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Get out in front! Call toll-free today to order, to get more details or a videotape demonstration.

1-800-433-2323
In Oregon, call collect 1-627-9000

<table>
<thead>
<tr>
<th>Features</th>
<th>2246</th>
<th>2245</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bandwidth</td>
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<tr>
<td>No. of Channels</td>
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<tr>
<td>Scale Factor Readout</td>
<td>Yes</td>
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<td>SmartCursors™</td>
<td>Yes</td>
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<td>Volts Cursors</td>
<td>Yes</td>
<td>No</td>
</tr>
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<td>Voltmeter</td>
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<tr>
<td>Vertical Sensitivity</td>
<td>2 mV/div</td>
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<td>Max. Sweep Speed</td>
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<td>2%</td>
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<td>Trigger Modes</td>
<td>Auto Level, Auto, Norm, TV Field, TV Line, Single Sweep</td>
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<td>Trigger Level Readout</td>
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<td>Warranty</td>
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<td></td>
</tr>
<tr>
<td>Price</td>
<td>$2400</td>
<td>$1875</td>
</tr>
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</table>

Featuring four channels, flexible triggering, extensive CRT readouts and push-button ease of use, the new Tek 2246 (left) and 2245 (above) bring high-quality, low-cost analysis to diverse applications in digital design, field service and manufacturing.

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53 PHONLINK INTERACTIVE REMOTE CONTROL
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Gene Roseth

58 R-E ROBOT
Part 7. More on the control board.
Steven E. Sarns

71 PC SERVICE
Use our exclusive direct-etch foil patterns to make circuit boards for a shortwave converter, the Phonlink, and digital tachometer.

TECHNOLOGY

8 VIDEO NEWS
Inside the fast-changing video scene.
David Lachenbruch

76 SATELLITE TV
A descrambling fraud.
Bob Cooper, Jr.

78 AUDIO UPDATE
Unwanted sound transmissions.
Larry Klein

CIRCUITS AND COMPONENTS

40 NEW IDEAS
A sound effects generator.

50 NEW LIFE FOR OLD CAR RADIOS
Part 2. How to build a shortwave radio converter.
Gary McClellan

61 TESTING SEMICONDUCTORS
Part 5. Transistor AC parameters.
TJ Byers

64 WORKING WITH FLIP FLOPS
A circuit cookbook.
Ray Marston

70 TV TROUBLESHOOTER'S NOTEBOOK
Black vertical bars.
Jay Shane

87 STATE OF SOLID STATE
Instrumentation amplifiers.
Robert F. Scott

RADIO

80 ANTIQUE RADIOS
Restoring a classic radio.
Richard D. Fitch

82 COMMUNICATIONS CORNER
Antennas and propagation
Herb Friedman

COMPUTER DIGEST

93 EDITOR'S WORKBENCH

97 DESIGNING PC BOARDS ON YOUR COMPUTER

100 THE KEPROM: SINKING THE SOFTWARE PIRATE

EQUIPMENT REPORTS

21 Leader LCD-100 Portable Oscilloscope/DMM

DEPARTMENTS

124 Advertising and Sales Offices

124 Advertising Index

10 Ask R-E

4 Editorial

125 Free Information Card

14 Letters

105 Market Center

30 New Products

6 What's News
It you like to keep your car up to date no matter how old it is, then our cover project—a digital tachometer—is for you. Although the tach is a digital project and offers a digital display, it also offers an easy-to-read analog indication. It will work with 4-, 6-, and 8-cylinder engines, and can even be used for tuning your engine! Next month, we'll show you how to build a matching speedometer to really jazz up your dash board.

THE JULY ISSUE IS ON SALE JUNE 4

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Overview of the newest equipment
Some example installations

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BUILD THE R-E ROBOT
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EDITORIAL

Why digital audio tape isn't here.

The biggest story—or should I say non-story—of the Winter Consumer Electronics Show was Digital Audio Tape or DAT. Several manufacturers—including Sony, Kenwood, Onkyo, and Mitsubishi—displayed prototype DAT players, and several more manufacturers—including TDK and 3M—displayed DAT tape. But the official word was that the units were prototypes only, and no marketing plans were in place.

