again! **P**

PARTS LIST FOR THE FM/TV AUDIO RECEIVER

SEMICONDUCTORS

IC1—TDA7000N, FM receiver, integrated circuit (Philips)
IC2—LM386N-1 audio amplifier, integrated circuit
D1—1N5232B 5.6-volt Zener diode
D2—22-pf or 33-pF varactor diode (see Table 2)

RESISTORS

(All resistors are ¼-watt, 5% units unless otherwise noted.)
R1—22,000-ohm
R2—4700-ohm
R3—100,000-ohm potentiometer (Mouser 594-43P103 or similar—see text)
R4—22,000-ohm
R5—10,000-ohm
R6—100-ohm
R7—50,000-ohm potentiometer, printed-circuit or panel mount (see text)
R8—10-ohm

CAPACITORS

C1—220-pF, 50-WVDC polyester
C2, C8—330-pf, 50-WVDC polyester
C3, C9, C17, C19, C22—0.1-µF, ceramic-disc
C4—68-pF or 100-pF, NPO ceramic-disc (see Table 2)
C5—47-pF or 68-pF, NPO ceramic-disc (see Table 2)
C6, C14—150-pF, ceramic-disc
C7, C15—0.0033-µF, 50-WVDC, polyester
C10—0.0022-µF, 50-WVDC polyester
C11, C23—0.022-µF, 50-WVDC, metal-film
C12, C13, C16—0.01-µF, 50-WVDC, ceramic-disc
C18, C21—100-µF, 16-WVDC, electrolytic
C20—47-µF, 16-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS

B1—9-volt alkaline transistor-radio battery
L1—0.1-µH or 0.12-µH inductor (see Table 2)
L2—0.083-µH or 0.12-µH inductor (see Table 2)
S1—Single-pole, single-throw toggle or slide switch
SPKR1—8-ohm loudspeaker
Enclosure (Mouser 616-71980 or similar), adapter for R3 (Mouser 594-612 or similar—see text), 9-volt battery clip, tuning knob, optional earphone jack, wire hardware, etc.

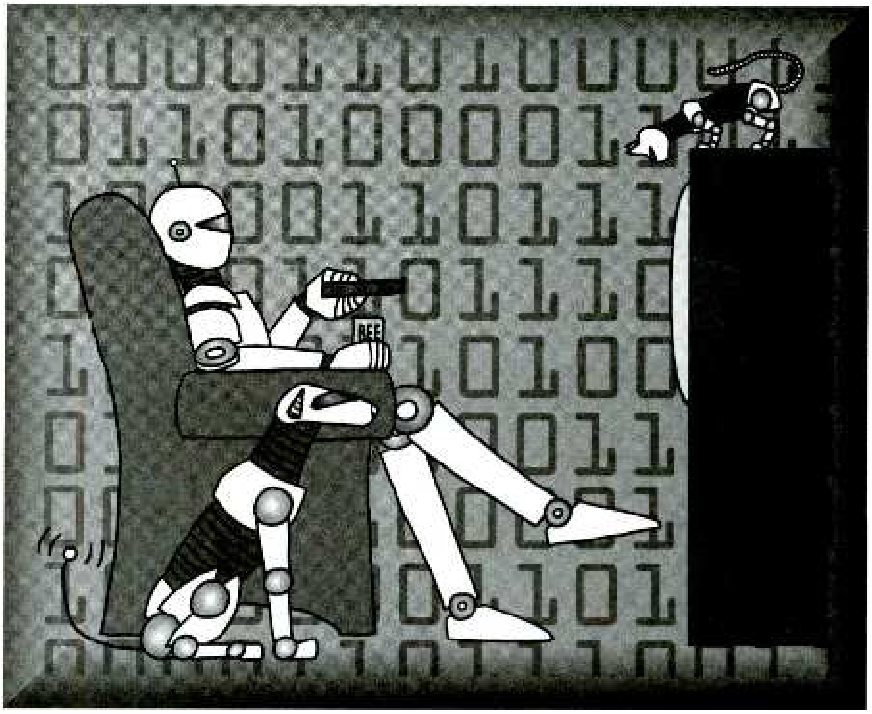
Note: The following parts are available from A. Caristi, 69 White Pond Rd., Waldwick, NJ 07463: Etched and drilled PC board, $15.75; IC1, $12.50; IC2, $3.00. Please add $5.00 postage/handling. NJ residents add 6% sales tax.

"That was the only way I could get it to scroll!"

Looking Ahead to DTV: Part 2

How digital television combines compressed video and audio signals and delivers them to a digital-ready television near you. Second of two parts.

GEOPHREY MCCOMIS



Last month, we looked at the mechanics of how digital television works, including how video (in a single high-definition format or several standard-definition channels) is compressed, squeezed, and otherwise mashed down to fit within a 6-MHz bandwidth. We also saw how the same techniques are able to supply home-theater-quality surround sound in a 5.1 format (four surround channels plus a center channel and subwoofer) with Dolby noise reduction to boot.

Now that we have the two major components of television (video and audio) digitized and compressed, let's see how we put them together. Be sure to have last month's issue handy; there will be occasional references to some of the charts and figures that were published in the first part of the article. To avoid confusion over which figure number belongs to which section, we're going to continue on with the numbering scheme as if this is one large book-length article.

Now that we have all of the disclaimers out of the way, let's plunge into this month's subjects. We'll start with...

The Service-Multiplex and Transport Subsystem. When you look back to Fig 1, the transport subsystem's primary function is obvious: it combines the elements from multiple programs with ancillary and control data to form a single transport stream. As with video, DTV transport streams conform to standards defined under MPEG-2 and constrained for DTV.

A very general summary of the transport subsystem might stop at that, but there are far more interesting issues that lurk just beneath the obvious.

Consider the synchronization of a program's audio and video. In analog-television systems, audio and video information is sent simultaneously and in real time—both are sent, received, and presented concurrently. A DTV program's audio and video are interspersed with other data, so even though the overall bit rate is constant, any one elementary stream appears in bursts in a fraction of the time required to decode and display it. Additionally, MPEG compression often results in frames being reordered for transmission, so there is no inherent synchronism between audio and video information.

For DTV, the secret to synchronism lies between the source and transport-encoding processes (Fig. 8). Elementary audio and video data are first grouped into *Packetized Elementary Stream* (PES) packets. PES packets are variable-length-data structures that tag audio and video frames with packet-start codes and various other header elements.

Among the PES header elements are two "time stamps:" the *Presentation Time Stamp* (PTS) and *Decode Time*

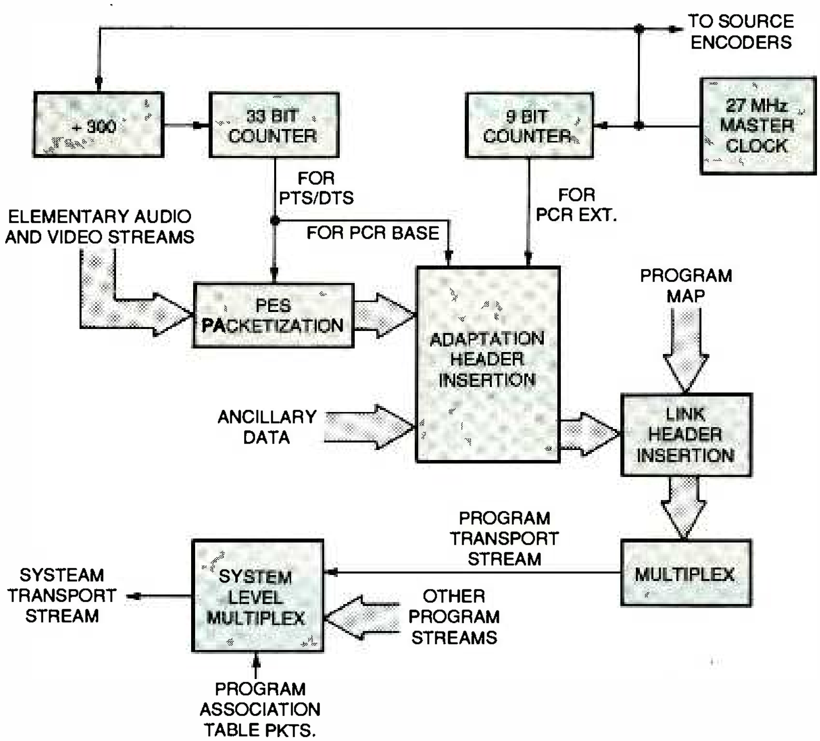


Fig. 8. Construction of DTV's transport streams is a fairly complex affair, involving multiple programs. All of the timing for the transport subsystem is based on a 27-MHz master clock. A 9-bit counter provides a high resolution snapshot of the time elapsed from packet to packet, while a phase-locked 90-kHz clock rate drives a 33-bit counter to place each packet within a large window of time.

Stamp (DTS). The Presentation Time Stamp indicates exactly when a given packet's contents should be presented. The Decode Time Stamp is included whenever frame reordering occurs; it notifies the decoder that the DTS-stamped packet will be required prior to its presentation time (usually in order to decode intervening B frames).

All of the timing for source encoding and decoding is based on a 27-MHz master clock. Both PTS and DTS values are snapshots of a 33-bit counter driven by a 90-kHz divided-down version of the master clock (Fig. 8). Thus, they provide accurate placement information within the overall context of a large window of time.

One step up from the PES level is the adaptation layer as shown in Figs. 8 and 9. Adaptation headers are variable in length—mandatory for audio and video and optional for other data. They exist primarily to facilitate the synchronization of program elements.

Chief among the adaptation header elements is the *Program-Clock Reference* (PCR). The PCR is comprised of two parts: the PCR base (taken from the same 33-bit counter used to generate time stamps) and the PCR extension (a sampling of a nine-bit counter driven directly by the master clock).

The master clock is also needed at the receiver to decode the incoming signal. The decoder generates a local representation of the master clock at the receiver, aligning it with the PCR embedded in the incoming bit stream. In this way, it establishes its own program clock, which becomes the reference for the presentation and decode times indicated by the incoming time stamps. That's how audio and video are synchronized.

The adaptation layer also provides indicators for random access and local program-insertion points.

Recall that once an MPEG decoder has acquired a given program stream, it must be initialized with an I frame. Thus, within a particular bit stream, the start of an I frame is a valid random entry point with respect to the video decoder. Such random entry points are flagged by the state of a special field in the adaptation header. This allows for faster redisplay when switching channels or programs.

And Now For a Word From Our Sponsor. Where would television be without commercials? Commercials are prominent examples of local programming. However, local program insertion might adversely affect the PCR and its representation at the receiver. Imagine, for example, that you have just enjoyed six minutes and twenty-seven seconds of your favorite TV drama; the current PCR and time stamp values will indicate "6:27:xxxxx." Then the local network affiliate cuts to five minutes of commercials. What happens to the time values? Must the PCR be yanked back to 0:00 at the start of each commercial, only to jump back to 6:28 when the program resumes? How might this affect decoder synchronization across brands of receivers?

The adaptation header's splice-countdown field embodies one attempt to provide respectable and consistent answers to those questions. During a normal program, it indicates the number of packets remaining before the occurrence of a splice point. During inserted programming, it reflects the anticipated time before resumption of the featured program.

The discontinuity indicator is another important adaptation-header field. It gives the decoder advance warning that the PCR is about to change (before the start of a new program, for instance).

While it is still up to the receiver to track a potentially shifting time base, the adaptation layer provides the additional support required to maintain reliable performance across the full spectrum of program insertion/change scenarios.

The link level is the final stage in the assembly of a transport packet. Link headers are fixed in length at

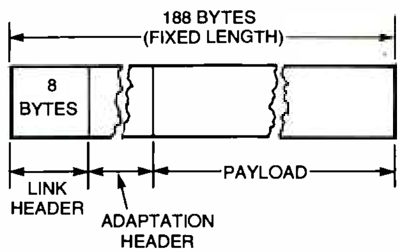


Fig. 9. Transport packets are the common currency of the transport subsystem. Most of the subsystem's per-program operations relate to the assembly of transport packets. System-level multiplexing amounts to shuffling them together, like cards.

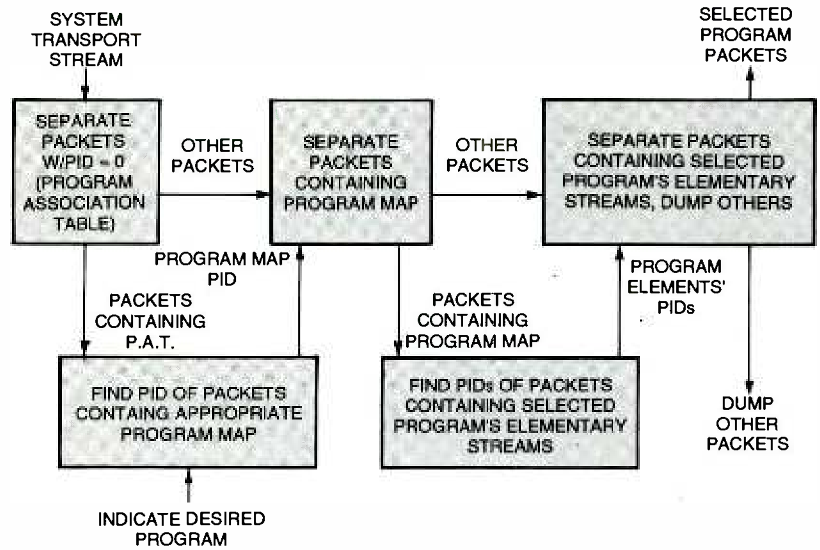


Fig. 10. De-multiplexing the system-transport stream is like a treasure hunt: several pointers must be followed to get to any single program's transport packets.

four bytes. As indicated in Fig. 9, the primary functions facilitated at the link level are packet synchronization and identification, error detection, and conditional-access notification.

The first eight bits of every packet are the link header's *sync byte*. Each sync byte carries the same value for all MPEG-2 bit streams. This allows ready detection and constant verification of the location of transport packet boundaries.

The *Packet-Identification* (PID) field occupies 13 bits in the center of the link header. Within a given system multiplex, packets that belong to any particular data stream carry a unique PID value. At the receiver, packets are ultimately sorted out according to their PIDs.

Two separate link-header fields provide error-handling utilities: the four-bit *continuity counter* and the one-bit *transport-packet-error indicator*. The latter is simply a flag that may be set by the modulator or demodulator to indicate that a given packet is known to be in error and should not be used.

The continuity counter confirms the delivery of successive packets of each payload-bearing PID. As the program stream is assembled within each set of packets for a particular PID, it cycles from zero through 15. So, for example, if one packet of PIDs carries a continuity-counter value of 7 and the next packet received for the same PID carries a value of 9, the decoder will recognize that data has been lost and should take steps to control the damage.

The DTV standard does not specify a particular method of encrypting data for conditional access (as with pay-per-view or premium services), but it does provide the means for program providers to do so. Link headers must be sent without encryption, but the balance of a transport packet could easily carry encrypted data. For this reason, the link header's transport-scrambling control identifies packets bearing scrambled payloads.

Transport packets are the common currency of the transport subsystem. They are fixed in length at 188 bytes and are easily multiplexed. Multiplexing at the program level is simply a matter of alternating a program's audio-, video-, and ancillary-transport packets. Together, they constitute a *program stream*. Multiplexing at the system level is more complex. Here, transport packets from multiple program streams must be interwoven. Still, transport packets will remain intact and will merely be placed end-to-end with packets of other programs' various elements. In that patchwork of program packets, each packet's PID identifies the program and element to which it belongs.

PID number zero is reserved for a special class of transport packets—those containing the program-association table for the system-level transport stream. The program association table is like a guidebook to the system stream. It identifies the stream's programs and the PID numbers that contain each program's program-map table. Each program-map table in turn identifies the PID numbers belonging to its associated program elements.

Figure 10 illustrates the process of unraveling the system-level transport stream to get at a particular program. First, packets whose PID is zero are gathered and interpreted to find the PID of the program map for the desired program. Those packets are then gathered and interpreted to find the PID numbers of

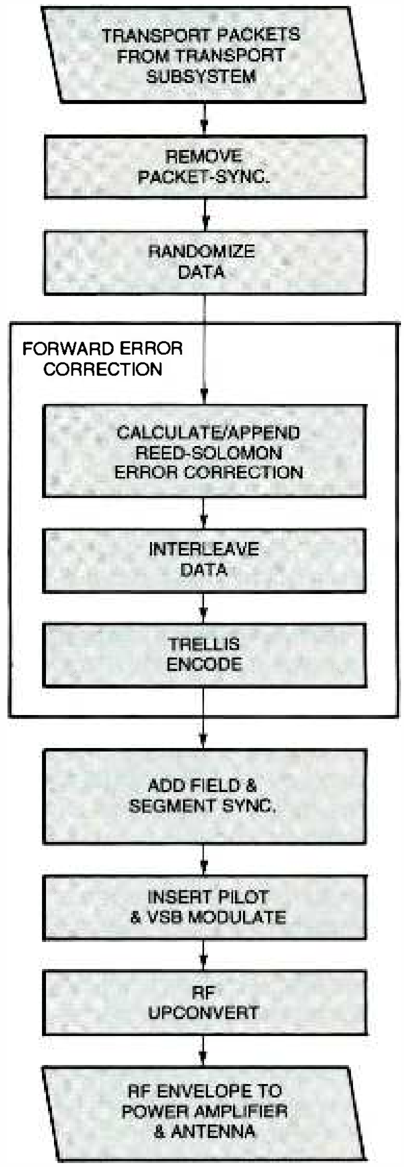


Fig. 11. Error correction is the central facet of DTV's terrestrial-transmission system.

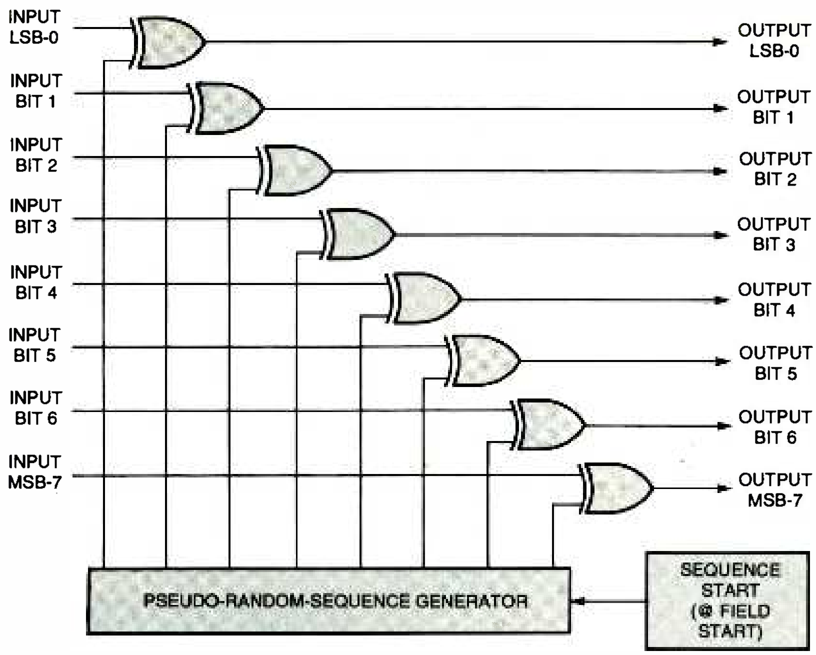


Fig. 12. The randomizer's XOR gates invert the information bits whenever a bit from the sequence generator is a one. In the receiver, the same sequence is XOR-ed with the randomized data, reversing the process.

the selected program's elementary streams, which in the end are separated for decoding, while the remainder of the system transport packets are ignored.

Program selection may be enhanced by the presence of a master-program guide. This is one ex-ample of an ancillary data type. While ancillary data may ultimately include anything from stock quotes to software, a unique PID (number 8189) has been reserved for it due to the program guide's essential role.

The RF/Transmission Subsystem. DTV's transport stream is already a complex entrée of digital information; serving it up over the open air is yet another challenge. This is the province of the RF/transmission subsystem. It reprocesses the contents of transport packets to blast them across the miles of noisy air, while maximizing the likelihood that they will emerge intact at their multiple destinations.

The ATSC standard actually describes two transmission modes: *8VSB* for terrestrial broadcast (open air) and *16VSB* for use in cable and other delivery systems in which high signal-to-noise ratios are easily maintained. VSB stands for *vestigial-side-band* modulation, in which either 8 or 16 discrete-amplitude levels are used to convey three or four bits at a time. While 8VSB uses robust-coding techniques to move 19.28 Mbps across a potentially noisy channel, 16VSB trades resilience for data-carrying capacity, delivering 38.57 Mbps. The balance of this article will focus on the 8VSB mode.

Figure 11 summarizes the progression of information through the terrestrial transmission subsystem.

First, transport packets are gathered and stripped of their sync bytes. These are unnecessary in transmission since the RF subsystem creates data frames of its own, and the positions of data from successive transport packets are clearly defined. Packet sync will be restored in the receiver, at the output of the RF stage.

Next, incoming data are randomized. Randomization gives each bit an equal chance of being a zero or a one, which optimizes the bit stream for the rest of the RF subsystem. Figure 12 shows how that is achieved. The start of every data frame triggers the start of an 8-bit pseudo-random sequence, which is XORed (EXCLUSIVE-ORed) with the incoming data bytes. The sequence appears to be random, but it actually emerges from a mathematical function that always yields the same result. Since the XORs invert the data bits any time a bit from the sequence generator is a one, the output data also appear to be random. In the receiver, the same sequence is XORed with the recovered randomized data, magically revealing the original.