Let's hope that following the Summer Consumer Electronics Show (which will be held from May 31 to June 3) we'll be able to announce the introduction of digital audio tape decks for consumer use. Why? Because DAT promises to do for audio tape what CD's have done for audio discs. And because the time—and the technology—is here to bring high-quality digital taping into the home.

Digital audio tapes are about half the size of a compact cassette, but slightly thicker. Yet a DAT cassette can provide two hours of recording time, and recording quality that rivals that of a compact disc. DAT cassettes are convenient: Digital codes stored on the tape permit relatively fast random addressing by program number. The cassettes are easy to handle, and the cartridge protects the tape from dust.

Unfortunately, the CD-player manufacturers and the recording industry don't want DAT, and they could kill the format before it even starts.

The manufacturers are afraid that DAT players would make consumers stop and think about whether they wanted to buy a CD player or a DAT machine—and perhaps buy nothing at all. The manufacturers fear that the introduction of DAT now would severely damage the CD market—and perhaps even kill the format.

That's nonsense! Both digital formats have a place, and each has its benefits. Compact discs are durable, and players can access tracks rapidly, in a user-programmed order. Digital audio tapes are not as durable, but they are more portable, and are much easier to handle in an automobile. And, of course, they offer recording capability.

The recording industry is worried about something else: piracy. DAT's recording capability is just so good that a copy would be indistinguishable from the original. They fear the loss of CD sales—and of pre-recorded digital audio tapes.

The RIAA (Recording Industry Association of America) wants anti-taping IC's to be incorporated into the DAT machines to prevent home recording of commercially recorded material. (The IC's would detect a special signal incorporated into the original recording.)

That would be a misguided effort: Home taping has nothing to do with commercial piracy. Such anti-taping IC's would destroy the main purpose of DAT—to make home recordings. But they would not stop commercial piracy—only prosecution will. Because of the huge illicit profits involved, pirates will find ways to beat anti-taping devices.

Undoubtedly, a black market would open up for home-deck conversions as well.

Home taping has become a consumer's right over the last 20 or thirty years. Recording a disc so you can conveniently listen to it in your car is transferring copyrighted material—which you bought the right to listen to—from one format to another. Making such format shifting illegal would be akin to selling recorded material for a specified number of listenings only, after which, you'd be violating a copyright.

Home cassette decks don't contain anti-taping IC's. Why should a new, superior technology be discriminated against? Doesn't it sound silly to prohibit DAT machines from recording just because they do a better job?

BRIAN C. FENTON
Managing Editor
The UnExpected HP-28C—
is this your next calculator?

A first report:

If you're at all like me, this is what you've been holding your breath for (in the calculator direction, of course). Just a few years back, calculators were exciting. Maybe once a year there was a new model that could do startlingly more. Not recently, however.

Now here's the next tantalizing toy and technical tool. I haven't got room here to do it justice, there are so many interesting features and specs for it. I'll sketch it for you, though . . .

You'll have ON-SCREEN MENUS and SOFTKEYS, just like a PC—sensible access to hundreds of functions (128K ROM) and high-level problem solving. Gamma function, random numbers, . . .

Complex numbers, matrices, vectors, lists, and algebraic expressions can be viewed, edited, and then used in calculations just as easily as ordinary numbers. Dot and cross products, determinant, . . .

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You'll do no programming to get solutions, either—it will solve for any unknown variable anywhere in your equation.

It will convert between different unit systems, too. The values of 120 units are built-in, and you can add your own. Are you ready for all this right now? (I have them in stock).

You'll use SEPARATE KEYBOARDS, the right hand one for NUMBERS and the left for LETTERS. Later, you can fold it to pop into your shirt pocket.

You can plot graphs of your functions, even two at a time. Then place the cursor near where the graphs cross and press a key to calculate the x-value of the crossing, correct to 12 digits. I was amazed.

Scatter plots of your statistical data are easy too. Imagine showing all this to your colleagues!

Plotting. Plot mathematical functions and statistical data; set plot scales, axes, and center; display graphics.


A major leap in technology—you'll do SYMBOLIC ALGEBRA, even SYMBOLIC CALCULUS. You'll manipulate unknowns and letters as well as numbers, even differentiate functions to get their derivative functions. This is the first small machine capable of doing symbolic mathematics, like MACSYMA on a mainframe, and it can be yours right now. (* Symbolsics, Inc.)

Symbolic Algebra. All real and complex number functions; expand, collect terms; expression editor; subexpression recall and substitution; symbolic solve; quadratic equations.

Calculus. Symbolic differentiation of arbitrary expressions; symbolic integration of polynomials; numerical integration of arbitrary expressions; Taylor series.

Programmability. You can use all of the built-in functions with your own menus and softkeys, plus sophisticated utilities.

Binary Integer Operations. Decimal, octal, hexadecimal, and binary bases; arithmetic; variable wordsize; bit shift and rotate, byte shift and rotate, arithmetic shift; logical operators; floating-point/integer conversion.

Programming Features. User-defined functions, local variables, indefinite nesting and recursion, IF ... THEN ... ELSE, FOR ... NEXT, DO ... UNTIL, WHILE ... REPEAT; halt, continue, abort, single-step, pause, read key, beep, display, error message, error number; set/clear/test 64 user flags; conditionals, logical operators; object type.

But you can't see the best part—Your HP-28C comes with a built-in InfraRed Printer Interface. This means no wires or cables to your portable thermal printer—just point your 28C at it and press a key for an instant record. Have your printer now, or get it later—your choice.

The HP-28C lists for $235.

It will be the world's standard for years to come. You're sure to get one sooner or later. Why not now? I have them in stock, and I'll give you a discount savings of $45 now.

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Order by mail: each HP-28C is $189.95; save $29 on each InfraRed Printer at $105.95 (Calif. residents add 6% tax). Add $4 for UPS delivery (no extra charge for multiple items). Allow 12 days for personal checks to clear, or send your MC/Visa number and card address.

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JUNE 1987
**Kodak introduces high-capacity, high-speed optical-disc system**

Eastman Kodak, long known for its leadership in the field of photography, is dramatically increasing its presence in the information-technology field with the introduction of an advanced optical-disc information storage and retrieval system. The 6800 optical-disc system is a high-capacity data storage and retrieval system that uses Kodak’s new 14-inch write-once/read-many-times optical discs. Each disc offers a capacity of 6.8 gigabytes of random-access on-line storage. The basic 6800 library unit consists of a single drive, controller, and 50 optical discs with robotic retrieval equipment in an environmentally controlled cabinet (a mini “clean room”). Three optional add-on units give the user the ability to increase the disc hardware and software capacity to up to 150 discs. At its maximum configuration, the system offers a total storage capacity of one terabyte (1,000 trillion bytes). For example, that is more than enough capacity to store 12 years of records of X-rays, CAT scans, and ultrasound examinations for a 250-bed hospital. Retrieval time for the system is 12 seconds or less.

Kodak’s Mass Memory Division will market the 6800 system on a limited basis in late 1987, and in quantity in 1988. It will not be sold directly to end users. “We will work through computer companies, original equipment manufacturers, and others, including business divisions within Kodak,” says Frank Strong, group vice president and general manager of Kodak’s Diversified Technologies. “These companies will integrate their equipment with ours and market specific products to end users.”

One such integrator will be Kodak’s own Business Imaging System, which will integrate the 14-inch optical discs into their line of KIMS systems. Such system are not inexpensive, however, with one, the KIMS 5000, expected to cost in the neighborhood of $700,000. Less ambitious KIMS systems will start at about $150,000.

**Descramblers and the law**

The Cable Home Group of General Instrument, manufacturer of the VideoCipher scrambling system, instituted a civil suit last March against Network, Inc., of Piscataway, NJ; Robert Cooper, Jr., well known to readers of this magazine; Dr. Stephen Bepko of Baltimore, and Karen Howes and Shaun Kenney of the Baresight satellite program. The suit charges them with distributing illegal descrambling IC’s at a “Descrambling Summit” trade meeting held in the British West Indies, and seeks damages including $5 million in “punitive damages” from the defendants.

Two of the defendants, Howes and Kenny, appear in a weekly television program distributed by satellite. Baresight is a 60-minute report on activities in the home dish industry, and has—as a matter of viewer information—listed sources outside the United States for VideoCipher IC’s.