Fixing Mistakes. *Forward-Error Correction* (FEC) refers to the addition of special error-correction data on the part of the sender in a one-way digital-communication system. A large part of the transmission subsystem is devoted to FEC. Without it, ATSC reception would falter due to interfering signals, multipath distortion, and adverse atmospheric conditions.

DTV employs three stages of FEC: Reed-Solomon coding, data interleaving, and trellis coding.

It's difficult to imagine how effective DTV's three-part FEC ensemble is. During evaluation while the system was in development, it was found that the threshold for the visibility of errors occurs at a signal-to-noise ratio (S/N) of 14.9 dB. From an analog perspective, this is astounding. It means that roughly one sixth of the signal voltage seen by the receiving system must be noise before any negative effects are observable.

Unfortunately, error correction can only forestall the inevitable. The slope of 8VSB-error probability as a function of S/N is so sharp that the system can't function as the S/N approaches 14 dB. This is the "brick-wall effect" often associated with DTV reception: you get either a perfect picture or no picture at all.

Reed-Solomon (RS) coding is no stranger to consumer electronics, since it's at the heart of the Compact Disc format. Though its mathematical underpinnings are inaccessible to most mortals, think of it as a sort of multi-dimensional parity. For every randomized packet (187 bytes), 20 RS parity bytes are calculated and tacked on. The parity bytes allow the reconstruction of up to ten corrupted bytes within a packet, even if some of the parity bytes are damaged. They are therefore very effective in the correction of random-bit errors.

To achieve partial immunity to longer-burst errors, the data are also interleaved. Interleaving refers to the systematic scrambling of bytes from adjacent packets. Figure 13

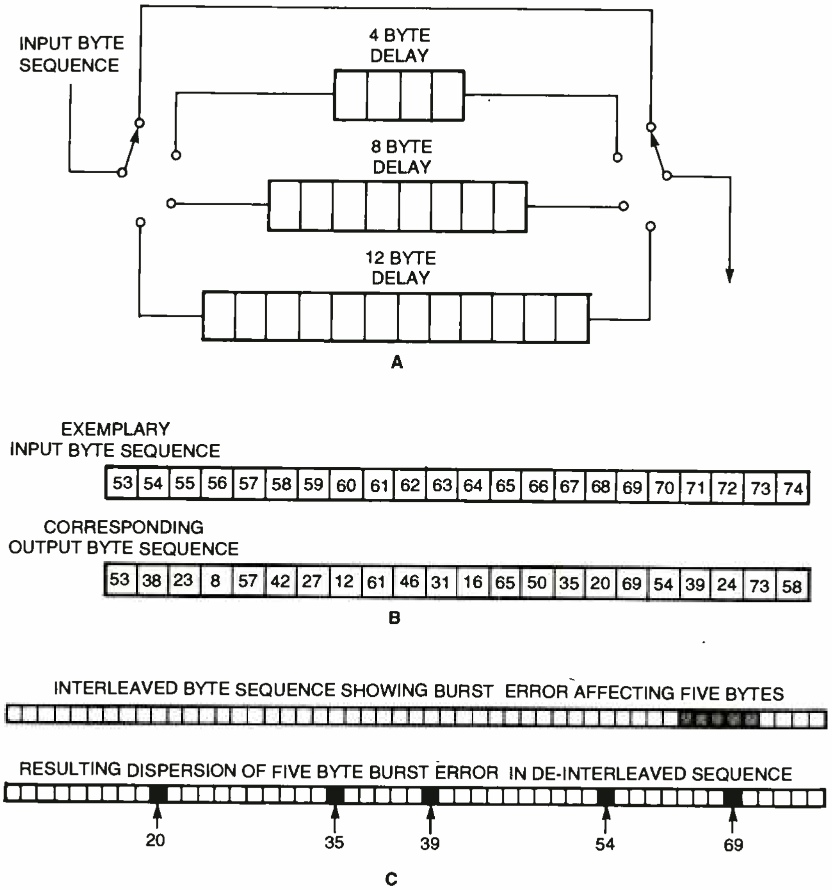


Fig. 13. From the receiver's viewpoint, interleaving causes burst errors to look like random bit errors.

provides an example of a simplified interleaver and shows how interleaving can distribute the effects of burst errors over a broad range of non-adjacent bytes. However, where the interleaver of Fig. 13 is comprised of only four stages with a maximum delay of 12 bytes, DTV's interleaver has 52 stages with a maximum delay of 204 bytes. The interleaving sequence is initialized at the start of every data field, resulting in the mixing of bytes over a range of 52 packets. When the data are "de-interleaved" in the receiver, burst errors are dispersed, affecting small portions of several packets rather than a large part of any one packet. This dispersion allows the use of RS parity to correct much larger errors than would otherwise be possible.

After interleaving, the data directly associated with any one packet are scrambled. When we look ahead to the structure of a VSB data frame, we see that interleaved data and RS parity bytes will be grouped into *segments.* One segment contains the data equivalent to 207 interleaved bytes, which is precisely the amount of data contained in one packet, plus its associated parity.

In the next and final stage of FEC, each interleaved byte (8 bits) will be converted to 12 *channel bits.*

Channel bits are the product of channel coding. The NATO alphabet—often heard in old war movies—provides a good example of channel coding. In a broken or noisy radio transmission, the sequence "Alpha-Bravo-Charlie" has a better chance of being correctly understood than simply "a-b-c," which could come out sounding like "a-e-e." Digital channel coding usually involves adapting a unit of data to a longer code word to enhance its intelligibility in a potentially noisy-transmission system.

Trellis Coding. Trellis codes belong to a family of channel codes that are called "convolutional." They are named after the appearance of the state diagrams that demonstrate their formation and decoding. Take a peek at Figs. 14 and 15—the diagrams look like trellises. They are considered convolutional, because at any point in time the output code word depends not only on the present input data, but also on the state of the encoder—a function of past input data.

Examine Fig. 14 more closely, and it's easy to see how trellis coding works. The encoder has four states, labeled "A" through "D." It

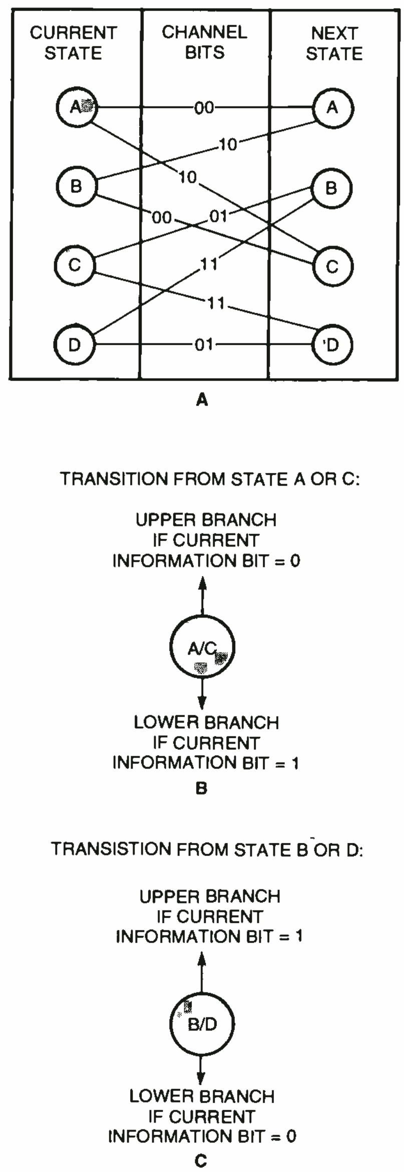


Fig. 14. At any moment, the trellis encoder exists at one of four states. As each information bit is received, the encoder outputs two channel bits and moves to the next state. The transition table and trellis diagram demonstrate the eight possibilities associated with the encoding of any information bit.

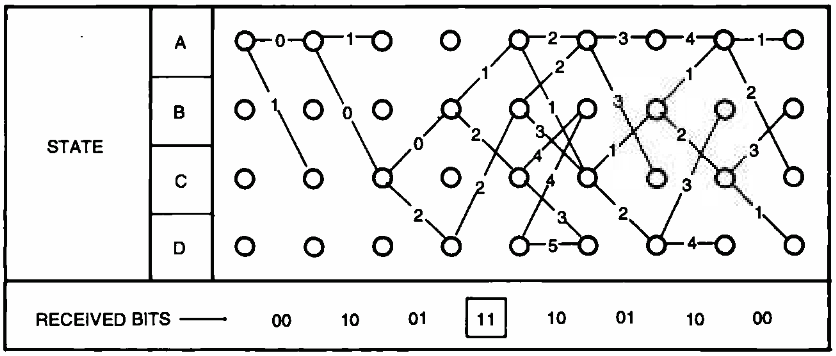


Fig. 15. Viterbi decoding is probabilistic. Each pair of received channel bits leads to a new vector in the trellis. The decoder compares all possible vectors with those suggested by the received data, and, over time, selects the path associated with the least number of errors (the most probable).

starts out at "A." As each bit enters the encoder, two channel bits emerge, and the encoder advances up or down to the next state—the example of Fig. 14 is a ½-*rate* code.

The most common method of unraveling trellis-encoded data has been named *Viterbi* decoding after its originator, Andrew Viterbi. For an example of how it works, consider Fig. 15. The initial state is assumed to be "A." The decoder receives the first pair of channel bits: 00. Check the transition table of Fig. 14, and you will see that 00 is a valid channel code from state "A." It is associated with a source bit of 0 and a transition back to state "A." That vector is traced in the decoder's memory with an indication to verify that no bit errors were received if the vector was the actual path intended in the original transmission.

The only other valid channel code from state "A" is 10. If 00 had been falsely detected in place of 10, then one bit would have been received in error. This possibility is also considered. The next two channel bits are 10, suggesting a valid source bit of 1 and a transition to state "C." Again, this vector and its single-error alternative are traced.

Skipping ahead to the fourth pair of received-channel bits, you will see something interesting. The current state is "B," and the received channel bits are 11. Although 11 is not a valid channel code from state "B," the decoder is not bothered by this. It simply traces the two possible vectors from state "B" and notes the number of requisite bit errors. The one-error vector would more likely be the intended path than the two-error vector, but the errors encountered at this point are carried through the next several nodes, and many possible paths are evaluated. As the decoding progresses, improbable paths are closed out and the path of least error emerges as the most likely. Viterbi decoding is probabilistic. It evaluates channel data and recommends the most probable source data.

There's an extra twist hidden in the trellis encoder. 8VSB uses a ½-

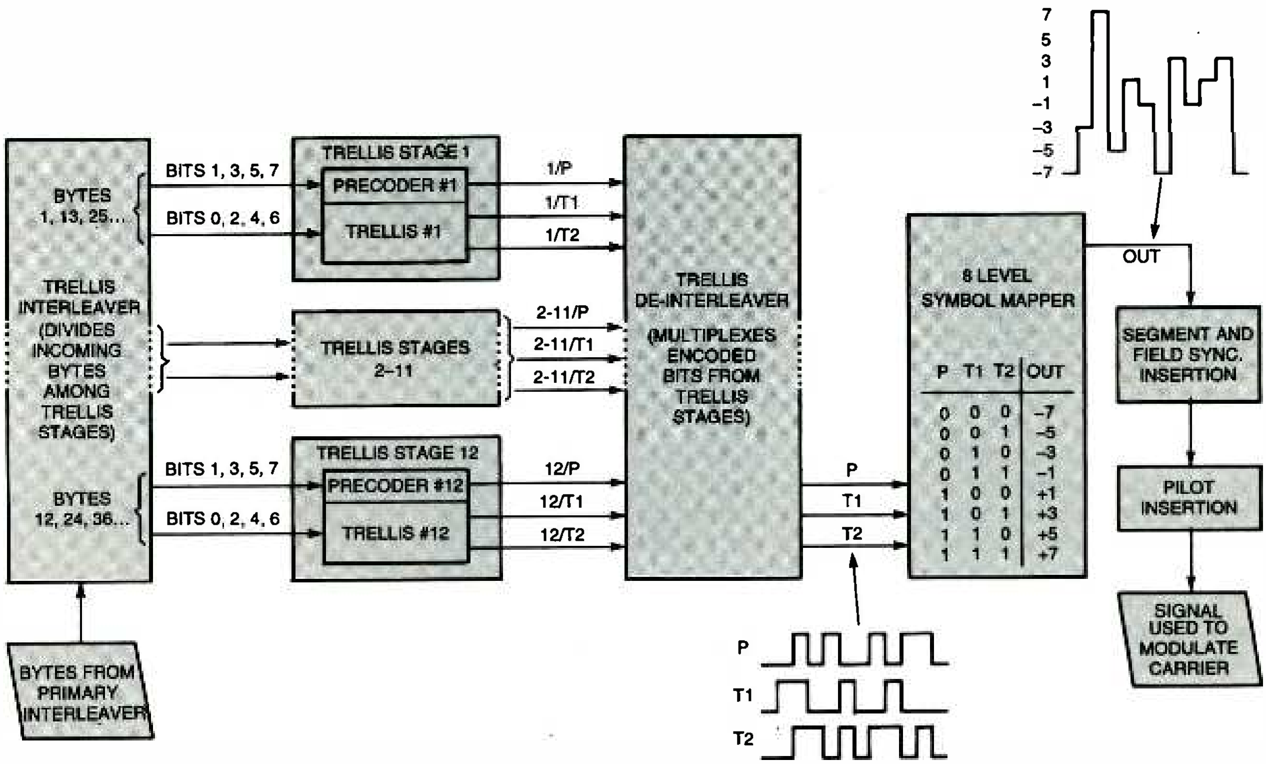


Fig. 16. DTV's trellis encoding approach is ingeniously wed to its 8VSB symbol mapping. Only half of the source bits are actually trellis encoded. The other bits determine the sign of the signal created by the symbol mapper (they are assigned the greatest bit weight), so they are least likely to be misinterpreted at the receiver.

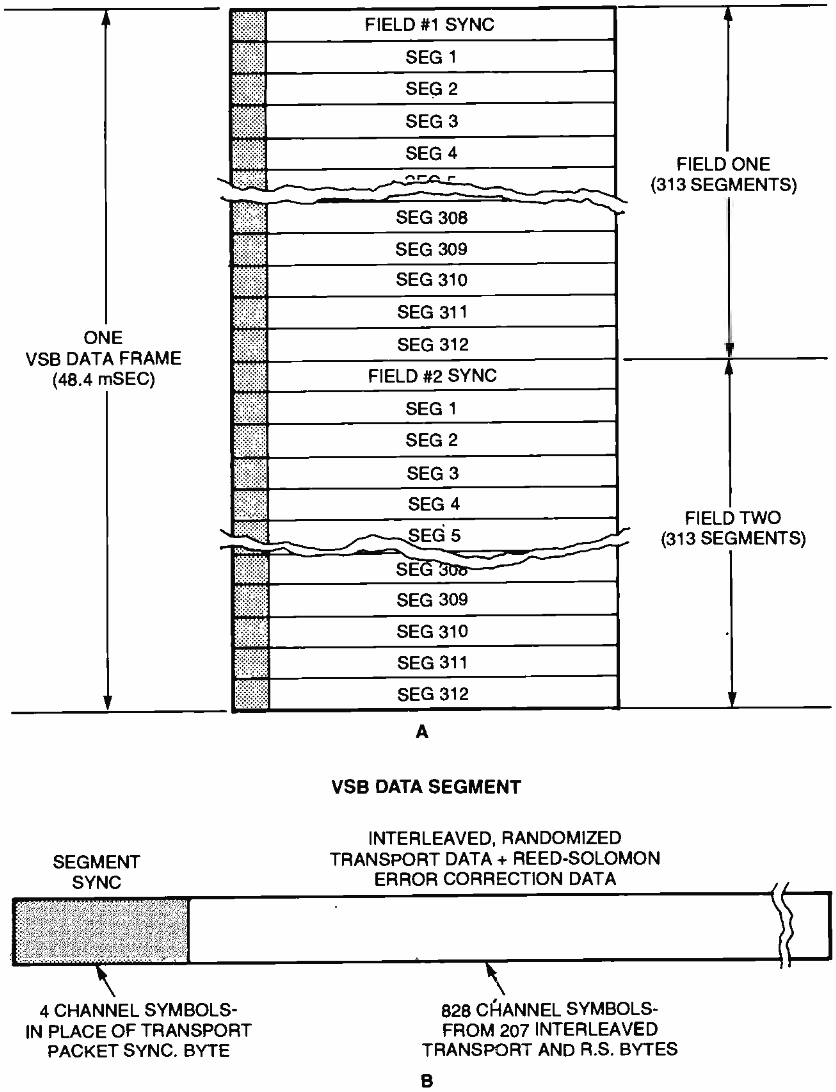


Fig. 17. ATSC transmissions have a framing structure reminiscent of analog video formats. Two fields, each comprised of 313 segments, make up a frame.

rate trellis code, yet its overall coding rate is 2/3. That's because only half of the source bits are trellis coded. As you can see in Fig. 16, at the threshold of the encoder, interleaved bytes pass through yet another interleaver. Unlike the primary interleaver, the second is merely a "traffic cop," directing the incoming bytes to one of 12 trellis stages. Each byte is split as it's fed to one of the 12 stages, and only its even bits (0,2,4,6) are trellis coded.

The odd bits pass through a *precoder*, which performs a simple operation. Starting with an output of zero, it generates a transition when its input is a one and holds its output state when its input is a zero. This treatment is easily undone at the receiver, and it produces a single bit for every bit processed.

The combination of a precoder and trellis coder forms a complete trellis stage. Each of the trellis stages generate three bits for every input pair, making up the overall 2/3 rate. The de-interleaver multiplexes the outputs of the 12 trellis stages into a single three-bit-wide data bus, completing the encoding process.

When you consider the symbol mapper, the elegance of the 2/3 approach becomes clear. The symbol mapper represents a trio of bits as one of eight discrete DC levels (a *symbol*), which will ultimately correspond to carrier-amplitude levels. From the chart on the symbol mapper in Fig. 16, note that the precoded bit determines the sign of the modulating DC level. It is unlikely that the receiver will confuse a positive for a negative level (or *vice versa*), except in the case of +1, and -1, at which point the two trellis-encoded bits are maximally differentiated (00 versus 11). Furthermore, instances of the same trellis-coded bits occurring on opposite sides of the polarity divide are always four levels apart (+1 and -7, +3 and -5, +5 and -3, +7 and -1). This highly efficient approach makes it possible to reap the benefits of trellis encoding, while only encoding half of the source data.

After symbol mapping is done, field- and segment-synchronization signals are added to the train of 8VSB channel symbols. They are binary for easy identification; and they toggle between high and low states, which correspond to 8VSB levels of +5 and -5. Fig. 17 details the positions of the sync signals in the overall framing structure.

Segment sync consists of the four-symbol pattern 1001. It is the only non-random repeating pattern in the transmission, occurring at regular 77.3 -microsecond intervals so it stands out clearly.

Field sync occupies a complete segment and occurs once in every 313 segments. Most of it consists of several repeating pseudo-random patterns, spanning 700 symbols. Of the remaining 128 symbols, 24 indicate the VSB mode of the transmission (currently either 8VSB or 16VSB). The balance is reserved, serving no defined purpose.

The combination of 8VSB channel symbols and sync patterns will be used to modulate the RF carrier, but not until a slight adjustment is made.

Pumping It Out. Any transmission system is most efficient if it fully utilizes all of its available bandwidth. DTV has been designed to use all of its 6-MHz channel bandwidth nearly all of the time. It is therefore said to be noise-like; when observing an ATSC channel over time, one finds an equal distribution of energy from upper to lower band edge—the defining characteristic of white noise.

DTV uses an amplitude-modulation format that takes advantage of a technique called *carrier suppression*. This eliminates AM's char

(Continued on page 67)

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Getting Inside an NCO

TOM NAPIER

Learn about numerically-controlled oscillators by building one.

One of the things that makes electronics fun is discovering the odd chips that have been developed to solve specific problems. I first heard of numerically-controlled oscillator (NCO) chips some ten years ago. If I hadn't, some of my designs, such as the VME bit synchronizer that I described in "Sifting Signals from Noise" (**Electronics Now**, April 1999), would not have been possible. Here, I'm going to explain how NCOs work and how you can learn about them by building one from a handful of TTL parts.

What Do NCOs Do? NCOs are very handy to have in your electronic "bag of tricks" once you understand their capabilities. For example, you can generate very pure and very accurate sinewaves anywhere from sub-audio frequencies to around 30 MHz with only a crystal oscillator, an NCO chip, a fast digital-to-analog converter (DAC), and a low-pass filter. The output can readily be phase- or frequency-modulated.

The frequency synthesizer in signal generators and in virtually every TV set and FM radio uses a voltage-controlled oscillator (VCO). Dividing its output down and then comparing it with a low-frequency reference sets its frequency. Any phase error between the divided frequency and the reference changes the voltage, which drives the oscillator. You change the output frequency by changing the division ratio. Unfortunately, the extent of the change is usually limited to about two-to-one by the varactor diode that tunes the LC oscillator. Since the rate at which the output frequency can change is limited by the bandwidth of the loop filter, a VCO can take tens of milliseconds to settle to a new frequency. Although that doesn't sound like much time, it does have an effect.

The NCO, as its name implies, uses a wide binary number to specify its output frequency. Consequently, an NCO's frequency can be set very accurately over a very wide range. Because the NCO is an open-loop device, its output frequency changes almost instantaneously. This makes the NCO ideal for generating FM- and frequency-shift-key (FSK)-modulated signals. Without NCOs, spread-spectrum transmitters and receivers would not be possible. As I'll explain, it's also easy to phase modulate the NCO's output.

The NCO is particularly easy to tune to a specific frequency since its output frequency is a linear function of the tuning number that you apply. Some NCO chips even accept a binary-coded-decimal (BCD) input and can be driven directly from front-panel thumb-wheel switches. The accuracy and stability of the output frequency is as good as that of the crystal oscillator that drives the NCO, and the output sinewave is free of harmonics. (It does contain traces of non-harmonically related "spurious" frequencies, which can be a nuisance in some applications.)

How Does An NCO Work? The NCO is based on a simple principle. If

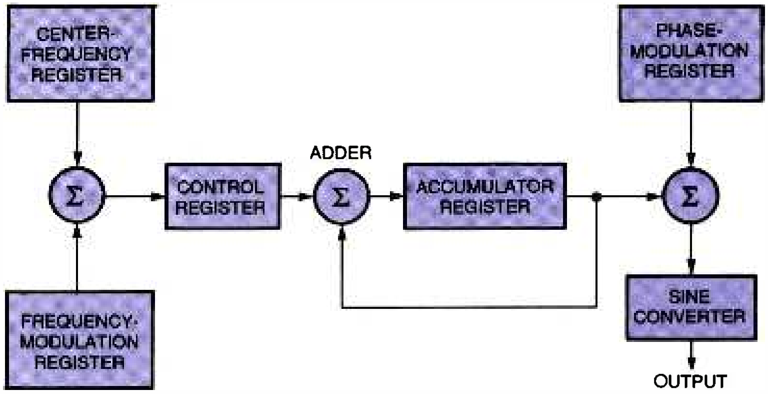

Fig. 1. A typical NCO chip contains circuits for phase- or frequency-modulation in addition to the basic phase accumulator and sine converter.

you keep adding the same number to a fixed-length binary register, the rate at which the register wraps around is a linear function of the number you add. Of course, it is also a function of how many times a second you add it.

Suppose you had a 16-bit register and an adder. Since any carries into the 17th bit are lost, any sum higher than 65,535 takes you back to the start. Because it takes 65,536 counts to loop around once, let's add a number to the register 65,536 times a second. If that number is 1, then every second you will have added it 65,536 times and the register will have wrapped around once. If you could connect a 16-bit digital-to-analog converter to the register, you would see an output voltage that would make 65,536 steps from zero to full-scale and then back to zero. It would repeat that ramp once per second.

Now add 2 every time. The ramp will go up in steps of two and repeat twice per second. If you added 1000 every time, the ramp would make 65 or 66 big steps. The wrap-around rate would now be 1 kHz even though the register wouldn't pass through the same steps each time. As you use bigger numbers, the shape of the ramp becomes more irregular, but its repetition rate is still exactly proportional to the number you add, if that number is less than about half the register size.

A ragged ramp might not look like a very useful output, but that's because we are not finished with it yet. Most NCO chips contain a sine-conversion section. This treats binary numbers as the phase of a sinewave and converts them into numbers that correspond to samples of a sinewave. When you put in a linear ramp, you get out numbers that, when converted to analog form, make a perfect sinewave. A complete NCO system consists of the digital NCO chip and a 12-bit DAC. The DAC generates a sinusoidal analog output from the numbers supplied by the NCO.

Of course, the sine output still has little steps in it. Since these occur at the NCO clock rate, they contain frequencies that are usually much higher than the desired output frequency. Filtering them out leaves a pure sinewave at exactly the specified frequency.

What's Inside An NCO Chip? A typical NCO chip is shown in Fig. 1. The register and adder are generally at least 32 bits wide; the registers of some chips go as high as 48 bits. The longer the register, the finer the frequency resolution. Only the top 14 or so register bits are connected to the sine look-up circuit. Additionally, not more than 12 bits are available to be connected to the DAC, mainly because fast DACs don't have more than 12 input bits.

The basic parts of the NCO are the frequency-control register, the adder register (often called the *phase accumulator*) and the sine converter. However, practical chips often contain other functions. For example, they might have two multiplexed frequency-control registers, allowing rapid FSK modulation by switching between them. Alternately, two frequency-control registers can be added together before being used. That allows one number to set the center frequency and a second number to apply frequency modulation. There is no discontinuity in the output sinewave when the frequency of an NCO changes. The new frequency starts at the phase and amplitude where the old one left off.

A number can also be added to the ramp from the phase accumulator before it is sine converted. This number changes the phase of the output signal, making it easy to apply phase modulation to the output. In an important special case, only the two most significant bits of the ramp are changed. This applies quadratic phase-shift modulation (QPSK) to the signal. QPSK is widely used for transmitting digital data, since two bits can be sent with each change of the carrier phase. Placing a multiplier chip between the NCO and the DAC allows the output to be amplitude modulated. Combining amplitude and phase modulation generates the QAM signals used in modems to transmit data down telephone lines.

What sets the output frequency? The output frequency of the NCO depends on three things:

- the accumulator width
- the update rate
- the size of the added number

The NCO's designer fixes the first, the clock that drives the NCO sets the second, and the user controls the third. A useful relationship between them is the frequency generated by one unit in the control number. This frequency is the resolution with which the output frequency can be set; it may be a tiny fraction of a Hz. The unit frequency is given by:

$$\text{clock frequency}/2^{\text{register width}}$$

If the clock frequency is 20 MHz and the register has 32 bits, the unit frequency is 20,000,000/4,294,967,296, or 0.0046566 Hz. With those constants, you can set any frequency you want from less than 1 Hz to over 5 MHz with an accuracy of better than 0.005 Hz.

If you wanted an output of 12,345 Hz, you would divide 12,345 by 0.0046566 and get a frequency set-

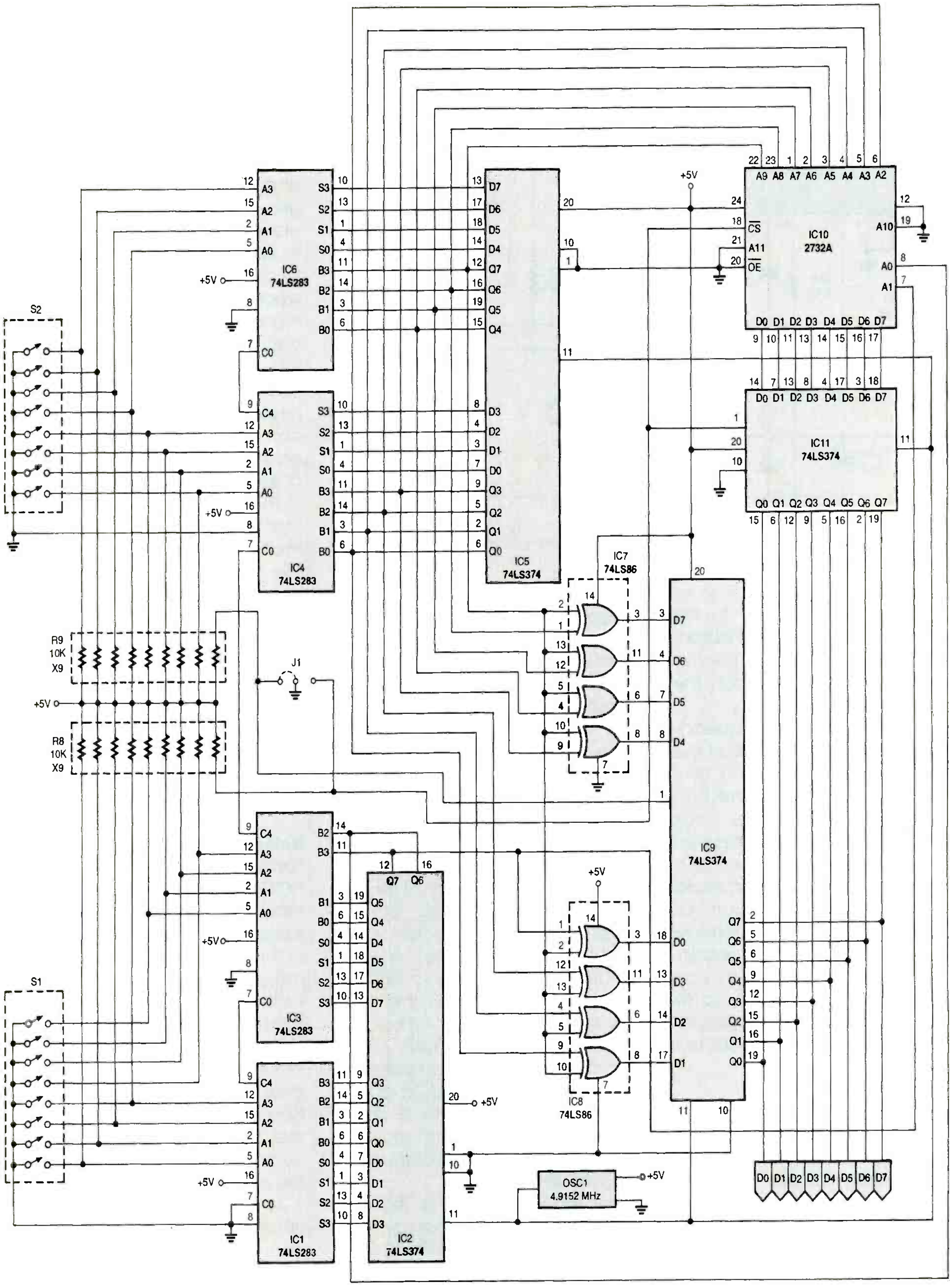

Fig. 2. The digital section of this NCO demonstrator uses registers, adders, and EXCLUSIVE-OR chips. The EPROM is only needed if you want to experiment with a sinewave output.

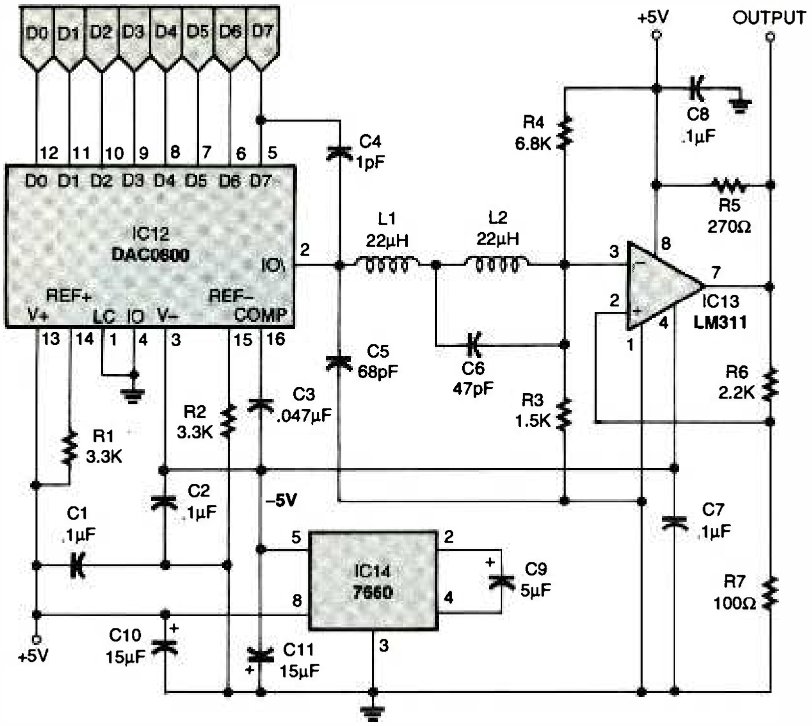

Fig. 3. This DAC, filter, and comparator circuit converts the ramp-up/ramp-down samples into a squarewave.

ting number of 2,651,068. In this case, the error in setting the output frequency is under 0.5 parts per million, probably much less than the error in the crystal frequency.

The practical upper frequency limit of an NCO is about 25% of the clock frequency. With careful filter design, that can be pushed to about 40%. What limits the clock frequency is how fast the chip can add wide numbers and how fast a DAC you can afford. Commercial NCO chips use tricks such as pipelining the addition to achieve clock rates in the 80-MHz region. With a fast enough DAC, they can generate sinewave outputs up to 30 MHz. Very expensive gallium-arsenide NCO chips run about ten times faster.

Why Filter? The filter on the output of the DAC is important because, by virtue of the steps generated by the DAC from each sample, the DAC output contains "image frequencies." The most bothersome of these is equal to the clock frequency minus the desired output frequency. The output also contains further images at these two frequencies summed with multiples of the clock frequency, but they are less important.

If you want an output of 10 MHz and your clock is 50 MHz, then there is an image frequency in the output at (50-10) or 40 MHz. The output filter must reduce the amplitude of that unwanted frequency to an insignificant level. This is not too hard, but as you increase the output frequency, the image frequency gets lower. At an output of 20 MHz, the image is at 30 MHz. You would need a rather sharp filter to get rid of it and still pass 20 MHz.

People often ask me, "Doesn't the filter need to be tuned to the output frequency?" The answer is "In theory, no. Its job is to filter out frequencies above half the clock rate, and that is fixed." In practice, if the clock rate is much higher than the highest output frequency you will ever use, it would pay to use a filter that cuts off just above your highest output frequency. This will give you a cleaner output with a simpler filter.

Choosing the filter is the one area of NCO design where you run into compromises. In general, sharp cut-off filters ring when you feed steps into them. This may not matter unless you phase modulate. Binary-phase modulation can cause full-scale steps in the sinewave output. A sharp cut-off filter will generate horrible spikes in the output waveform. It may be better to use a filter with a gentler roll-off and a better step response, although this limits the output frequency to a smaller fraction of the clock frequency.

Making Tunable Squarewaves. Oddly enough, a major use of NCOs is to generate accurate tunable squarewaves. The filtered sinewave is fed to a zero-biased comparator chip to make a jitter-free squarewave whose frequency can be set over many decades. In effect, the sine conversion and the filter interpolate between the fixed-time intervals set by the NCO clock. That makes a far more versatile and compact clock for a data-recovery system than the usual VCO and adjustable-divider circuits.

The problem with NCO chips is that not many companies make them, and you can't always get the combination of functions that you want. They also are not cheap—they range from about $15 to $150 each. Thus, users tend to look for alternative solutions. For example, it is quite easy to implement the phase-accumulator part of an NCO in a programmable logic chip; the sine-conversion part takes up space. That's what prompted me to find another way to interpolate the time intervals.

Doing Without Sine Conversion. Some years ago, I was using an NCO whose sine table was in an external PROM. This was a nuisance, so I looked for a way around it. The NCO's output was the raw ramp samples, but it could be switched to generate a ramp-up/ramp-down waveform. Suppose I fed that NCO output to the DAC? Provided that the sample rate is greater than four times the output frequency, there will always be a line between two adjacent DAC output levels that crosses zero at the same point in each cycle.

As it happened, I was rather familiar with linear-interpolation filters. Putting one of them on the DAC output generated a waveform whose zero crossings were exactly where the squarewave transitions should be. I tacked on a comparator chip and got squarewaves without using either

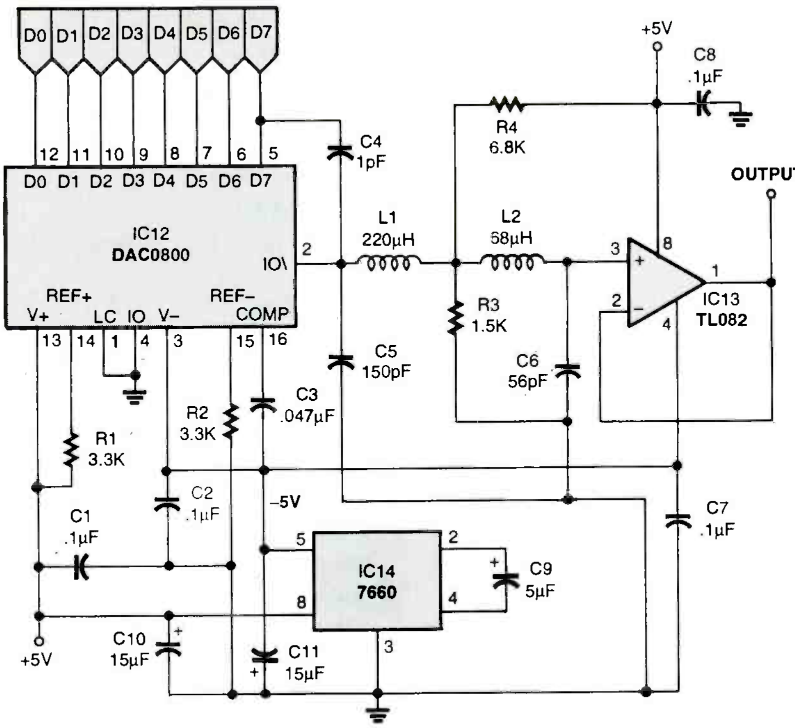

Fig. 4. Use this filter to get a sinewave output from the EPROM.

a sine convertor or a sharp cut-off filter.

This circuit gives perfect results up to 25% of the clock frequency. The squarewave doesn't become too jittery to be useful until you increase the output frequency beyond 35% of the clock, which is about where the conventional circuit also fails. The interpolation filter uses only two capacitors and two inductors, none of which is very critical. This circuit has another advantage: it can be easily built from TTL parts and standard inductors.

A Do-It-Yourself NCO. There are four ways to experiment with NCOs. You can buy an NCO chip and figure out how to drive it. If you have the tools, you can program an FPGA to emulate an NCO in hardware. You can even program a microcontroller to emulate a slow NCO in software.

However, while no one would want to use so much board space in a commercial design, the cheapest and easiest way to get started is to build an NCO from TTL parts. Figure 2 shows the digital section of a basic 16-bit NCO made from registers and adders. The EPROM and its output register (IC10 and IC11) are optional.

The 74LS283 four-bit adder chips (IC1, IC3, and IC4) and the 74LS374 8-bit registers (IC2 and IC5) form the basic phase accumulator. This is one application where the pinout of the 74LS374 is more convenient than the straight-across pinout of the 74LS574. All chips have 0.1-µF capacitors between their 5-volt lines and ground pins.

I used 8-bit DIP switches (S1 and S2) with 10k pull-up resistors (R10 and R11) for the frequency input. You might want to use a more sophisticated input such as register chips linked to a computer's parallel port. Commercial NCO chips often use a computer-compatible byte-wide input to load the frequency setting register a byte at a time.

The ramp from the accumulator is converted to a ramp-up/ramp-down waveform by two 74LS86 EXCLUSIVE-OR chips (IC7 and IC8). I reclocked their output with a further 74LS374 (IC9) for two reasons. One is that the DAC output has smaller glitches when all of the input bits change synchronously. The other is that by disabling the outputs of the LS374, you can connect other sources, such as a sine generator, to the DAC. You don't need to use LS parts; HC or HCT series chips will work as well and

PARTS LIST FOR THE NUMERICALLY-CONTROLLED OSCILLATOR

SEMICONDUCTORS

IC1, IC3, IC4, IC6—74LS283 4-bit adder, integrated circuit
IC2, IC5, IC9, IC11—74LS374 8-bit register, integrated circuit
IC7, IC8—74LS86 EXCLUSIVE-OR gate, integrated circuit
IC10—2732A 4-kB EPROM, integrated circuit (optional-see text)
IC12—DAC0800 8-bit digital-to-analog converter, integrated circuit
IC13—LM311 comparator or TL082 op-amp, integrated circuit (see text)
IC14—ICL7660 DC-DC converter, integrated circuit

RESISTORS

(All resistors are ¼-watt, 5% units unless otherwise noted.)
R1, R2—3300-ohm
R3—1500-ohm
R4—6800-ohm
R5—270-ohm
R6—2200-ohm
R7—100-ohm
R8, R9—10,000-ohm, 10-pin, single-inline package

CAPACITORS

C1, C2, C7, C8—0.1-µF, ceramic-disc
C3—0.047-µF, ceramic-disc
C4—1-pF (see text)
C5—68-pF or 150-pF, ceramic-disc (see text)
C6—56-pF or 47-pF, ceramic-disc (see text)
C9—5-µF, 16-WVDC, tantalum electrolytic
C10, C11—15-µF, 16-WVDC, tantalum electrolytic

ADDITIONAL PARTS AND MATERIALS

J1—Jumper block
S1, S2—Single-pole, single-throw, 8-device DIP-switch bank
OCC1—4.9152-MHz oscillator (Digi-Key CTX108-ND or similar)
L1—22-µH or 220-µH inductor (see text)
L2—68-µH or 22-µH inductor (see text)
IC sockets, wire-wrap board, wire-wrap wire, hardware, etc.

might be easier to find these days.