Dr. Bepko is an electronics engineer who appeared as a lecturer at the summit. Cooper, the publisher of Coop’s Satellite Digest and a Radio-Electronics contributing editor, was the organizer of the meeting, which was held on the island of Providenciales.
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- DC current: 2mA - 2A, 4 ranges  
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CIRCLE 59 ON FREE INFORMATION CARD
**Kiddie camcorder.** We've seen all kinds of new VCR formats lately—8mm, Super VHS, 4mm, etc.—so why not a VCR that uses a standard audio cassette? That presumably is what Fisher-Price, the toy company, thought when it decided to introduce what it hopes will be next year's hottest Christmas gift for kids—a complete camcorder for less than $150. Pixelvision records 11 minutes (5½ minutes per side) of black-and-white video on a C-90 audio cassette. The one-piece unit contains a low-cost fixed-focus video camera and a record and playback deck that will run for five hours on six AA-size alkaline batteries. The entire package, including tape and batteries, weighs two pounds.

The secret behind the unit is that it uses a stationary head and lays down a longitudinal recording track; conventional decks use heads mounted on a revolving drum and lay down a helical track. The tape is recorded at a high speed, virtually equivalent to the fast-forward speed of an audio tape recorder.

Interestingly, Fisher-Price's recording method harks back to the earliest efforts to develop a videotape recorder, back in the 1940's and 1950's. Those early attempts were unsuccessful. But presumably a fixed-head recorder is practical today because of advances in head design, although Fisher-Price currently isn't giving out any technical details on Pixelvision.

**RCA Labs changes hands.** The David Sarnoff Research Center, informally known as "RCA Labs," isn't RCA Labs any more. The nation's leading electronics research organization has been donated as a gift to SRI International by General Electric, which is RCA's new owner.

The Sarnoff Center, in Princeton, NJ, was founded in 1941 to bring together research efforts scattered around RCA's various operations. It was a prime mover in the development of U.S. black-and-white and color television, stereo, injection lasers, high-speed computer memories, and videodiscs.

SRI International, formerly Stanford Research Institute, was originally part of Stanford University, but now is an independent research organization with headquarters in Menlo Park, CA. GE donated the Sarnoff Center to SRI because GE has its own research and development operations, and much of the work would be redundant. To get the newly independent lab off to a good start, GE plans to fund about $250 million in research, much of it in consumer electronics, over the next five years.

**Super VHS specifications.** Although relatively little still is known about Super VHS, the JVC-developed home-VCR format that can record and play back a picture of better-than-broadcast quality (Radio-Electronics, May 1987), JVC has released some specifications for the new system. Super VHS is capable of recording a signal with a horizontal resolution of better than 400 lines. It uses high-band circuitry with a carrier shift of 2.6 MHz in white-peak frequency; white-peak frequency is 7 MHz, as opposed to 4.4 MHz in standard VHS.

Outlining the recording method, JVC says: "Although Super VHS will use the same frequency-modulated recording method used in the conventional VHS format for luminance-signal recording, the FM frequency range has been changed from the conventional format's 3.4–4.4 MHz to 5.4–7 MHz. Frequency deviation has been changed from conventional VHS's 1 MHz to 1.6 MHz. To achieve overall high picture quality for video output signals, separated Y (luminance) and C (chrominance) signals are used in addition to NTSC signals currently used in order to eliminate interference between luminance and chrominance signals."

The tape used for Super VHS is coated with a cobalt-doped oxide and has a coercivity of 880 to 900 oersteds, as opposed to about 750 oersteds for the best standard VHS tapes. A special notch in the cassette tells the recorder that Super VHS tape is being used. The Super-VHS format will be used for camcorders as well as home decks, according to JVC, but only when sufficiently high-resolution pickup devices are available, so that the advantages of the new format may be applied to home-movie making.
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$69

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$99

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AIR IONIZERS

I've heard a lot about air ionizers and am wondering how effective they really are. What can you tell me?—T.L., Hamilton, OH.

Experience tells me to stay out of this one. Probably more arguments start with the discussion of air ionizers and positive and negative ions than on "the direction of current flow." But I'll try and give you an answer without putting my foot in my mouth.

Research on ionized air and its effects on humans, animals, and plants has been going on since the middle 1930's. Here are some of the "findings" and opinions:

- The concentration of ions in the air does have a pronounced effect on animals and plants. Also, the polarity of ionization has a distinct effect on life.
- Ion depletion is said to cause depression, mental fatigue, headaches, and respiratory problems in man, and has been shown to reduce the survival rate of animals.
- Increasing ion concentration promotes healing, relieves the pain of burns, and promotes plant growth.