A 4.9152-MHz crystal oscillator (XTAL1) provides the clock. The adders can run at about three times that

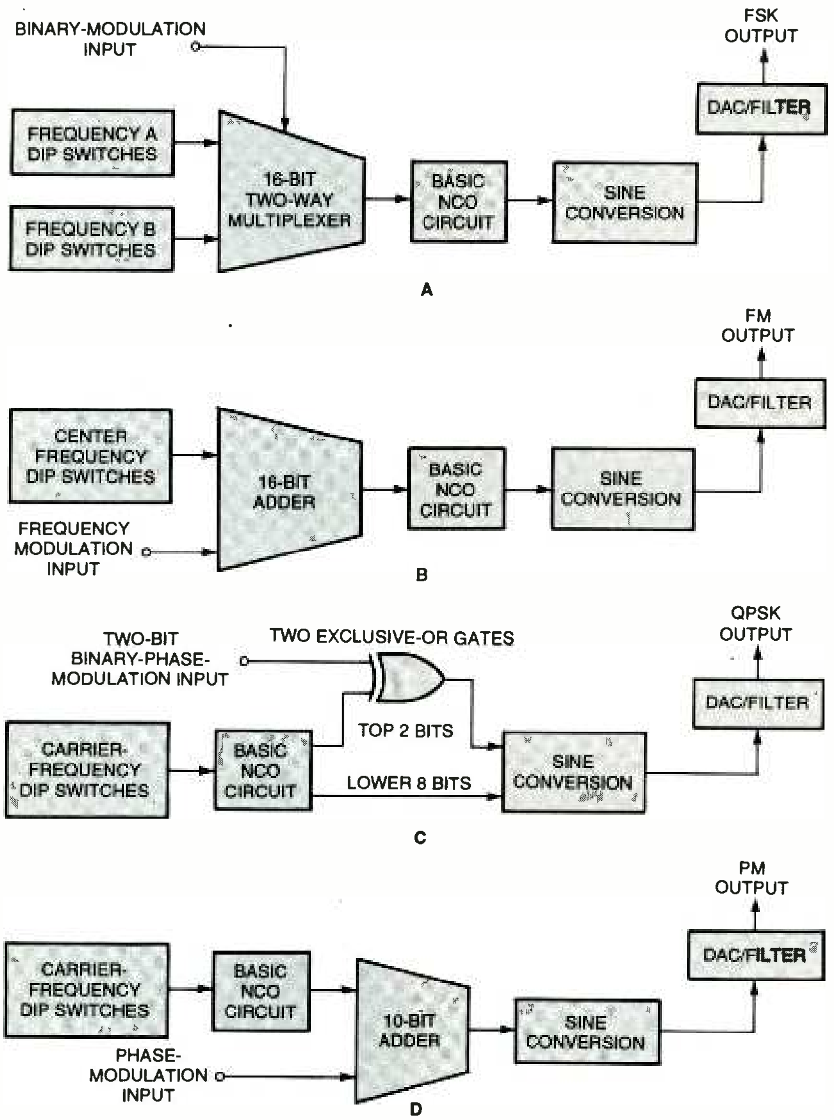

Fig. 5. These diagrams show additions to the basic NCO circuit for frequency-shift keying (A), frequency modulation (B), binary phase-shift keying (C), and phase modulation (D).

rate, but the DAC output gets messy if you go much faster. A 5-MHz speed is also about as fast as a sine-pattern look-up EPROM can run if you chose to add one.

This clock gives a unit frequency of 75 Hz so you can set any frequency which is a multiple of 75 Hz. The maximum useful output frequency is around 1.5 MHz. Using more adders and registers will improve the resolution by a factor of 16 per adder chip.

Figure 3 shows the DAC, filter, and the comparator circuit, which converts the ramp-up/ramp-down samples first into an analog ramp and then into a squarewave. Adjusting R4 can equalize the on-off ratio of the squarewave.

National Semiconductor's DAC0800 is a cheap ($2.20) 8-bit DAC chip that is just fast enough for this application. It does need a negative supply between –5 volts and –15 volts. I wanted to run this board off a single 5-volt supply, so I added an ICL7660 inverter chip (IC14) to supply a few milliamps at –5 volts. This rail also runs the LM311 comparator (IC13).

The filter shown here will interpolate linearly between samples that are 200 nS apart. If you change the clock frequency, you should change the inductance (L) and capacitance (C) values in proportion.

Since this circuit is only the start of an NCO-experimentation system, it pays to hook it up with wire-wrap sockets on a board with room for expansion. I wired the filter on top of a DIP socket so that I could unplug it and change things.

This was just as well since I found two problems. One was that the comparator output chattered at low-output frequencies; I had to add about 250 mV of hysteresis with R6 and R7. The other was that the "major-carry" glitch of the DAC0800 comes just at the point where you want the comparator to fire. Glitches can't be filtered out, but they can be cancelled. Capacitor C4 in Fig. 3 is about 1 pF. It consists of two pieces of wire-wrap wire twisted together for about an inch. It couples enough of the digital input into the analog output to minimize the effect of the glitch.

Makers of NCO chips

Intel Corp.
350 E. Plumeria Dr.
M/S XHP3-105
San Jose, CA 95134
408-545-9700
www.developer.intel.com/design/digital/

Intersil Corp.
2401 Palm Bay Rd.
Palm Bay, FL 32905
888-468-3774
321-724-7000
www.intersil.com

Analog Devices, Inc.
Box 9106
Norwood, MA 02062
781-329-4700
www.analog.com

Making Sinewaves. This circuit has a squarewave output. If you want a sinewave output; then, as shown in Fig. 2, you can wire in an EPROM that has been programmed to convert addresses to sinewave samples. The necessary code is available as an Intel hex file from the **Poptronics** FTP site (*www.gernsback.com/pub/pop/sinewave_pattern.hex*).

The sine table is only 1024 bytes long; which EPROM you use depends on what you can find and program, provided it has an access time of 200 nS or better. I used a 4-kB 2732A chip from an old computer board, but these are difficult to find now.

(Continued on page 67)

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GORDON MCCOMB

Working with Servomotors

The typical DC motor is inherently an "open-feedback" system—you give it juice and it spins. How much the motor spins is not always known, not even for a stepper motor, which turns by finite degrees based on the number of pulses it gets. Should something impede the rotation of the motor, it may not turn at all. There's no easy, built-in way that the control electronics would know that something is in the way.

Servomotors, on the other hand, are designed for "closed-feedback" systems. The output of the motor is coupled to a control circuit; as the motor turns, its speed and/or position are relayed to the control circuit. If the rotation of the motor is impeded for whatever reason, the feedback mechanism senses that the output of the motor is not yet in the desired location. The control circuit continues to correct the error until the motor finally reaches its proper point.

Servos come in various shapes and sizes. Some are smaller than a walnut, while others are large enough to take up their own seat in your car. You can find them in everything from the controls for computer-operated lathes to copy machines, model airplanes, and cars. Those last applications are the ones of most interest to the hobby-robot builders: the same servomotors used with model airplanes and cars can readily be used with your robot.

These servomotors are designed to be operated with a radio-controlled link and so are commonly referred to as radio-controlled (or R/C) servos. However, the servomotor itself is not what is radio-controlled; it merely connects to a radio receiver on the plane or car. You can control a servo with your PC or a microcontroller such as the Basic Stamp.

This month, we'll review what R/C servos are and how they can be put to use in a robot. We will limit the discussion to R/C servos. While there are other types of servomotors, the R/C type is commonly available and reasonably affordable. When you see the term servo in the text that follows, understand that, for simplicity's sake, it specifically means an R/C servomotor, even though there are other types.

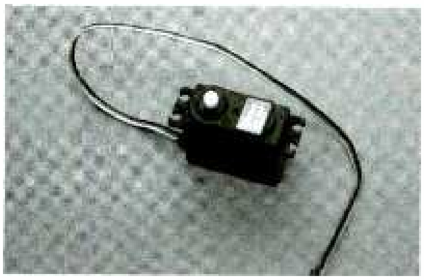

Fig. 1. A typical radio-controlled (R/C) servo motor.

How Servos Work

Figure 1 shows a typical standard-sized R/C servomotor, which is used with flyable model airplanes and model racing cars. The size and mounting of a standard servo is the same regardless of the manufacturer, which means that you have your pick of a variety of makers.

Inside the servo is a motor, a series of gears to reduce the speed of the motor, a control board, and a potentiometer. The motor, potentiometer, and control board connect together to form a closed-feedback loop. A constant DC voltage (usually between 4.8 and 7.2 volts) powers both control board and motor. To turn the motor, the control board sends out a digital signal. That signal activates the motor, which, through a series of gears, turns the potentiometer. The position of the potentiometer's shaft indicates the position of the output shaft of the servo. When the potentiometer has reached the desired position, the control board shuts down the motor.

As you can surmise, servomotors are designed for limited rotation rather than for continuous rotation like a DC or stepper motor. While it is possible to modify an R/C servo to rotate continuously, the primary use of the R/C servo is to achieve accurate rotational positioning over a range of 90° or 180°. While this may not sound like much, in actuality such control can be used to steer a robot, move legs up and down, rotate a sensor to scan the room, and more. The precise angular rotation of a servo in response to a specific digital signal has enormous uses in all fields of robotics.

Positioning the motor shaft of an R/C servo uses a technique called pulse-width modulation (PWM). In that system, the servo responds to the duration of a steady stream of digital pulses. Specifically, the control board responds to a digital signal whose pulses vary from about one millisecond (one thousandth of a second, or mS) to about two mS. Those pulses are sent some 50 times per second. The exact length of the pulse, in fractions of a millisecond, determines the position of the servo. Note that it is not the number of pulses per second that controls the servo, but the duration of the pulses, that matters. The servo requires about 30 to 60 of those pulses every second. This is referred to as the

Table 1
Typical Servo Specifications

Servo Type	Length	Width	Height	Weight	Torque	Transit time
Standard	1.6 in.	0.8 in.	1.4 in.	1.3 oz	42 oz-in	0.23 sec/60°
¼-scale	2.3 in.	1.1 in.	2.0 in.	3.4 oz	130 oz-in	0.21 sec/60°
Mini-micro	0.85 in.	0.4 in.	0.8 in.	0.3 oz	15 oz-in	0.11 sec/60°
Low profile	1.6 in.	0.8 in.	1.0 in.	1.6 oz	60 oz-in.	0.16 sec/60°
Small Sail winch	1.8 in.	1.0 in.	1.7 in.	2.9 oz	135 oz-in	0.16 sec/60° (1 sec/360°)
Large Sail winch	2.3 in.	1.1 in.	2.0 in.	3.8 oz	195 oz-in	0.22 sec/60° (1.3 sec/360°)

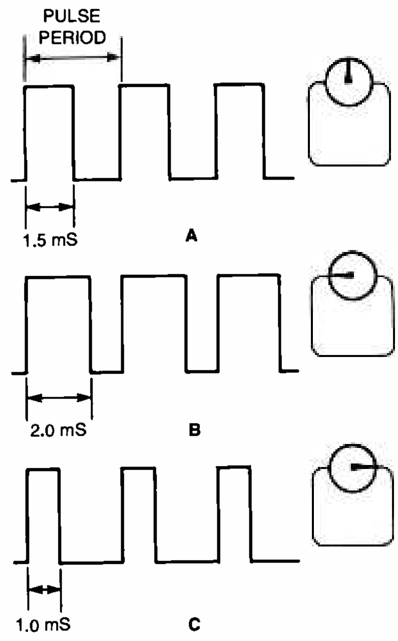

Fig. 2. Pulse-width modulation controls the position of the output shaft of the servo motor.

refresh rate; if the refresh rate is too low, the accuracy and holding power of the servo is reduced.

At a duration of one mS, the servo is commanded to turn all the way in one direction (let's say counterclockwise, as shown in Fig. 2C). At two mS, the servo is commanded to turn all the way in the other direction. Therefore, the 1.5-mS length sets the servo to its center (or neutral) position.

The power delivered to the motor inside the servo is also proportional to the difference between where the output shaft is and where it's supposed to be. If the servo has only a little way to move to its new location, then the motor is driven at a low speed. This ensures that the motor doesn't "overshoot" its intended position. But if the servo has a long way to move to its new location, then the motor's driven at full speed in order to get it there as fast as possible. As the output of the servo approaches its desired new position, the motor slows. What seems like a complicated process actually happens in a very short period—the average servo can rotate a full 60° in a quarter- to half-second.

The actual length of the pulses varies between servo brands and sometimes even between different models by the same manufacturer. The 1- to 2-mS range is typical but is by no means set in stone. When you are purchasing a servo for a model airplane or car, you should typically mate it with a radio receiver made by the same company to ensure compatibility. Since you're not likely to use a radio receiver with the R/C servos in your robot, you'll need to do some experimenting to find the best pulse-width ranges for the servos you use. This is just part of what makes robot experimenting so much fun!

Servos also vary by the amount of rotation they will perform for the 1- to 2-mS (or whatever) signal. Most standard servos are designed to rotate back and forth by 90° to 180°, given the full range of timing pulses. You'll find the majority of servos will be able to turn a full (or very near) 180°.

Should you attempt to command a servo beyond its mechanical limits, the output shaft of the motor will hit an internal stop. This causes the gears of the servo to grind or chatter. If left this way for more than a few seconds, the gears of the motor may be permanently damaged. Therefore, when experimenting with servomotors, exercise care to avoid pushing them beyond their natural limits.

While the standard-sized servo is the one most commonly used in both robotics and radio-controlled models, other R/C servo types, styles, and sizes exist as well. Examples include:

- *Quarter-scale (or large-scale) servos*—These are about twice the size of standard servos and are significantly more powerful. Quarter-scale servos are designed for large model airplanes, but they also make perfect power motors for a robot.

- *Mini-micro servos*—About half the size (and smaller!) of standard servos, mini-micro servos are designed to be used in tight spaces in a model airplane or car. They aren't as strong as standard servos, however.

- *Sail-winch servos*—Designed with maximum strength in mind, these are primarily intended to move the jib and mainsail sheets on a model sailboat.

- *Landing-gear-retraction servos*—To retract the landing gear of medium- and large-sized model airplanes, you would use this type of servo. The design of the landing gear often requires the servo to guarantee at least 170° rotation, if not more (i.e., up to and exceeding 360° of motion). Retraction servos tend to have slimmer profiles than the standard variety because of the limited space on model airplanes.

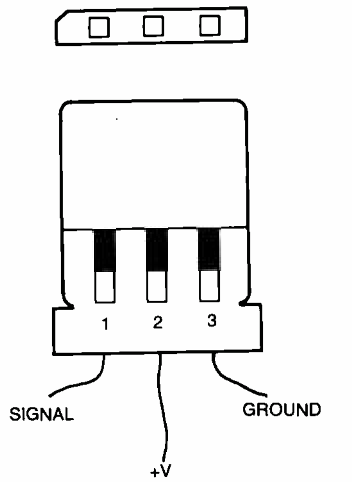

Fig. 3. The standard pinout of servos is pin 1 for signal, pin 2 for +V, and pin 3 for ground. In this configuration, damage will not usually occur if you accidentally reverse the connector.

Typical Servo Specifications

R/C servomotors enjoy some standardization. This sameness applies primarily to standard-sized servos, which measure approximately 1.6 inches by 0.8 inch by 1.4 inches. For other servo types, the size varies somewhat between makers, as these are designed for specialized tasks.

Table 1 outlines typical specifications for several types of servos, including dimensions, weight, torque, and transit time. Of course, except for the size of standard servos, these specifications can vary between brand and model. A few of the terms used in the specs require extra discussion; let's start with torque. The torque of the motor is the amount of force it exerts. The standard torque unit

Table 2
Connector Pinouts Of Popular Servo Brands

Brand	Pin 1 (Left)	Pin 2 (Center)	Pin 3 (Right)
"New" Airtronics	Signal	+V	Gnd
"Old" Airtronics	Signal	Gnd	+V
Futaba	Signal	+V	Gnd
Hitec	Signal	+V	Gnd
JR	Signal	+V	Gnd

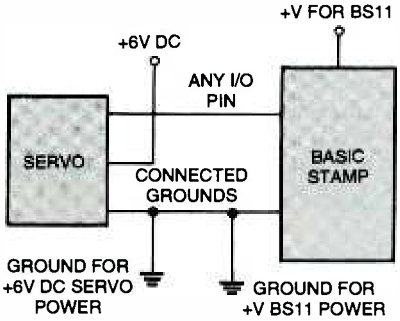

Fig. 4. Hookup diagram for connecting a servo to a Basic Stamp II.

of measure for R/C servos is expressed in ounce-inches—or the number of ounces the servo can lift when the weight is extended one inch from the shaft of the motor. Servos exhibit very high torque thanks to their speed-reduction gear trains.

The transit time (also called slew rate) is the approximate time it takes for the servo to rotate the shaft X° (usually specified as 60°). Small servos turn at about a quarter of a second per 60°, while larger servos tend to be a bit slower. The faster the transit time, the "faster acting" the servo will be.

You can calculate equivalent RPM by multiplying the 60° transit time by 6 (to get full 360° rotation), and then dividing the result into 60. For example, if a servomotor has a 60° transit time of 0.20 seconds, that's one revolution in 1.2 seconds (0.2 × 6=1.2), or 50 RPM (60/1.2=50).

Bear in mind that there are variations on the standard themes for all R/C servo classes. For example, standard servos are available in the more expensive high-speed and high-torque versions. Servo manufacturers list the specifications for each model, so you can compare and make the best choice based on your particular needs.

Many R/C servos are designed for use in special applications, and these applications can be adapted to robots. For example, a servo engineered for a model sailboat will be water resistant and therefore useful on a robot that works in or around water.

While many aspects of servos are standardized, there is great variety in the shape and electrical contacts of the connectors used to attach the servo to a receiver from one manufacturer to another. There are three primary connector types found on R/C servos: the "J" or Futaba style, the "A" or Airtronics style, and the "S" or Hitec/JR style.

The physical shape of the connector is just one consideration. The wiring of the connectors (called the pinout) is also critical. Fortunately, all but the "old-style" Airtronics servos (and the occasional oddball four-wire servo) use the same pinout, as shown in Fig. 3. With very few exceptions, R/C servo connectors use three wires, providing DC power, ground, and signal (or control). Table 2 lists the pinouts for several popular brands of servos.

Most servos use color coding to indicate the function of each connection wire, but the actual colors used for the wires vary between servo makers. Table 3 lists the most common colors used in several popular brands.

Controlling a Servo

Unlike a DC motor, which runs if you simply attach battery power to its leads, a servomotor requires proper interface electronics in order to rotate its output shaft. While the need for interface electronics may somewhat complicate your use of servos, the electronics are actually rather simple. Moreover, if you plan to operate your servos with a PC or microcontroller (such as the Basic Stamp), all you need for the job is a few lines of software.

A DC motor typically needs power transistors, MOSFETs, or relays for computer control. A servo on the other hand can be directly coupled to a PC or microcontroller with no additional electronics. Saving you the hassle, the control board in the servo takes care of all of the power-handling needs. This is one of the main benefits of using servos with computer-controlled robots.

The Basic Stamp II is a popular microcontroller used to interface with various robotic parts, including servos. The Stamp can directly control one or more servos. However, the more servos being controlled, the more processing time is required to send pulses to each one (without resorting to some higher-level programming, which we'll leave to the Stamp-specific books).

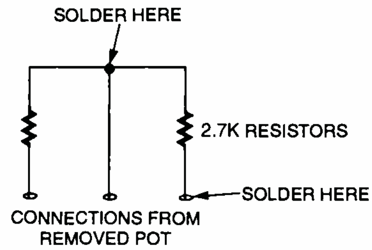

Fig. 5. To modify a servo, you must replace the internal potentiometer with two 2.7K resistors, wired as shown here.

Figure 4 shows the hookup diagram for connecting a standard servo to the Basic Stamp II. Note that the power to the servo does not come from the Basic Stamp II or any prototyping board that it's on. Servos require more current than the Stamp provides. A pack of four AA batteries is sufficient to power the servo. For proper operation, ensure that the grounds are connected between the Stamp and the battery pack. Use a 33- to 47-µF capacitor between +V and ground of the AA-battery pack to help kill any noise that may be induced into the electronics when the servo turns on and off.

Software for operating the servo can be found on the Basic Stamp Web page at *www.parallaxinc.com*, among other sources.

R/C receivers are designed with a maximum of eight servos in mind. The receiver gets a digital pulse train from the transmitter, beginning with a long sync pulse, followed by as many as eight servo pulses. Sending pulses to a series of servos can consume all the computational time of the typical microcon-

Table 3
Color Coding Of Popular Servo Brands

Servo	+V	Gnd	Signal
Airtronics	Red	Black	White
	Red stripe	Blue	White
	Brown	Blue	White
Cirrus	Red	Brown	Orange
Daehwah	Red	Black	White
Fleet	Red	Black	White
Futaba	Red	Black	White
Hitec	Red	Black	Yellow
JR	Red	Brown	Orange
KO	Red	Black	Blue
Kraft	Red (4.8 v)	Black	Orange
	White (2.4 v)	Black	Yellow
Sanwa	Red stripe	Black (in center)	Black

troller (Basic Stamp, BasicX, OOPic, etc.), leaving little or no "spare" time for other robotic functions. A dedicated servo controller, available from a number of sources, including Scott Edwards Electronics and NetMedia, off-loads the servo control task allowing the microcontroller to concentrate on other things. Dedicated servo controllers can operate five, eight, or even more servos autonomously, which reduces the program overhead of the microcontroller or computer you are using.

The main benefit of dedicated servo controllers is the ability to control a great number of servos simultaneously, even if your computer, microcontroller, or other circuitry is not multitasking.

Modifying a Servo for Continuous Rotation

Many brands and models of R/C servos are readily modifiable for continuous rotation like a regular DC motor. Such modified servos make great drive motors for your robot. Modified servos can be easier to use than regular DC motors since they already have the power-drive electronics built in; they come already geared down; and they are easy to mount on your robot.

Servo modification varies somewhat between makes and models, but the basic steps are the same:

- Remove the case of the servo to expose the gear train, motor, and potentiometer. Remove the four screws on the back of the servo case and separate the top and bottom.

- File or cut off the nub on the underside of the output gear that prevents full rotation. This typically means removing one or more gears, so don't lose any parts. If necessary, make a drawing of the gear layout so you can replace things in their proper location!

- Remove the potentiometer and replace it with two 2.7K, 1% tolerance ("precision") resistors, wired as shown in Fig. 5. That fools the servo into thinking that it's always in the "center" position. An even better approach is to relocate the potentiometer to the outside of the servo case, so that you can fine-tune adjustments to the center position. Alternatively, you can attach a new 5K or 10K potentiometer to the circuit board outside the servo.

On the Web

Dedicated Servo Controllers

FerretTronics
www.ferrettronics.com

Scott Edwards Electronics
www.seetron.com

Selected Microcontrollers for Amateur Robotics
Basic Stamp
www.parallaxinc.com

BasicX
www.basicx.com

OOPic
www.oopic.com

Servos and Amateur Robots
www.robotoid.com/
www.seattlerobotics.org/guide/servohack.html

NetMedia
www.web-hobbies.com

- Reassemble the case.

Specific instructions for modifying servos can be found at *www.seattlerobotics.org/guide/servohack.html.*

Attaching Servos to Wheels and Robots

Servos reengineered for full rotation are most often used for robot locomotion and are outfitted with wheels. Since servos are best suited for small- to medium-sized robots (under about three pounds), the wheels for the robot should ideally be between two and five inches in diameter. Larger-diameter wheels make the robot travel faster, but they can weigh more. You won't want extra-large 7- or 10-inch wheels on your robot if each wheel weighs 1.5 pounds; that's the three-pound practical limit right there.

The general approach for attaching wheels to servos is to use the round control disc that comes with the servo. The underside of the disc fits snugly over the output shaft of the servo. You can glue or screw the wheel to the front of the disc. Here are some ideas in that department:

- Large LEGO "balloon" tires have a recessed hub that exactly fits the control disc included with Hitec and many other servos. You can simply glue the disc into the rim of the tire.

- Lightweight foam tires, popular with model airplanes, can be glued or screwed to the control disc. The tires are available in a variety of diameters. If you wish, you can grind down the hub of the tire so it fits smoothly against the control disc.

- A gear glued or screwed into a control disc can be used as an ersatz wheel or as a gear that drives a wheel mounted on another shaft.

In all of those cases, it's important to maintain access to the screw used to secure the control disc to the servo. When you are attaching a wheel or tire, be sure not to block the screw hole. If necessary, insert the screw into the control disc first, and then glue or otherwise attach the tire. Make sure that the hub of the wheel is large enough to accept the diameter of your screwdriver, so you can tighten the screw over the output shaft of the servo.

Servos should be securely mounted to the robot so that the motors don't fall off while the robot is in motion. In my experience, attaching servos with duct tape, electrical tape, and hook-and loop (Velcro) leaves much to be desired because of sticky residue and the inability to accurately align the motors.

Gluing is a quick and easy way to mount servos on most any robot-body material, including heavy cardboard and plastic. Use only strong glue, such as two-part epoxy or hot-melt glue. I prefer hot-melt glue because it doesn't emit the fumes that epoxy does, and it sets much faster (about a minute in normal room temperatures versus a minimum of five minutes for fast-setting epoxy).

Another option is the servo mounts included in many R/C radio transmitters and separately available servo sets. You can also buy them separately from the better-stocked hobby stores. The servo mount has space for one, two, or three servos. The mount has additional mounting holes that you can use to secure it to the side or bottom of your robot. Most servo mounts are made of plastic, so if you need to make additional mounting holes they are easy to drill.

You'll find more tidbits that are interesting about using servos with amateur robots at my Web page at *www. robotoid.com*. That's all until next time. **P**

mailto: amazingscience@gernsback.com

JOHN IOVINE

"Wrecking Nice Beaches" with Voice Recognition

Voice-recognition technology has come a long way from the days where systems would interpret the phrase "Recognize Speech" as "Wreck A Nice Beach." Nowadays, computer-based software (for control and text dictation) as well as stand-alone hardware is available at reasonable prices. This month, we're going to explore the latter with the VoiceDirect 364 module from Sensory, Inc. This module (see Fig. 1) is a great introduction to the world of speech recognition. While not as sophisticated as the HM2007 speech-recognition kit that we looked at back in December 1999 (**Popular Electronics**) and January 2000 (**Poptronics**), the module is less expensive and more flexible. As with the HM2007 kit, the Voice Direct 364 performs speech recognition independently in a stand-alone mode or it can function as a slave under a host processor. The VoiceDirect 364 Speech Recognition kit was recently reviewed in the "New Gear" column (**Poptronics**, June 2000). The sidebar has updated contact information.

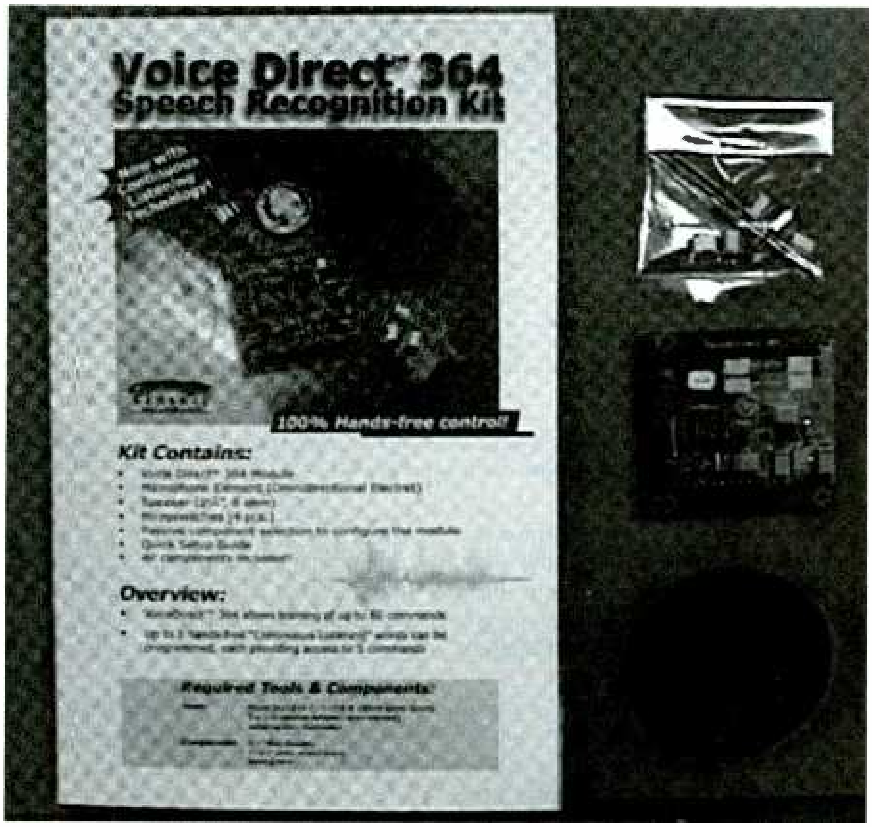

Fig. 1. The VoiceDirect 364 speech-recognition kit has a pre-built board that, with the included additional components, will have you issuing verbal orders to electronic equipment in no time.

In stand-alone mode, the VD 364 module can recognize up to 15 words or phases lasting up to 2.5 seconds each. Working as a slave under a host CPU, the module can recognize up to 60 words. Communication between the master CPU and the speech recognition module takes place over a three-wire serial interface.

When the module hears a word that it's been trained to recognize, it outputs a digital signal corresponding to the word recognized. The output line(s) associated with the word is brought high for one second. That signal can be used to control external devices with a minimum of external hardware. The module is designed to be embedded into electrical switches, appliances, and consumer electronics.

Speech-recognition systems fall into two processing categories: speaker-dependent and speaker-independent. The person who will use the system trains a speaker-dependent system to recognize his or her individual voice. Speaker-independent systems, on the other hand, respond to a word regardless of the speaker. The VoiceDirect 364 Module is speaker-dependent. This is the most common approach employed in software for personal computers.

Recognition Styles

Another factor in speech-recognition systems concerns the style of speech that they can recognize. There are three distinct styles of speech recognition: isolated, connected, and continuous. The three styles are defined as follows:

- Isolated—These speech-recognition systems can only handle words that are spoken separately. Ideally, each word will be "isolated" by a moment of silence before and after it is said.
- Connected—This style allows multiple words. The VoiceDirect 364 is

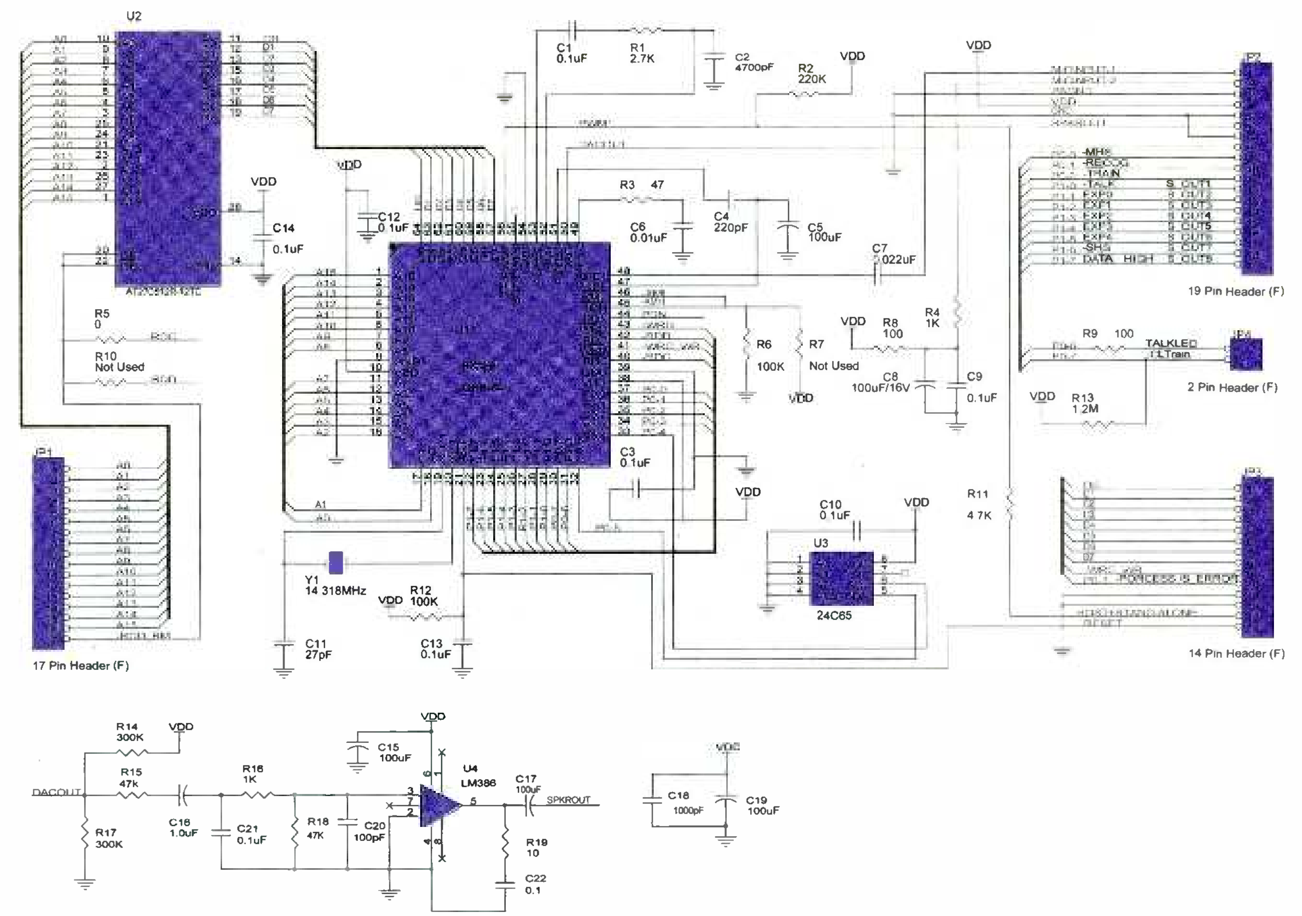

Fig. 2. The VoiceDirect 364 evaluation board has taken care of the "fussy" design requirements for you; just add power and go! (Schematic courtesy Sensory, Inc.)

such a system and can recognize verbalizations up to 2.5 seconds long. However, there should not be a pause or period of silence greater than ½ second during the verbalization.

- Continuous—This is the natural, conversational speech that we are used to in everyday life. It is extremely difficult for a speech-recognizer to sift through speech; the words tend to merge. For instance, "Hi, how are you doing?" sounds like one long word to a machine: "Hi-how-r-u-doing."

The VoiceDirect 364

The heart of the VoiceDirect 364 module is the 364 speech-recognition processor. The VoiceDirect 364 processor is available in a 64-pin quad flat-pack package for anyone that needs or wants to build a circuit from scratch. Thankfully, the VoiceDirect 364 module provides much of the preliminary hardware-design work, including an AGC (automatic-gain-control) audio amplifier, serial EEPROM memory, and clock circuitry. The module's schematic, from the Sensory, Inc. documentation, is shown in Fig. 2. The module contains extensive socket headers (JP1–JP4) making it easy to connect external circuits to the module.

Table 1 details the various module pins that we're going to work with, along with their function.

Getting Up and Running

We can best explore the capabilities that the VoiceDirect 364 offers by getting a module up and running. The VoiceDirect 364 Speech Recognition Kit costs $49.95 and contains the assembled VoiceDirect 364 module, microphone, speaker, four microswitches, two resistors, an LED, and a set-up guide.

The schematic for connecting the external components to the VoiceDirect 364 Module is shown in Fig. 3. The VoiceDirect 364's printed-circuit board measures 2 inches on each side. On one side of the board are the 0.1-inch header sockets that make it easy to connect to the circuit. While the components supplied with the basic kit will get it up and running, I added a few other components to make experimentation easier. The kit includes LED9, R9, and R10. The addition of R1–R8 and LED1–LED8 makes monitoring the outputs easier.

To experiment with the module, I placed all the external components on a solderless breadboard. Figure 4 is a photograph of that basic circuit. The components are connected with 22-gauge stranded wire. I mounted the microswitches, resistors, microphone, and LEDs on the breadboard—it might not be that clear from the photograph.

Caution! The schematics shown in the VoiceDirect 364 manual detail the board as seen from the top side. The header sockets are mounted on the bottom side of the board, making the manual's diagram a mirror image from the actual device in your hand. In contrast, Fig. 4 shows the view of the board from the solder side with the header sockets facing up as you would actually see them. Keep this in mind when comparing the Fig. 4 drawing to any of the manual drawings.

TABLE 1
VoiceDirect 364 Pinouts

Name	Module	Pin	Description
JP1	1-16	Not used	
JP2	9	Not used	
JP3	1-9	Not used	
Preamp in	JP2	1	Microphone Input Connection
Mic Bias	JP2	2	Mic Bias (Electret microphone)
AGND	JP2	3, 5	Analog Ground—do not connect to digital ground because of noise
+5V	JP2	4	V_{cc}
PWM1	JP2	6	Pulse Width Modulator Output 1, connects to 8–32-ohm speaker (+)
PWM0	JP2	7	Pulse Width Modulator Output 0, connects to 8–32-ohm speaker (-)
DACOUT	JP2	8	Analog Audio Output—Provides better quality sound than PWM output, requires amplifier
-MHS	JP2	9	Stand-Alone Mode: not used (P0.1) Slave Mode: Master Handshake (MHS)
RECOG	JP2	10	Recognition-sensitivity selection and recognition activation Slave Mode: not used
TRAIN	JP2	11	Training sensitivity selection and training activation Slave Mode: not used
Out1-Out7	JP2	12-18	Stand-Alone mode: output lines 1-7
High/Out8	JP2	19	Stand-Alone mode: output line 8 or higher Slave Mode: Serial-Interface Data (SID)
	JP3	1-9	Not Used—leave open
ERROR	JP3	10	Stand-Alone mode Error Signal
GND	JP3	11,12	Digital Ground, CPU core (pins 1 and 33)
Mode	JP3	13	Stand-Alone or Slave
Reset	JP3	14	V_{cc}
LED	JP4	1	Talk LED Slave Mode: not used
Config	JP4		CL Mode

What Did You Say?

The VoiceDirect 364 module can recognize 15 words in stand-alone mode. When the Voice Direct Module recognizes a word, it bring that output associated with that word high for one second. However, it has only eight outputs (connector JP2, pins 12-19). To indicate that one of words 9 through 15 has been recognized, the VoiceDirect 364 uses an odd non-binary scheme:

Word 1	Output 1
Word 2	Output 2
Word 3	Output 3
Word 4	Output 4
Word 5	Output 5
Word 6	Output 6
Word 7	Output 7
Word 8	Output 8
Word 9	Outputs 8 and 1
Word 10	Outputs 8 and 2
Word 11	Outputs 8 and 3
Word 12	Outputs 8 and 4
Word 13	Outputs 8 and 5
Word 14	Outputs 8 and 6
Word 15	Outputs 8 and 7

In order to access the individual outputs for all 15 words, you would need to devise a decoding circuit that switches between two banks of outputs depending on the state of output 8. Unfortunately, that page-switching technique would need to take into account the fact that Output 8 is also used for (suprisingly) Output 8—as long as Outputs 1 through 7 are not active. For simplicity, I am only using eight outputs (eight words), so I do not need to add a decoding circuit; I'll leave that design exercise up to you.

Speech-Recognition Mode Selection

The VoiceDirect 364 Module has three operating modes for recognition. The first mode, called the SD mode, forces a user to press a button before uttering a word for the circuit to recognize. This is a counterintuitive operation for any speech-recognition function. If a user is forced to press a button each time the circuit needs to recognize a word, why not just control the functions with buttons in the first place? Okay, so we'll forget about the SD mode and chalk it up to an obsolete mode held over from previous generations of speech-recognition circuits from Sensory.

The operating mode that we shall use is the continuous-listening (CL) mode, where the VoiceDirect 364 Module stays in a continuous-listening loop. The listening loop is controlled by a target word that puts the module in a listening mode. This is called the CL training word. The reason for using a CL training word is to prevent false triggering. An example should clear up any confusion.

Suppose you want to control a few home lights and appliances with a few voice commands like "lights on" and "lights off." You don't want the circuit listening to your normal conversation because it might interpret some word in the conversation as commands. The solution is to choose a "key" word that, when the VoiceDirect 364 hears it, puts it into a listening mode. You must therefore begin any command with the CL word that you chose. If you chose the word "computer," the command might be "Computer...lights on." Simply saying, "lights on" would do nothing.

That control technique was also demonstrated in the television series *Star Trek: The Next Generation*. In the Enterprise's Holodeck, speaking the command word "Arch" would allow access to a control panel for the room.

Choosing a command word is not a trivial task. You must take into account

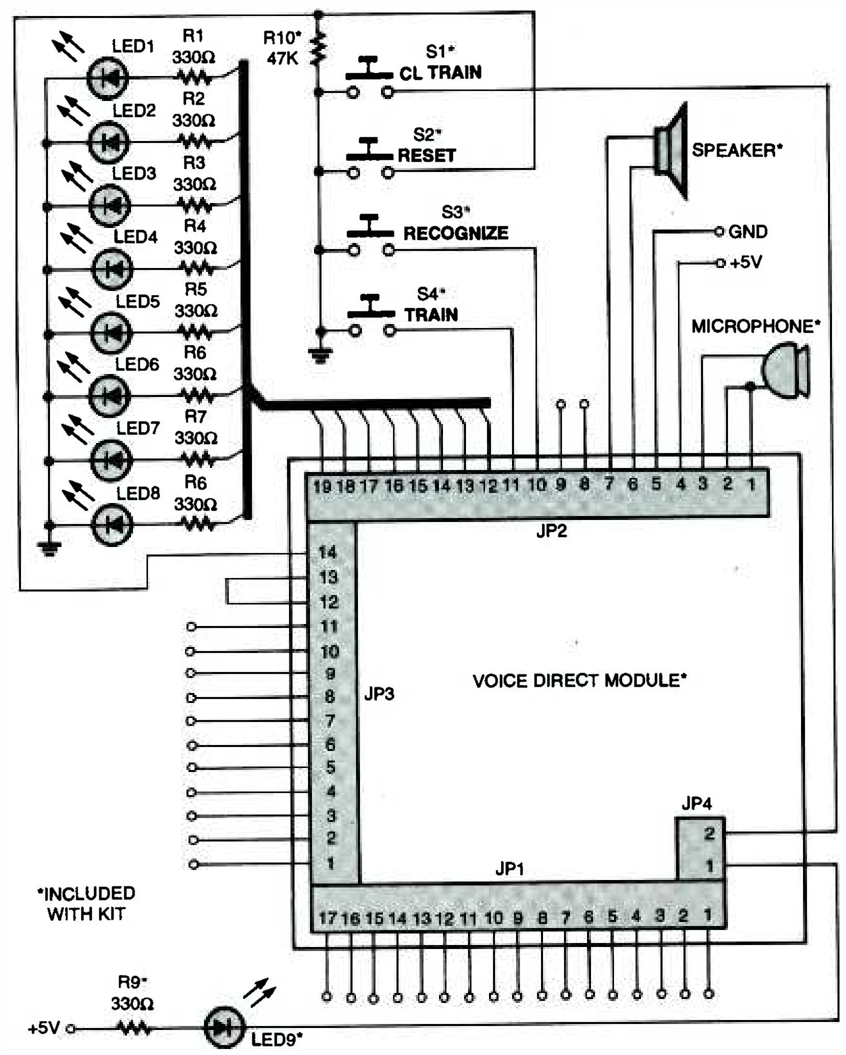

Fig. 3. Connecting the VoiceDirect 364 evaluation board to a handful of external components is simple. You can add a set of resistors (R1–R8) and LEDs (LED1–LED8) to monitor the outputs.

your normal, everyday speech patterns. Nothing is more embarrassing to a **Poptronics** reader than chatting with a friend about their new voice-recognition system:

"...And if I say the words, 'Computer...lights out,' the system will...Hey! What happened to the lights?"

Don't let that happen to you.

Training The VoiceDirect 364's CL Mode

When the CL Train pin is pulled to ground for at least 100 mS, training begins. Press the momentary contact switch marked "CL Train." The VoiceDirect 364 begins by first prompting the user verbally, "Say Word One."

Say the word that you want the circuit to recognize into the microphone.