- High concentrations of negative ions seem to promote mental agility and alertness and, over the long term, greatly reduce employee-days-lost due to respiratory illnesses.
- Positively charged ions tend to promote hostility and aggressiveness while negative ions promote tranquility.
- Atmospheric pollution in cities and industrial areas tends to promote a drastic depletion in air-ion concentration and to increase the critical positive-to-negative air-ion ratio. Perhaps that explains why

Fluke breaks the old mold.

Dollar for dollar the Fluke 37 breaks into the market with more features for the money than any other bench DMM. It's bold new design includes built-in handle and storage compartment, and it has all the high performance features of the world's best, most reliable 3½-digit DMMs.

Autoranging, to eliminate guesswork. Audible Continuity, so you don't have to look at the display. An exclusive analog and digital display. Superior EMI shielding. Plus a two-year warranty.

And, how many other bench/portable meters give you these features? Min/Max recording, for monitoring signals. 38 components dedicated exclusively to input protection. Relative mode, to help you calculate changes in readings. And Fluke's patented Touch Hold, to give you an extra set of hands when you're taking critical measurements.

None. Only the Fluke 37.

For more information call 1-800-426-0361.
Here's your chance to win a complete monitoring package from Regency Electronics and Lunar Antennas. 18 scanners in all will be awarded, including a grand prize of the set-up you see above: the Regency HX1500 handheld, the Z60 base station scanner, the R806 mobile unit, and a Lunar GDX-4 Broadband monitoring/refernce antenna.

55 Channels to go!
When you're on the go, and you need to stay tuned into the action, take along the Regency HX1500. It's got 55 channels, 4 independent scan banks, a top mounted auxiliary scan control, liquid crystal display, rugged die-cast aluminum chassis, covers ten public service bands including aircraft, and, it's keyboard programmable.

Compact Mobile
With today's smaller cars and limited installation space in mind, Regency has developed a new compact mobile scanner, the R806. It's the world's first microprocessor controlled crystal scanner. In addition, the R806 features 8 channels, programmable priority, dual scan speed, and bright LED channel indicators.

Base Station Plus!
Besides covering all the standard public service bands, the Regency Z60 scanner receives FM broadcast, aircraft transmissions, and has a built-in digital quartz clock with an alarm. Other Z60 features include 60 channels, keyboard programming, priority control, digital display and permanent memory.

Lunar Antenna
Also included in the grand prize is a broadband monitoring/reference antenna from Lunar Electronics. The GDX-4 covers 25 to 1300 MHz, and includes a 6 foot tower.

Grand Prize (1 awarded)
1. Regency Z60 Base station scanner
2. Regency HX1500 Handheld scanner
3. Regency R806 Mobile scanner
4. Lunar GDX-4 Antenna

First Prize (5 awarded)
1. Regency Z60 Base station scanner
2. Regency R806 Mobile scanner

Second Prize (5 awarded)
1. Regency HX1500 scanner

Contest rules: Just answer the questions on the coupon. (all answers are in the ad copy!) Fill in your name and address and send the coupon to Regency Electronics, Inc., 7707 Records Street, Indianapolis, IN 46226. Winners will be selected from all correct entries. One entry per person. No purchase necessary. Void where prohibited by law. Contest ends June 30, 1987.

1. The Regency Z60 is
   [ ] a digital alarm clock
   [ ] an FM radio
   [ ] a scanner
   [ ] all of the above
2. The Regency R806 is the world's first ________ controlled crystal scanner.
3. The Regency HX1500 features
   [ ] 55 channels
   [ ] Bank scanning
   [ ] Liquid crystal display
   [ ] all of the above
4. The Lunar GDX-4 antenna covers ______ to ______ MHz.

Name: __________________________
Address: ________________________
City: __________ State: ___ Zipcode: ______
I currently own ________ scanners.
Brands owned: __________

Send a photo (like this one of Mike Nikolich and his Regency monitoring station) and receive a free gift from Regency. Be sure to include your name, address and phone number.
suburbanites—breathing the clean country air—escape some of the health and mental problems suffered by city dwellers.

**SCA DECODER**

I am modernizing my old tube-type FM receiver and would like to add a solid-state SCA decoder so I can receive the programs that some FM stations transmit on a 67-kHz subcarrier. Can you provide an appropriate circuit?—J.C.M., Baldwin, NY.