The word or phrase may be up to 2.5 seconds long, but may not contain silences longer than 0.5 second. For example, let's use the word "computer." After the user says the word "computer," the VoiceDirect 364 will ask that it be repeated a second time with the phrase, "Repeat." Repeat the word. If the VoiceDirect 364 is happy with what it heard, it will say, "Accepted."

Once the CL word has been trained, we continue training of our command words. The sequence is the same: Press the training button, wait for the VoiceDirect 364 to say that it's ready, say the word, repeat it when asked, and wait for the VoiceDirect 364 to say, "Accepted."

A typical training session might go like this (the VoiceDirect 364 responses are in SMALL CAPS):

Press the train button
"SAY WORD ONE"
"Lights on"
"REPEAT"
"Lights on"
"ACCEPTED"

Press the train button
"SAY WORD TWO"
"Lights off"
"REPEAT"
"Lights off"
"ACCEPTED"

Press the train button
"SAY WORD THREE"
"Fan on"
"REPEAT"
"Fan on"
"ACCEPTED"

Press the train button
"SAY WORD FOUR"
"Fan off"
"REPEAT"
"Fan off"
"ACCEPTED"

and so on.

Please notice that when training words, we are pressing the "train" button and not the "CL train" button. Each time a word is trained, the module creates a word template. The two templates for each target word are compared and, if they are similar enough, are averaged together and stored into memory.

If the templates are too far apart, an error is generated and the module asks you to repeat the word starting with the initial template.

Before storing any new word templates, the module compares it is compared to the word templates already stored in memory. If the new template is too close to an existing template, the word will not be accepted.

Training Features

The VoiceDirect 364 Module has automatic gain control over the audio amplifier to provide optimum signal strength. It also monitors the background noise in an environment and gives a warning if the noise level is too high for recognition. A steady background

ADDITIONAL PARTS FOR THE VOICEDIRECT 364 KIT

LED1–LED8—Light-emitting diode, any color
R1–R8—330-ohm, ¼-watt, 5% resistors

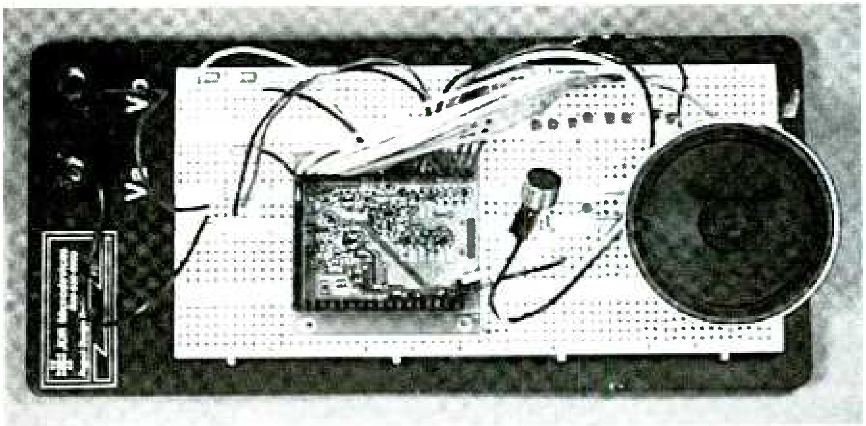

Fig. 4. My VoiceDirect kit was set up on a solderless breadboard.

noise (such as a fan) has less impact on recognition than background noise that is not steady (like a radio).

The best recognition will obviously occur in low-noise environments.

Other aspects of the VoiceDirect 364's training features include:

- *End Training*—Training can be interrupted or stopped at any time simply by not pressing the train button for the next word.
- *Resume Training*—Training may be resumed at any time by pressing the train button. The module automatically begins training new words at the end of the words already trained. For instance, if you trained six words and then stopped, the module automatically begins training at word seven when you resume.
- *Erasing Templates*—You can't erase or redo individual words and phrases. However, the entire set of words can be deleted at any time by pressing the TRAIN and RECOGNIZE button simultaneously for at least 100mS. The VoiceDirect 364 will say "Memory Erased."
- *Recognition Errors*—There are two common errors associated with speech recognition: rejection and substitution. Rejection is when the system fails to recognize a target word; substitution recognizes a non-target word or gets confused between two target words (the "wreck a nice beach" situation mentioned at the beginning of this column). Depending upon the application, the impact of those errors will vary.
- *Other Errors*—The VoiceDirect 364 can detect some errors. Errors will initiate a verbal response like "Spoke too soon," "Please talk louder," "Please talk softer," etc.

Increasing Selectivity

The VoiceDirect 364 module has the ability to increase its selectivity. The schematic shown in Fig. 4 is configured for relaxed CL training, relaxed training, and relaxed recognition. Upon power up or reset, the train and recognize pins control the selectivity.

Bridging a 100,000-ohm resistor across the train switch—essentially pulling the train pin to ground through the resistor—puts the module in a *strict-training* mode. The module becomes harder to train, rejecting more similar-sounding words. The result is better recognition for the words accepted.

If we pull the "recognize" pin to ground with a 100,000-ohm resistor, it places the module in strict-recognition mode. The module recognizes fewer words and may reject trained words; fewer substitutions are allowed during recognition.

If we replace R10 with a 680,000-ohm resistor, the CL training becomes harder still, rejecting even more similar-sounding words.

In the schematic, both the "train" and "recognize" pins are left floating (open circuit), which places the module in the Relaxed Mode. The CL-training switch is bridged with a 47,000-ohm resistor for relaxed CL Training.

ENVIRONMENTAL MATCHING TIPS

A sucessful application of the VoiceDirect 364 depends on the proper match between environment and hardware. Here are a few pointers in that regard:

Microphone—The type of microphone should be the same exact device used for both training and recognition.

Distance—Keep the microphone the same distance from your mouth during training and use.

Stress—The voice changes under stress or excitement. For instance, if you are creating a voice-controlled joystick to fly your favorite military-flight simulator, your voice, when engaged in a dogfight yelling "Fire! Fire! Bank left," will be quite different when sitting at your desk calmly programming your voice into the chip. In that case, you must try to emulate the stress and excitement you feel playing the game when programming the voice commands.

Exertion—Physical stress is another factor. If you are programming exercise equipment, such as a Stairmaster or a stationary bicycle to respond to voice, you might want to record people who are a little out of breath.

Background Noise—Background noise is always a problem. A steady background noise—like an air conditioner or a fan—has less impact on speech-recognition accuracy than a non-steady background noise (TV or radio).

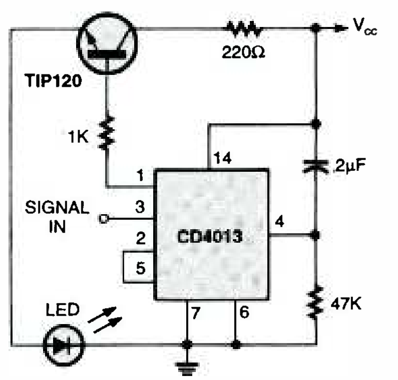

Fig. 5. You can turn the VoiceDirect 364 outputs into "push-on, push-off" controls with this simple add-on circuit.

Improving Recognition

Different techniques can improve or optimize recognition. Number one on the list is word selection. Avoid homonyms—words that sound alike—such as red, bed, said, dead, etc. To optimize recognition, use dissimilar sounding words. Replace a word with a synonym or an approximate synonym. For instance, use "crimson" or "scarlet" in place of "red." For "bed," try using "bunk," "mattress," "berth," or "cot." For "said," one may use "spoke," "voiced," or "uttered." For "dead,"

(Continued on page 62)

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SAM GOLDWASSER

Play and Record Control Problems

When it comes to VCR problems related to playing or recording a tape, we can neatly divide the types of problems into two camps: those that are not directly related to video quality, and those that screw up your tapes and screen royally. This month, we're going to "divide and conquer" the non-video-related problems and finish off the survivors next month.

We have a bit of ground to cover until the battle is won, so let us go (to quote Shakespeare) "Once more unto the breach, dear friends, once more!"

Problems With Randomly Switching Speeds, Tracking Problems, And Muddy Sound

First, don't ignore the possibility that you are attempting to play an old, worn, or defective tape. This is especially true of rental tapes that have been through who-knows-what kind of VCR hell. The control and audio tracks—along the edges of the tape—are the first to wear. Weak, muddy sound and erratic tracking are also common symptoms caused by old, worn tapes. There have even been instances of new name-brand tapes that were cut too wide, though that would be extremely rare.

To confirm that it is your VCR doing the dastardly deed, play or record for at least a minute on a tape known to be in good condition. Rewind the tape back about 15 seconds. Eject the tape, open the cassette's door by releasing the latch, and inspect for edge crinkling. Any rippling along either edge of the tape is a symptom of a possible problem. It isn't only that the tape does not make good contact with the audio or control head (depending on which edge is damaged), but it could also be an indication that the tape may not be precisely positioned when moving through the transport.

If there is the same problem on multiple tapes and known good (new) tapes are also damaged, then it is possible that the tape path alignment is off or rubber parts (probably the pinch roller) need replacing. The tape is wandering up and down as a result of unequal pull from the capstan due to a glazed or worn pinch roller. There could also be other aspects of tape-path alignment like roller-guide tilt (which is probably not adjustable), A/C head tilt, dirt, roller-guide height problems (don't mess with it), etc.

We'll be covering tape-path alignment in a future "Service Clinic."

It could also be worn feet on the roller-guide assemblies, which would cause the guides to be misaligned. Replacement of those parts may be the only cure. Other much less likely possibilities include excessive or varying backtension, a tight idler clutch, or electronic problems.

For a VCR with very high mileage, it is also possible that there has been a ridge worn in the surface of the control head, preventing consistent contact between it and the tape. Other related symptoms include:

- Sound does not always appear at full volume or normal quality for a few seconds after the VCR starts playing. It might vary in loudness during play as well. Slightly changing the back-tension may make a big difference in audio.
- If your VCR has autotracking, its indicator might be flickering as the logic attempts to solve an impossible problem.
- On a "HiFi" VCR, there will likely be no high-fidelity sound, as its tracking is even more critical than video tracking.
- Tape speed may be changing resulting in the sound wavering or even

Losing Lock

There are probably so many ways for a VCR to lose lock on the tape signal, it's sometimes amazing that the system works as reliably as it does. If you've got a lock-loss problem, here are some of the main causes and how to test for them:

- *Dirt or bits of tape or oxide on control head*—Clean and inspect the control head.
- *Defective control head*—Try making a recording. If recording plays normally on another VCR, then the control head is probably OK.
- *Tape wandering up and down*—If this is bad enough, the control track will not be sensed properly. How is the sound? The sound will fluctuate or miss as the tape wanders.
- *No firm tape-control-head contact*—This could be a mechanical fault such as a stuck movable-guide post.
- *No firm capstan-pinch roller contact*—Again, this could be mechanical or a mode-switch problem. Under certain conditions—possibly at the beginning of a tape when the take-up tension is greatest—the take-up reel might have enough torque to pull the tape past the video heads without the capstan controlling the speed as it should.
- *Servo or control circuitry*—The defect could be in the circuit or possibly in the power supply, especially if the voltage is out of tolerance.
- *Bad tape*—Don't overlook this possibility, especially if it is an old or rental tape. The control track might have gotten erased or worn off; it *is* at the edge of the tape. Try another tape.

running (usually) faster than normal. This might be due to the control head not reading the control track reliably.

If you look carefully, you should be able to see the tape wandering slightly, producing the muddy sound and erratic tracking. The tape might not be perfectly smooth in passing over the various guides and rollers. Normally, you will hardly be able to tell that the tape is moving at all except by examining the reel rotation—it is that mirror smooth.

First, clean the tape path properly, especially the capstan and pinch roller, tape guides, and A/C head. Inspect the pinch roller for glazing, cracking, etc. and replace if necessary. Perform a general cleaning and rubber parts replacement (if necessary). We've discussed the cleaning and rubber-parts-replacement dance in earlier "Service Clinic" installments; refer to them for details, or go to my Web site at *www.repairfaq.org*.

Possibly, the control portion of the A/C head stack is dirty or defective, or there are problems in the wiring or its circuitry. Double-check that the tape is in solid contact with the bottom of the A/C head stack (where the control track is located), that the head is clean, and its connector is clean and seated properly. Also, look for any broken wires or bad connections.

VCR Plays, But At Fast Forward Speed (Or Beyond)

Normally, speed is controlled by phase locking the capstan to the 30-Hz control pulses read off the tape through the stationary audio/control head. On a VCR with autotracking, the autotracking light might be flickering as well.

Possible causes for loss of lock are listed in the sidebar.

Inspect the tape path really, *really* carefully to determine if there is some obstruction preventing tape-control head contact or if there is other mechanical problems. Try cleaning the tape path and checking the rubber parts. Check the power-supply voltages if you can determine what they should be. If these procedures do not reveal anything amiss, you will need a service manual to pursue electronic faults.

Tape Edge Creases And/Or Randomly Switches Speeds

As always, rule out the possibility that this is just a bad tape. As I've mentioned before, there have even been instances of new name-brand tapes that were cut too wide—though that is extremely rare. It could have been creased by someone else's VCR. Try a tape that you can afford to sacrifice (though it will still be safely usable) and run it through the VCR. Sometimes, there will be a problem only near one end, so you will need to try it at various sections of tape. Record a few minutes and then back it up a bit and inspect for damage by opening the cassette door (press the release on the side). I've already detailed that test at the beginning of this column. Both edges should be perfectly flat and smooth. If you get similar playback symptoms with this cassette and/or find that the tape is being creased along one or both edges, then it is your VCR doing the dirty work.

When the bottom of the tape is creased, the control head may no longer align with the control track and servo lock on the sync signal is lost. The audio may be fluctuating in intensity as well since the audio track is wandering also, and the tape may be intermittently going in and out of correct tracking and/or changing speeds. Since the tape can no longer seat stably on the lower drum-guide ridge, there could be other problems such as noise bars along the top or bottom of the picture, jumping, and so on.

The problem could be the guide posts or other tape path components, but before you turn every screw you can find and make it hopelessly worse, replace all of the rubber parts—including the belts, idler tire, and pinch roller. While you are at it, give the machine a good cleaning.

A dirty, worn, hard, dried-out pinch roller in particular can result in the tape wandering up and down causing tracking problems and creasing the tape in the process. This is probably the most common cause of tape damage—assuming that the VCR itself has not been abused by removing a jammed cassette with a pair of Vice-Grips!

With a thorough cleaning of everything before buying the new rubber (which, by the way, should not be more than a total of $10 to $15 from a place like MCM Electronics), you might at least see a temporary improvement in performance—and confirmation of the diagnosis.

You really need to determine exactly where the tape is being creased. Once you do that, you might be able to determine the cause and visually verify whether the problem is affected by any of your adjustments or probing.

I've listed a few other possible causes and remedies in the sidebar.

Recording Stops At Random Times On Previously Used Tapes

Symptoms might be that the tape counter stops moving and/or the VCR enters its stop mode and shuts down.

"The VCR That Ate My Tape" And Other Horror Shows

Nothing can be more frustrating than having a VCR merrily chew up and spit out a garbled wad of Mylar that used to be one of your prized tapes. Before picking up the poor VCR and giving it the old "heave-ho" out the second-story window, you might consider some of the more common causes (as well as possible cures) for that malady:

- *Worn feet on the roller guides*—If this happens, it could be because they are not precisely vertical. Sometimes there are adjustments for tilt; usually there are none. Sometimes replacements are readily available (especially if this is a common problem with your model).
- *Cassette not seating properly*—Press down on the cassette while playing a known good tape. If it moves, check for obstructions or foreign objects such as toys or grilled-cheese sandwiches! A dirty, oily, or just tired belt might not grip well enough for the mechanism to complete the cassette-load cycle.
- *Oil- seal washer on bottom of capstan*—If this item has worked its way up out of place, carefully push it back down and then clean the capstan shaft.
- *Various guides too high or too low*—This is pretty unlikely unless they have loosened somehow. Don't adjust them unless you have a service manual or are absolutely sure that they have changed height.
- *Backtension misadjusted (usually too great)*—The tape should not pass around the backtension lever at too straight of an angle. If it does, the lever won't bend enough. In addition, it might simply not seat properly when passing around the subsequent guidepost or impedance roller (that white plastic wheel that doesn't seem to serve any purpose). One or more guide posts or roller guides might be binding as well.

Assuming that this is not a mechanical problem—bad idler, belt, etc., make sure that you don't accidentally have an *insert editing* mode enabled. Insert editing uses the previously laid-down control track as the timing reference. This provides clean glitch-free transitions between scenes. Insert editing will not work at all on a new or bulk-erased tape for the obvious reason that the control track has never been recorded or is wiped to oblivion.

If you routinely use your cassettes repeatedly, there will be varying amounts of previously recorded material—with control tracks—on the tapes. At some point, your recording might start to use tape beyond the recorded sections and... presto! No more control track. The poor VCR is confused and aborts.

Record (Or Play) Stops After 15 Minutes, 30 Minutes, etc.

Make sure that you are using the proper record button. Most VCRs have an OTR (*One-Time Record*) or "quick-record" feature that starts just like a normal record but stops after a multiple of (usually) 15 minutes, depending on how many times you press the button. The (normally) red button should be used for unrestricted, untimed recordings.

Some VCRs also have other timed modes—sort of like the timed-off function of a clock radio. Pressing the "Off-T" button adds time to record or play in 15-minute increments and then shuts off the VCR.

Tape Counter Is Erratic

The result can be the inconsistent positioning of the tape if you use the counter to locate programs. It might also result in the VCR aborting its PLAY, REC, FF, REW, or search modes if it thinks that the counter is not changing as expected—missing pulses or skipped counts.

For real-time counters, this might mean a problem deep in the electronics, requiring a service manual. However, if you are attempting to play a tape that has nothing on it, the real-time counter will not change. This is normal as there are no control pulses on the tape.

For non-real-time counters, if the display skips counts or "free runs" (counts very quickly at certain times), this could be due to a defective sensor or *hysteresis* circuit. If it counts in the wrong direction, a logic problem is indicated as direction is determined by the microcontroller being aware of what mode the VCR is in—there is likely no actual direction sensing on the reel.

That about wraps it up in terms of this month's "Battle of the Balky VCR." Next month, we'll get into the causes of video-related problems. In the meantime, just keep those e-mails coming, folks! **P**

AMAZING SCIENCE

(continued from page 59)

there's "deceased," "expired," or "late."

A little thought will solve any homonym dilemma.

Another important consideration is in matching the environment and equipment where the VoiceDirect 364 will be used. See the sidebar for some thoughts on this subject.

Interfacing Circuit

Depending upon the application, the experimenter could design a variety of interfacing circuits. Although you might need a design that only you can create, we can still provide a generic circuit. Since the output lines (Out1–Out8) only remain high for one second, some type of latching circuit would be handy. For our latch, we will press into service one half of a CD4013 dual-D flip-flop as shown in Fig. 5.

The flip-flop turns the transistor on and off each time a command is given. For instance, let's connect the OUT1 (JP2, pin 12) from the VoiceDirect 364 module to pin 3 of the flip-flop. The first time that the command associated with Word One is given, the flip-flop is set, turning on the TIP120 transistor that lights the LED. The LED will remain lit until the command associated with Word One is given a second time, which resets the flip-flop and turns off the transistor. In that way, the same command word may be used to turn on and off appliances. That action is similar to a push-on, push-off switch. That way, other commands can be given without affecting any existing commands.

You could also use a pair of outputs to set and reset a flip-flop. Be sure to double-check the pulse polarities needed by the flip-flop; you might need to use inverters on the outputs.

Going Further

The VoiceDirect 364 module is a wonderful introduction to speech recognition. The VoiceDirect 364 module is also capable of running as a slave under a host CPU through a three-wire serial-communication link. If you would like to see another article on this module, please write to me. For a detailed data book that includes more technical specifications and programming information, visit Sensory's Web site at *www.sensoryinc.com*. An Adobe Acrobat (.PDF) file on this speech processor is available for download. **P**

WHERE TO GET IT

The VoiceDirect 364 Module is available for $49.95 plus shipping from the following sources:

Images Company
P. O. Box 140742
Staten Island, NY 10314
718-698-8305
www.imagesco.com

Jameco Electronics
1355 Shoreway Rd.
Belmont, CA 94002
650-592-8097
www.jameco.com

JDR Electronics
1850 South 10 St.
San Jose, CA 95112
800-538-5000
www.jdr.com

Sensory, Inc.
521 East Weddell Dr.
Sunnyvale, CA 94089
408-744-9000
www.sensoryinc.com

mailto: basiccircuitry@gernsback.com

CHARLES D. RAKES

Warning! Danger! Alarming Circuits Ahead!

This time around, get ready for some alarming fun! We're going to look at a number of basic burglar-alarm-sensor circuits that you can put together with a control system. Hopefully, you'll outsmart the next burglar that might come your way. A seasoned burglar usually knows the basics about simple alarm systems and how to breach them; but if you design your own system and build it to look and operate differently from the typical store-bought unit, you'll have a very good chance of sending the burglar on his way without any loss to you.

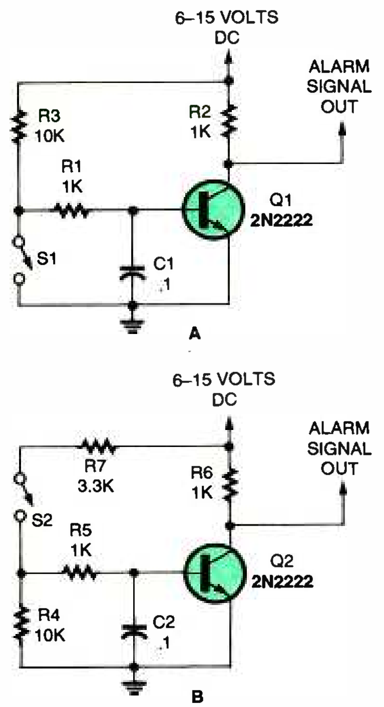

Fig. 1. A simple transistor switch can be used as an alarm circuit. By placing the sensor switch in the right part of the circuit, you can use a normally-closed (A) or normally-open (B) switch with the same circuit.

PARTS LIST FOR THE PERIMETER LOOPS (FIG. 1A and 1B)

RESISTORS
(All fixed resistors are ¼-watt, 5% units.)
R1, R2, R5, R6—1000-ohm
R3, R4—10,000-ohm
R7—3300-ohm

ADDITIONAL PARTS AND MATERIALS
C1, C2—0.1-µF, ceramic-disc capacitor
Q1, Q2—2N2222 NPN transistor

A savvy burglar probably won't spend too much time trying to figure out an unorthodox alarm system, and a dumb burglar will likely set it off—possibly getting caught in the process or at least leaving without taking anything.

Alarm sensors are usually placed at the perimeter of the area where protection is needed. How the sensors are selected and installed will determine the success or failure of an alarm system. In addition, we'll look at various methods in locating sensors, placing "red herrings" in just the right places, and other schemes that can help confuse a would-be burglar. Hopefully, next month we can follow up with some choices for a control system.

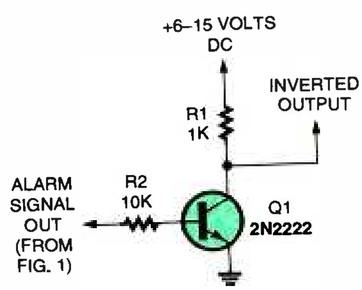

Fig. 2. If you need to invert the output signal from Fig. 1, an additional transistor stage will do the trick.

Basic Perimeter Loops

In the simplest of alarm systems, there are two basic types of sensors: the normally-open circuit and the normally-closed circuit. In either case, an alarm output only occurs when the sensor's normal circuit condition reverses. The very basic alarm sensor would be a switch that is set in either a normally-open or normally-closed condition. Opening a door or window or any similar movement that would cause it to switch from its normal set condition could activate the switch. A single switch properly hidden can be a very effective sensor and will fool most intruders.

Our first normally-closed sensor circuit, see Fig 1A, is a transistor-buffered circuit that outputs a high (positive) voltage in the set condition. As long as the sensor's element is closed, the transistor's bias is zero; and its collector voltage is at the positive supply level. Opening the sensor element allows the voltage at the transistor's base to rise and turn on the transistor. The transistor's collector operates like a turned-on switch, taking the output voltage to near ground level. That sends out a low-voltage alarm signal to the control unit. Components R1 and C1 make up a low-pass filter that helps keep stray RF signals and noise

PARTS LIST FOR THE OUTPUT INVERTER (FIG. 2)

Q1—2N2222 NPN transistor
R1—1000-ohm, ¼-watt, 5% resistor
R2—10,000-ohm, ¼-watt, 5% resistor

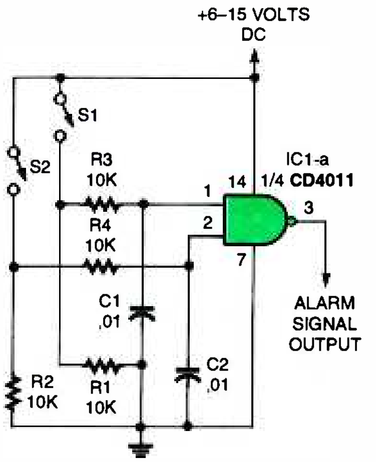

Fig. 3. More than one sensor switch can be handled by this CMOS-based alarm circuit.

PARTS LIST FOR THE NAND-GATE ALARM (FIG. 3)

IC1—CD4011 quad 2-input NAND gate, integrated circuit
R1–R4—10,000-ohm, ¼-watt, 5% resistor
C1, C2—0.01-µF, ceramic-disc capacitor

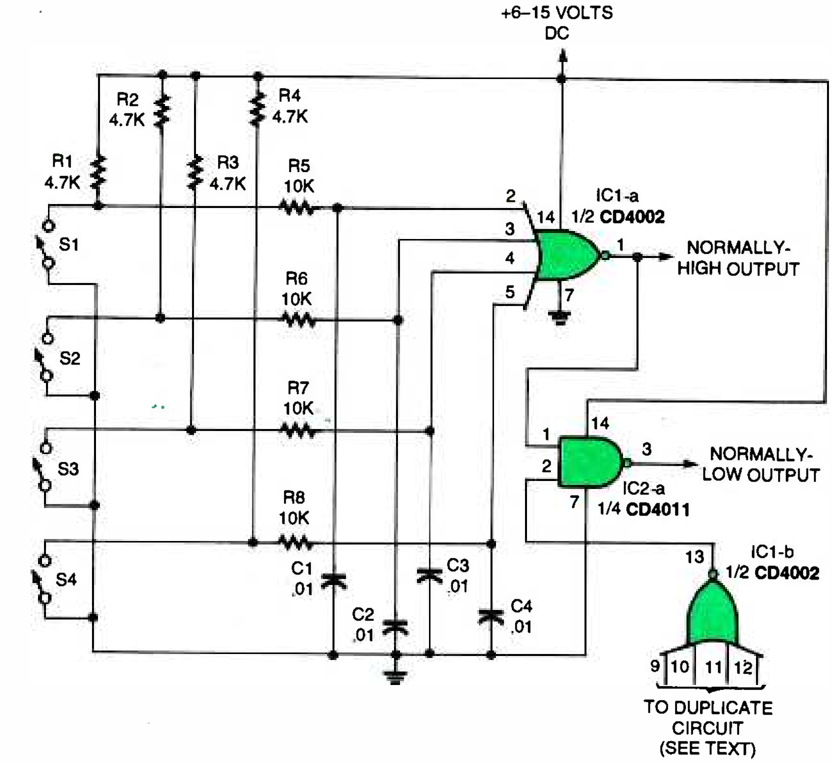

Fig. 4. With a 4-input NOR gate, there can be up to eight sensors to trigger the alarm.

from causing a false-alarm output. The sensor element may be made up of any number of normally closed circuits wired in series, as long as the total series resistance is less than a hundred ohms.

The other type of sensor, see Fig. 1B, is a normally open circuit. The transistor-buffered sensor input circuit is very similar to Fig. 1A. The normal alarm output signal is also positive and only goes low when the input sensor changes state from open to closed. Any number of normally open sensors may be used and wired in parallel. All it takes is one sensor closing to send out the low alarm signal.

One of the easiest ways to confuse a burglar is to intermix the two types of alarm sensors. Mixing them up makes it more difficult to determine which sensors to jump and which to cut to disable the system. Throwing in a few false sensors increases the frustration factor, probably causing the burglar to make a mistake—setting off the alarm in the process of trying to bypass it.

Flip It Around

The circuit in Fig. 2 inverts the alarm-output signal from a high to low or a low to high, allowing the sensors to operate with about any type of alarm-control system. Some control systems require a high-input signal to trigger the alarm; others operate with a low-input signal. If a normally high-output signal is fed to the input of the inverter circuit, the output will be low; and a low input produces a high output. These circuits may seem extremely elementary—and they are—but a good alarm system is made up of many simple circuits.

PARTS LIST FOR THE NOR-GATE ALARM (FIG. 4)

SEMICONDUCTORS
IC1—CD4002 dual 4-input NOR gate, integrated circuit
IC2—CD4011 quad 2-input NAND gate, integrated circuit

RESISTORS
(All resistors are ¼-watt, 5% units.)
R1–R4—4700-ohm
R5–R8—10,000-ohm

CAPACITORS
C1–C4—0.01-µF, ceramic-disc

Pass It Along

The next two circuits show several ways that CMOS ICs can be used as interfacing devices for various alarm sensors. The circuit in Fig. 3 is a two-

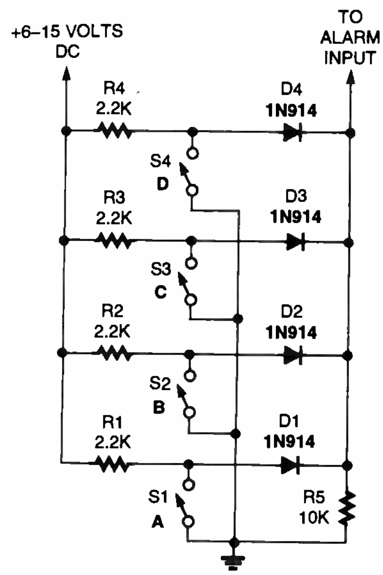

Fig. 5. You don't need sophisticated transistor- or IC-based circuits for a reliable alarm. This simple diode-steering circuit will do the job just as well.

PARTS LIST FOR THE DIODE-LOGIC ALARM (FIG. 5)

D1–D4—1N914 silicon signal diode
R1–R4—2200-ohm, ¼-watt, 5% resistor
R5—10,000-ohm, ¼-watt, 5% resistor

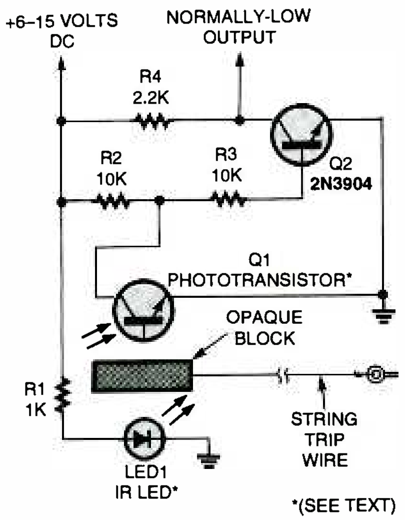

Fig. 6. An updated trip-wire circuit uses an infrared switch to detect if the wire was broken.

PARTS LIST FOR THE TRIP-WIRE ALARM (FIG. 6)

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

ADDITIONAL PARTS AND MATERIALS
Q1—Slotted-optical sensor switch (Mouser 512-H21A2 or similar)
Q2—2N3904 NPN transistor
LED1—(part of Q1)
Trip string, opaque material, etc.

sensor input circuit designed for normally closed sensors and has a low non-alarm output. Both inputs to IC1-a are held high through the two sensors and 10K resistors. With both inputs high, the gate's output is low. If either or both input sensors open, the gate's output will switch from low to high, giving out a positive alarm signal. Resistors R1 and R2 guarantee that the inputs go low when either sensor is opened; a NAND gate's output will only go high if one or more of its inputs go low. Simple low-pass filters, consisting of C1, C2, R3, and R4, keep RF and high-level noises from producing a false-alarm output. The IC package has a total of four gates in it, so you can use the remaining three gates for sensor interfacing by duplicating the Fig. 3 circuit.

Our next entry (Fig. 4) turns a dual 4-input NOR gate into an eight-input, normally closed, sensor-interfacing circuit. All inputs of a NOR gate must be low to produce a high output. If just one input gate goes high, the output will switch low. A single gate of IC2 is used to combine the outputs of IC1-a and IC1-b into a single alarm output. If either input of IC2-a goes low, its output will switch high—producing a positive alarm-output signal.

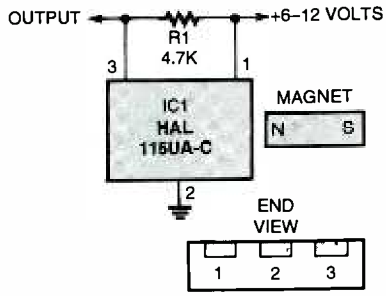

Fig. 7. Mechanical devices such as reed switches can be replaced by solid-state Hall-effect sensors.

PARTS LIST FOR THE HALL-EFFECT ALARM (FIG. 7)

IC1—HAL 115UA-C Hall-effect sensor, integrated circuit (Digi-Key HAL115UA-C-ND or similar)
R1—4700-ohm, ¼-watt, 5% resistor
Permanent magnet

"Intelligent" Diodes

The sensor-interface circuit shown in Fig. 5 allows any number of normally closed input sensors to be connected together to produce a positive alarm output if any one of the sensor circuits open. The voltage at the anode of each diode is at ground level when the sensors are in their normally closed condition. When any one of the sensors open, the voltage climbs to the supply level and passes the positive signal through the isolation diode to the output.

Who Goes There?

Now that we've looked at several methods of interfacing sensors to the alarm's control system, it is time to look over a few different types of sensors. Our first sensor, see Fig. 6, is a solid-state replacement for the old trip-wire type of sensor that operated when an intruder actually broke a fine wire positioned around the protected area. The wire loop operated just like any of the normally-closed input sensors used in our previous interface circuits. When the wire breaks, the sensor circuit opens and the alarm goes off.

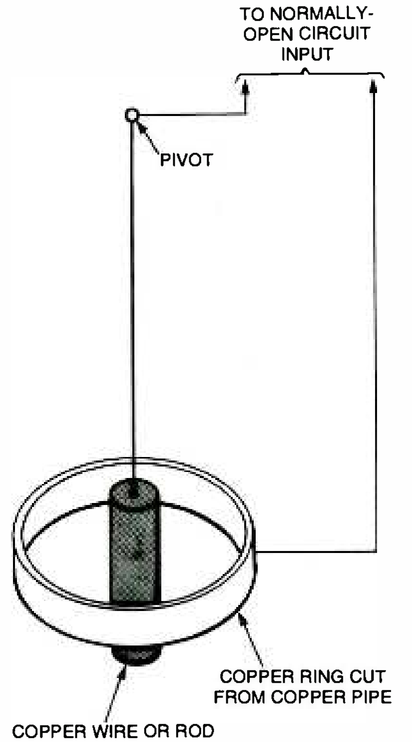

Fig. 8. A simple form of tilt sensor can be made from a ring of copper tubing and a piece of copper rod or wire suspended from a pivot point. If the system is tilted far enough, the rod touches the ring, completing the circuit.

PARTS LIST FOR THE TILT SENSOR (FIG. 8)

Copper ring, copper wire or rod

Our electronic version uses an infrared interrupter switch, which is actually an IR-emitter LED and a phototransistor mounted together in a single package. The one used in the circuit is a Mouser 512-H21A2, but just about any similar IR interrupter switch will work.

An opaque object is placed in the slot between the IR-emitting diode and the phototransistor to block the light path. A string or wire is tied to the opaque object and to a fixed object across from and in front of the protected area. All an intruder has to do is to catch on the trip cord, pull the opaque object from between the solid-state pair, and watch the fun begin. Cats, dogs, and other animals have been known to set these types of alarms off more often than an actual burglar or trespasser, so be prepared for some false alarms.

Magnetic Personalities

Our next entry, see Fig. 7, replaces the common magnetically-operated reed-

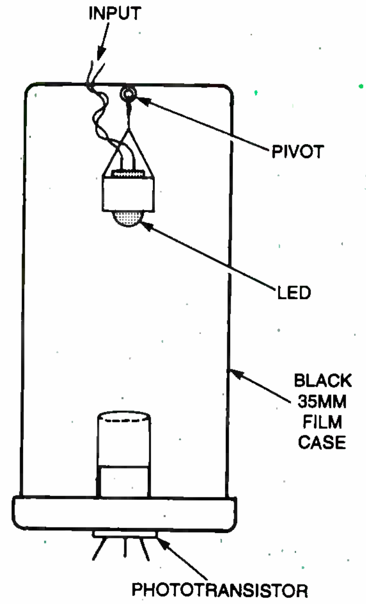

Fig. 9. An infrared version of the tilt sensor uses a phototransistor and an IR LED that is suspended so that it can swing to and fro like a chandelier.

PARTS LIST FOR THE IR TILT ALARM (FIGS. 9 and 10)

R1—1000-ohm, ¼-watt, 5% resistor
R2—10000-ohm, ¼-watt, 5% resistor
LED1—Infrared light-emitting diode (Mouser 512-LED55B or similar)
Q1—Infrared-sensing phototransistor (Mouser 512-BPW37 or similar)
35-mm film case (black), fine wire for LED leads, etc.

switch sensor with a solid-state CMOS Hall-effect sensor. These interesting and useful Hall-effect ICs are available from Digi-Key (part number HAL115UA-C-ND) for less than a buck in single quantities. The Hall-effect's output is high when a magnet is in close proximity but when the magnet is moved away from the device, the output changes to a low state. The sensor's output can tie directly to the alarm's control circuitry or go through one of the interface circuits. This combination could be used to detect when an intruder opens a door or window. The Hall-effect IC is very small and can be mounted in the door or window facing, and the magnet can be mounted inside the door or window. These components should be carefully installed where they cannot be seen or easily discovered by an intruder. Proper installation is the key to a successful alarm system.

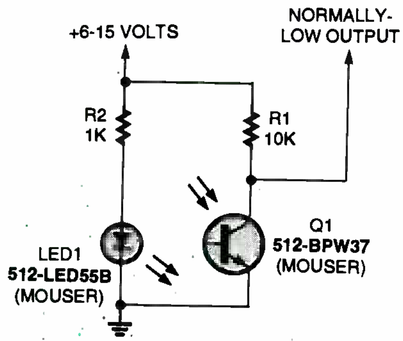

Fig. 10. The schematic diagram of the infrared tilt sensor is simplicity personified.

Lots of Shaking

A simple tilt- or movement-alarm sensor is shown in Fig. 8. This sensor has a normally open output and can connect to one of the interface circuits designed for normally open circuits. This type of mechanical tilt switch has been around for many years and can still be found in some equipment. One place that I believe it is still being used is in pinball machines. A few years ago, it was used in an automobile to detect motion if someone tried to move the car without first deactivating the alarm.

This type of sensor could be mounted on anything that opens with a forward or backward motion, such as a door, a desk drawer, or anything else that can be moved horizontally.

An electronic version of the tilt alarm is shown in Fig. 9. An IR LED is supported in an opaque 35-mm film case. A pivot arrangement with fine wire leading out the top connects to the circuitry in Fig. 10. An IR phototransistor is mounted in the bottom of the film case with its leads coming out the bottom. With the spacing between the two solid-state devices being so close, just about any IR pair will work with the Fig. 10 circuit.

With the two devices properly aligned, the voltage at the collector of Q1 will be at its lowest value. As the container is tipped, the voltage should begin to increase and rise to the positive supply level. If the IR-light beam is too broad, a small section of shrink tubing can be placed around either the emitter or detector. Actually, for the best possible sensitivity, shrink tubing can be placed around each device.

The drawing in Fig. 9 is just to get you going. Like many of the sensors that we've been looking at, they can be built in your own unique style. That way, only you will know the secrets behind each one, including how they are built and used.

Looks like this is a good place to wind down. At our next meeting, we'll continue with another sensor or two and then get into the control-system circuitry. Good-bye and good circuitry until next time.

DTV: PART 2

(continued from page 43)

acteristic power spike at the carrier frequency, leaving all the available transmitter power for the information-rich sidebands. In vestigial-sideband formats, one of the sidebands is also suppressed. Since the sidebands are mirror images, one of them is superfluous. In DTV's case, only the upper sideband and a slight vestige of the lower sideband are actually transmitted.

Carrier suppression makes the receiver's job a little trickier, since it must essentially regenerate the missing carrier in order to recover the information from the sideband(s). This would be especially difficult in DTV's case, since its use of channel spectrum is basically flat, looking like noise.

To help the receiver identify the carrier, a small "pilot" is added to the transmission at the carrier frequency. In other words, a little bit of the carrier is preserved for the benefit of the receiver. Before the combined channel symbols and sync are sent to the modulator, a DC level that corresponds to exactly 1.25 8VSB level divisions positively biases them. All of the 8VSB and sync levels are raised by that amount. Adjusting the modulating signal in this way is called *pilot insertion*. Although the modulator performs carrier suppression, the added DC content of the modulating signal preserves the carrier as part of the modulated information. While sufficient to aid the receiver, the power level of the pilot signal is slight, remaining 11.3 dB below the average data-signal power.

With the pilot level in place, the 8VSB signal is modulated on an intermediate-frequency carrier, then upconverted to the transmitter's specified operating frequency.

Statistical analysis of DTV's 8VSB mode has shown that 99.9% of the time, the peak transmitter power is within 6.3 dB of the average power. From a practical standpoint, the average- to peak-power relationship allows an ATSC transmitter to achieve the same coverage as an NTSC transmitter at the same frequency with an average power level 12 dB lower than NTSC's peak sync power (where the bulk of NTSC's signal power is concentrated).

Additional Resources. So now you know a thing or two about DTV. Nevertheless, if you plan to remain a videophile or hope to become a guru, you'll probably want to know more.

The Internet is a great resource for information on DTV. You might start with a visit to the ATSC's Web site: *www.atsc.org*. There you can freely download the DTV standard and an excellent companion reference, *Guide to the Use of the ATSC Digital Television Standard*. Another great Web site is the National Association of Broadcasters (NAB): *www.nab.org*. They maintain links to a variety of broadcast-related information resources, including a page dedicated to DTV off their "Current Issues" page.

As the countdown to 2006 continues, it will be fascinating to watch the changes in television broadcasting unfold. May your vantage point be an enlightened one. ■

GETTING INSIDE AN NCO

(continued from page 50)

You can use a 4-kB CMOS chip—the 27C32 (Digi-Key NM27 C32BQ200-ND) or the cheaper and faster 8k part—the 27C64 (Digi-Key NM27C64Q-150-ND). The latter part has 28 pins; its unused address pins should be tied to ground.

Since the EPROM generates glitches every time the address inputs change, it needs an output latch (IC11) to get good results. Jumper J1 allows quick swapping from ramp to sine outputs. Wire pin 1 of IC9 to ground if you don't use a sine converter. For best results, you should change the filter to the one shown in Fig. 4.

Modulating The Output. Figure 5 shows how different types of modulation can be applied to the basic NCO. Adding frequency-shift modulation is simple; just add a second frequency source (more DIP switches, for instance) and a bank of two-way multiplexer chips. Driving the multiplexer with a binary signal switches the output between the two frequencies you have set.

Quadratic-phase modulation is also easy. All it takes is two more EXCLUSIVE-OR gates between the adder and the existing EXCLUSIVE-OR bank. The EPROM can also be programmed to generate QPSK modulation from a signal applied to its address inputs.

If you want to experiment with continuous-frequency modulation, you need to digitize the analog signal and add it to the DIP-switch input. You can generate narrow-band FM without adders by using the bottom bits of the frequency-control number as the modulation input and the top bits as the carrier-setting number. Putting adders between the ramp output and the EXCLUSIVE-OR gates implements continuous-phase modulation.

With a little experimentation, you will soon learn the value of these unique devices and will be ready to use an NCO chip in your own designs. ■

More Information About NCO Generators

"Digital Frequency Synthesis" *Circuit Cellar Ink*, October 1998 (*www.circuitcellar.com*). This article discusses how to generate accurate, modulated audio-frequency signals with a cheap microcontroller.

"Making Waves with NCOs," *Circuit Cellar Ink*, December 1997–January 1998. A signal-generator construction project using a Harris (now Intersil) NCO chip to generate both sinewave and squarewave output from 1 Hz to 10 MHz.

"Push Numerically-Controlled Oscillators Beyond Their Limits," *EDN*, September 12, 1997 (*www.ednmag.com*). An introduction to NCOs and some ideas for extending their frequency range. This article includes more detail on generating a squarewave without a sine conversion.

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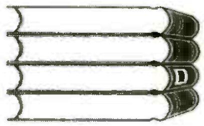

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This product can be used with any 3-1/2 IDE hard drive up to 1" high. It includes an electronic keylock for safe removal and insertion. Made of ABS 707 fireproof plastic. Use this product to protect sensitive hard drive data, take your hard drive between work and home or even set up different users with their own hard drives that they physically insert every time they use a PC. Other models available from C.S.I. include RH10 series and RH20 series, which are interchangeable within the same interface design (IDE or SCSI). *Other Models are Available. See www.web-tronics.com under "hard drive and accessories" for more details and pictures.*

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Removable Hard Drive Rack with Auto Door And Cooling Fan

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- Auto door on the outer frame
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#MR-27

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#3201

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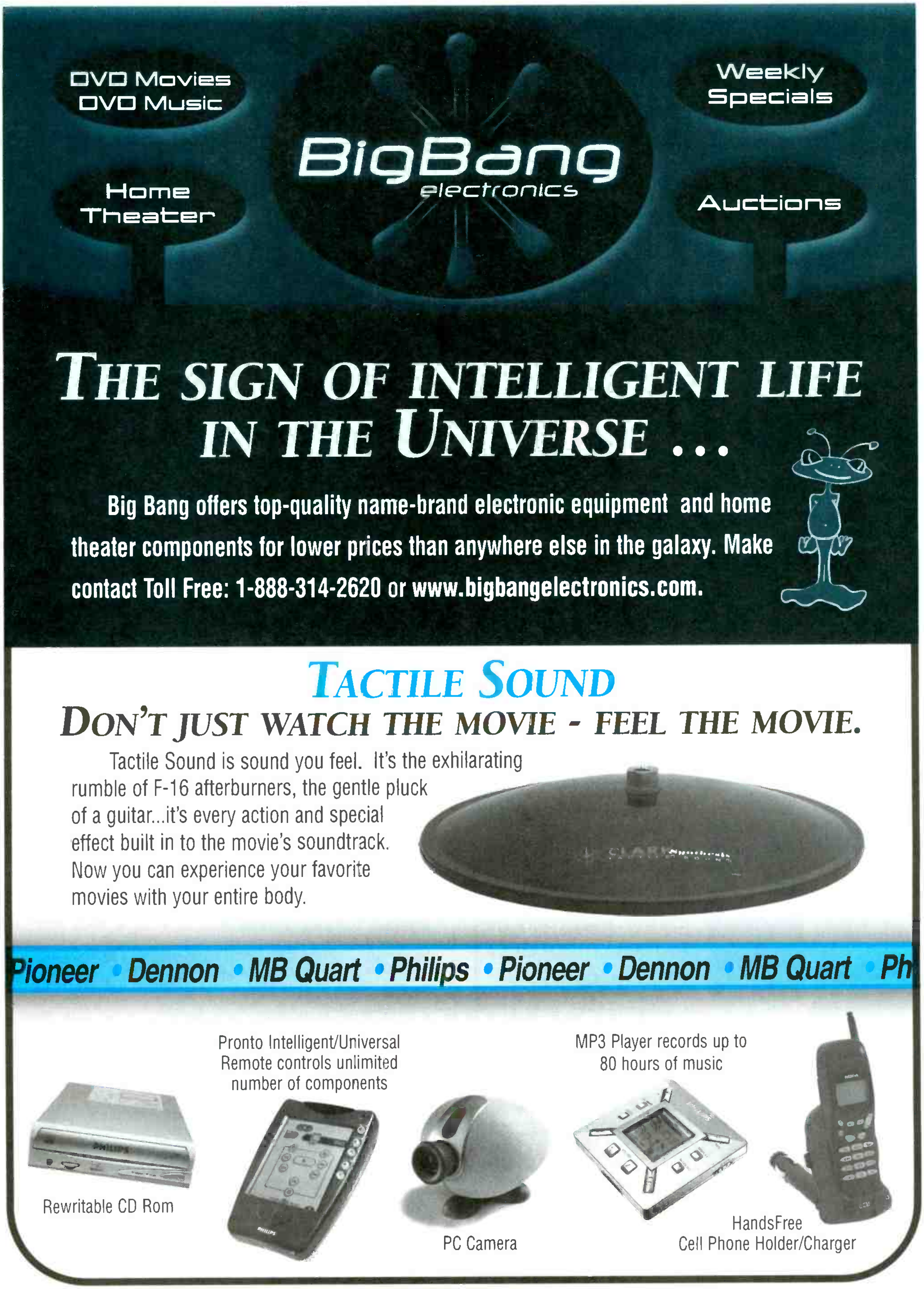
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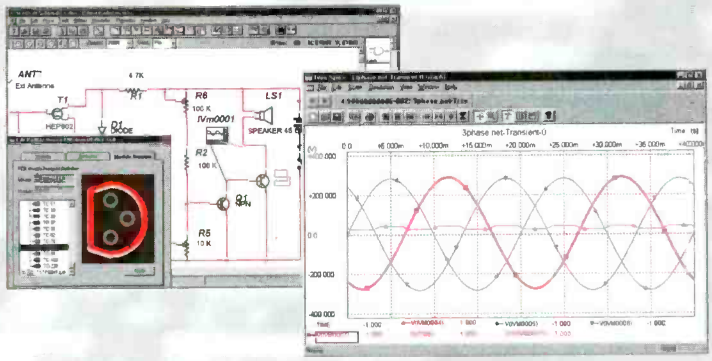

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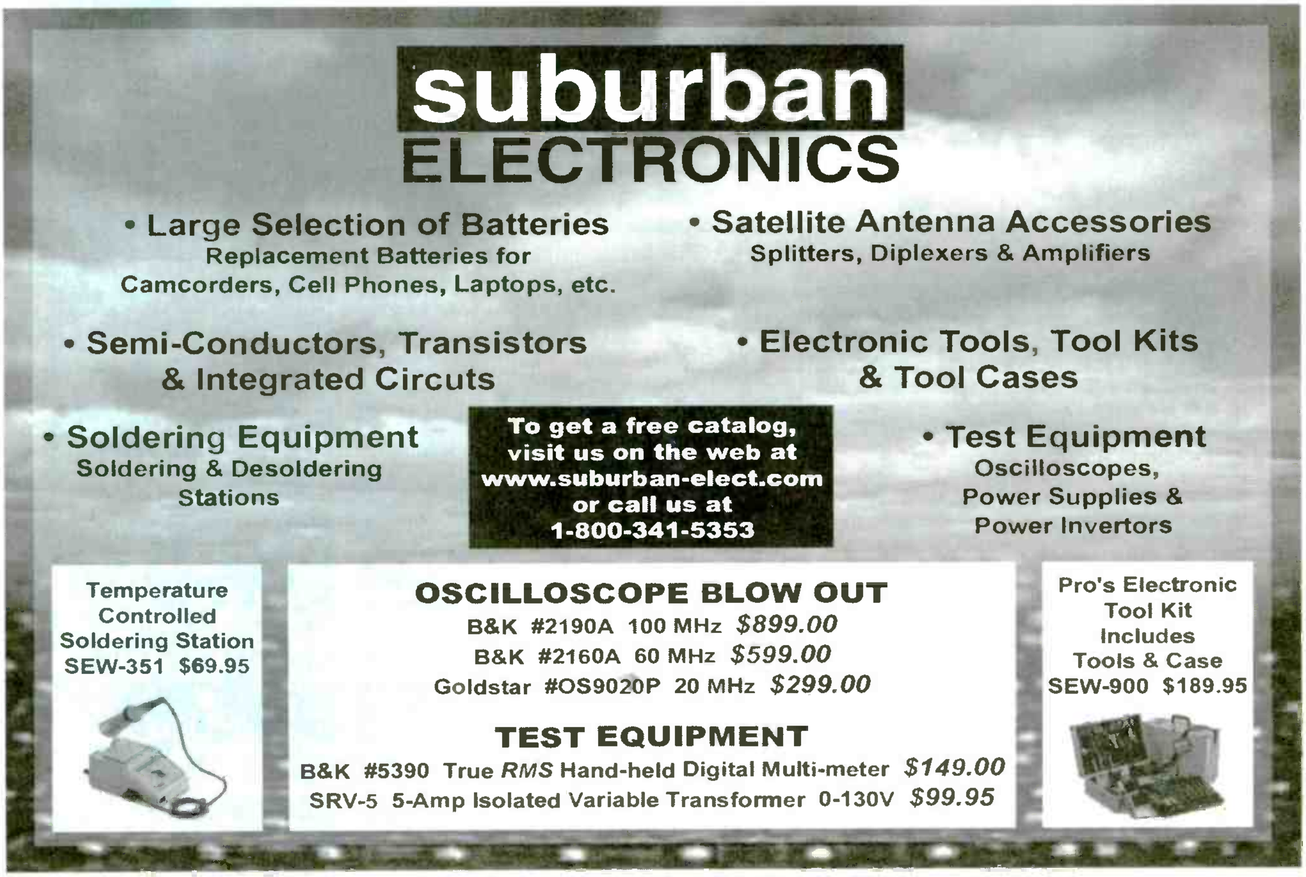

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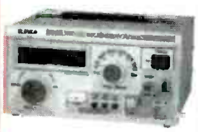

Features internal AM mod. of 1kHz, RF output 100MV - 35MHz. Audio output 1kHz @ 1V RMS.

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SG-9000 .... $119.95
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Elenco Sweep Function Generator
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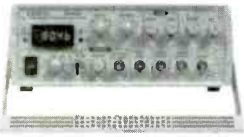

This sweep function generator with counter is an instrument capable of generating square, triangle, and sine waveforms, and TTL, CMOS pulse over a frequency range from 0.2Hz to 2MHz.

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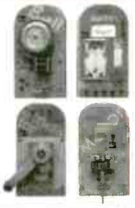

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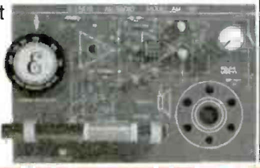

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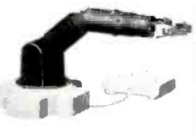

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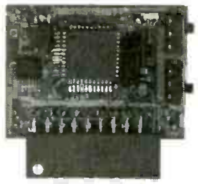

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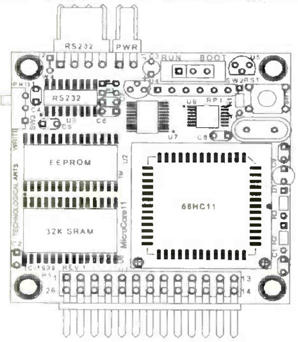

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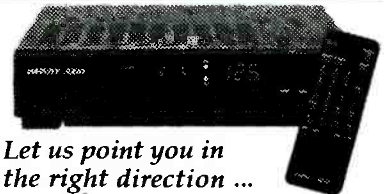

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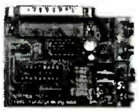

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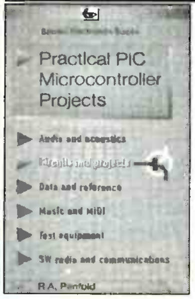

This book covers a wide range of PIC based projects, including such things as digitally controlled power supplies, transistor checkers, a simple capacitance meter, reaction tester, digital dice, digital locks, a stereo audio level meter, and MIDI pedals for use with electronic music systems. In most cases the circuits are very simple and they are easily constructed. Full component lists and software listings are provided. For more information about PICs we suggest you take a look at BP394 -- An Introduction to PIC Microcontrollers.

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ET10

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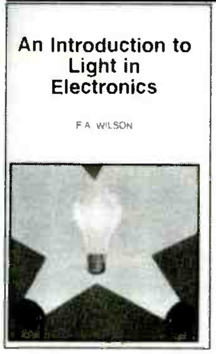

Taken for granted by us all perhaps, yet this book could not be read without it, light plays such an impressive role in daily life that we may be tempted to consider just how much we understand it. This book makes a good start into this fascinating and enlightening subject. It has been written with the general electronics enthusiast in mind.

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ET08

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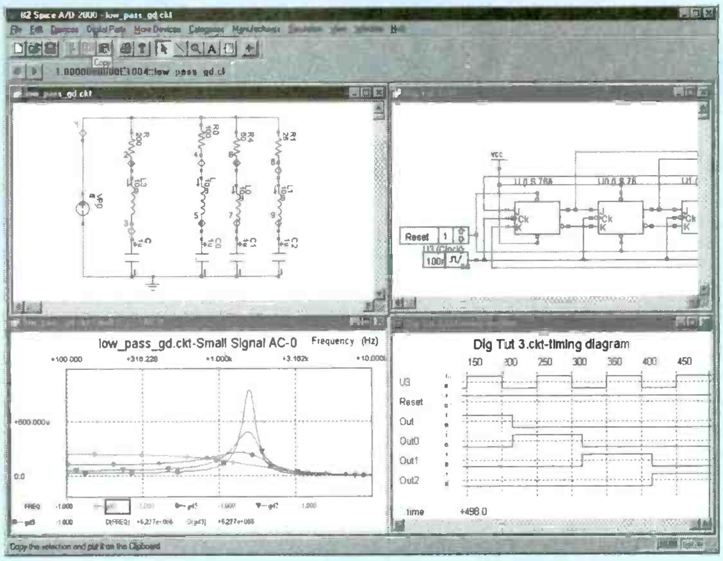

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Parameterized AC Sweep	X	-
Pole Zero	X	-
Transfer function	X	-
DC Sensitivity	X	X
Distortion	X	X
Noise	X	X
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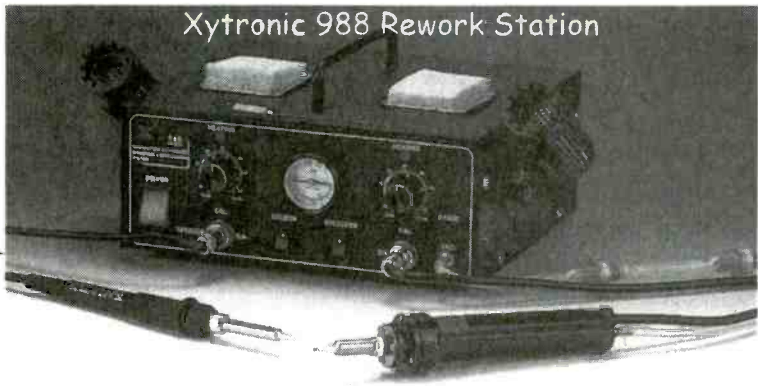

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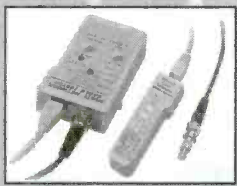

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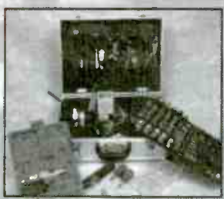

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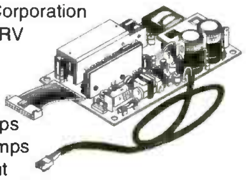

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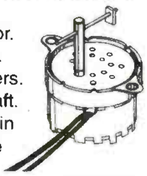

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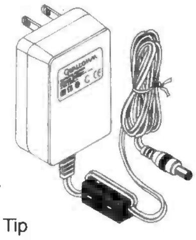

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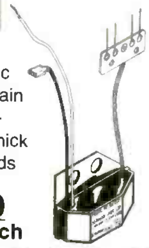

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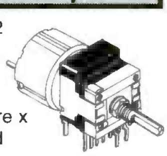

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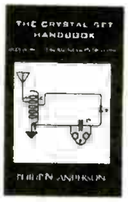

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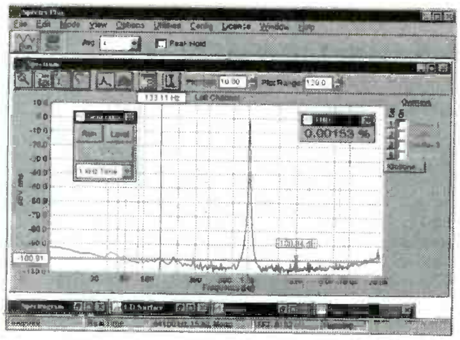

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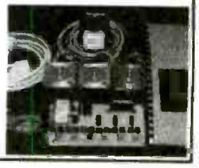

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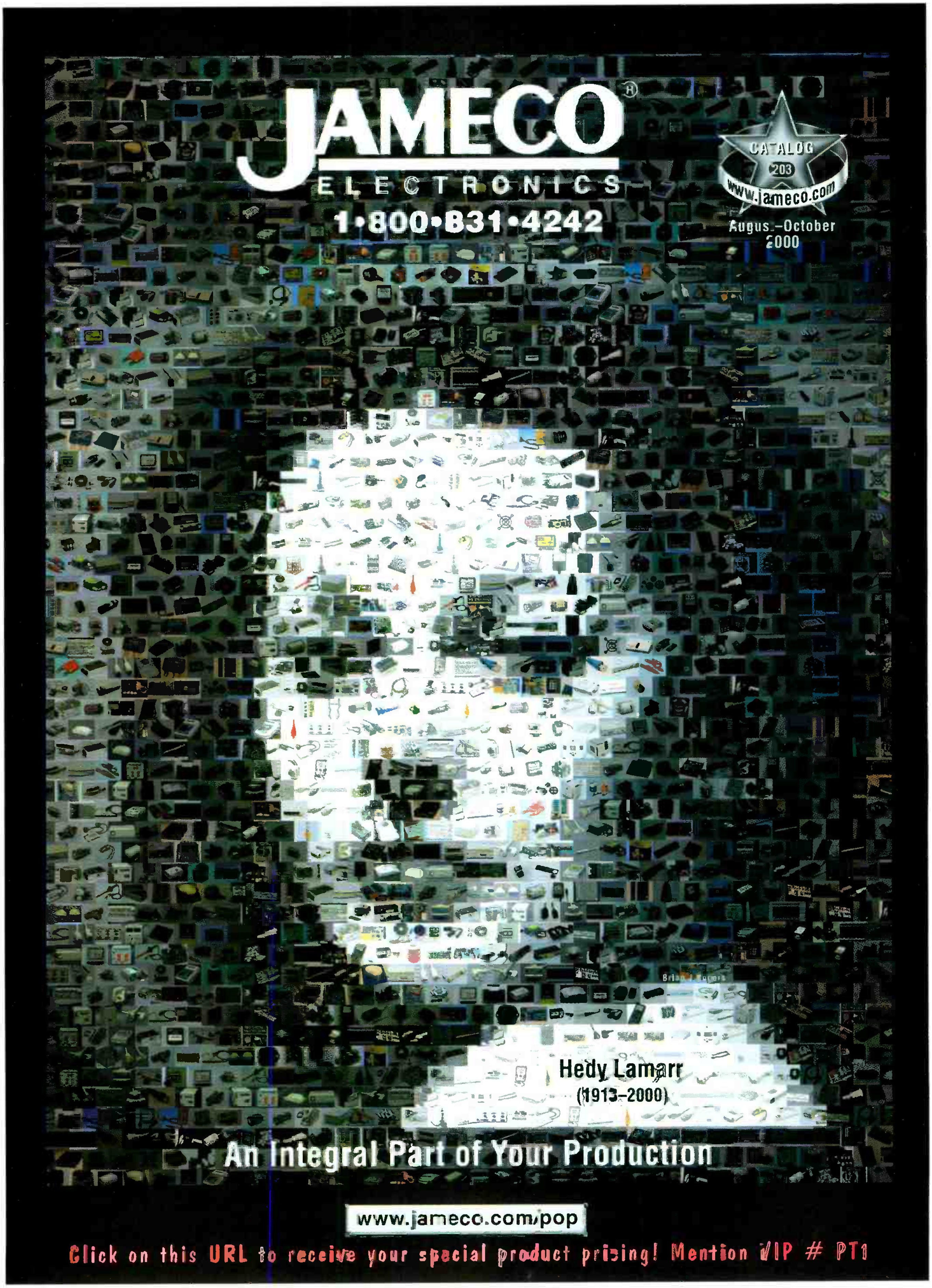
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