I have found that replacing a high-performance vacuum-tube circuit with a solid-state version does not always ensure equal or superior operation. It should be done only when no alternatives are available. However, putting together a tube-type SCA circuit is impractical because of its high component count. Instead, use a solid-state circuit like the one shown in Fig. 1. That circuit uses a Signetics NE565 PLL (Phase-Locked Loop) as a detector to recover the SCA signal; the circuit is taken from that company's data sheet for the device. The input to the SCA decoder circuit is connected to an FM receiver at a point between the FM discriminator and the de-emphasis filter network.

The early tube-type SCA decoders that I'm familiar with have several resonant circuits that must be tuned and aligned. Since resonant circuits are not used in the circuit shown in Fig. 1, there will be some slight spill from a stereo station's main channel. The PLL, IC1, is tuned to 67 kHz by R7, a 5K potentiometer. Tuning need not be exact since the circuit will seek and lock onto the subcarrier.

The demodulated signal from the FM receiver is led to the input of the 565 through a high-pass filter consisting of two 510-pF capacitors (C1 and C2) and a 4.7K resistor (R1). Its purpose is to serve as a coupling network and to attenuate some of the main-channel spill. The demodulated SCA signal at pin 7 passes through a three-stage de-emphasis network as shown. The resulting signal is around 50 mV, with the response extending to around 7 kHz. R-E
A robot is a robot... was a robot. Until HERO 2000.

HERO 2000 is much more than a robot. It's a walking, talking 16-bit computer. With 64K ROM and 24K RAM expandable to more than half a megabyte. And a fully articulated arm with five axes of motion. Yours to program. Command. Modify and expand. Total system access and solderless experimenter boards provide almost limitless possibilities. Its remote RF console with ASCII keyboard gives total control. Available with three self-study courses. Backed by Heath Company, world leader in electronic kits.

Build your own HERO 2000. Or buy it assembled. Have fun learning skills that translate directly to the world of work.
THE POLAPULSE BATTERY

The article, "Using the Polapulse Battery," by Fred Blechman in the February 1987 Radio-Electronics was well-written, and the many unique properties of the Polaroid battery line were described very well. There were, however, a few small errors that we would like to correct.

The first paragraph should state that the P500 battery gives 100 mA for 12 hours, not 20 hours. The P70 battery was developed for use in the original SX-70 film. The 600 film pack, which usually must power an electronic flash as well as the camera, uses the new higher-power P80, as described correctly. The special contact described in the article is available from us, but only in minimum lots of 100 pieces. Under carefully controlled conditions only, the P100 battery has been successfully recharged; but under no circumstances should the P500 battery be charged.

Ameritoy has new address: 6039 West Washington Blvd., Culver City, CA 90232. Exergen has moved to 251 W. Central St., Natick, MA 01760; Sinclair no longer sells the P500 batteries at a loss, and a limited number of their TV sets are still available from A+ Computer Response, 69B Island St., Keene, NH 03431.

The article did not mention the Polaroid Safety Flasher, a compact amber flashing light that weighs just 4 oz., but which can be seen for over a mile, and runs over 4 hours on one P100 battery. Those are distributed by Consumer Products Source, 881 Dover Drive,
NEW! TurboScan™ Scanners

"Communications Electronics," the world's largest distributor of radio scanners, introduces new lower prices to celebrate our 16th anniversary.

NEW! Regency® TS-2A
Allow 30-60 days for delivery after receipt of order due to the high demand for this product.
List price $499.95/CE price $319.95

NEW! Regency® Z60-MA
List price $299.95/CE price $159.95/SPECIAL 3-Band, 40 Channel + No-scrambler

NEW! Regency® Z45-MA
List price $299.95/CE price $159.95/SPECIAL 6-Band, 45 Channel + No-scrambler

NEW! Bearcat® 800XT-MA
List price $499.95/CE price $289.95/SPECIAL 12-Band, 40 Channel + No-crystal scanner

NEW! Bearcat® 800XT-MA
The Under $100 XT Treasure 40 channels in two banks. Scans 15 channels per second. Size 9x14" x 1/2".

FREE! Radio Sweepstakes

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Learn robotics and you build this

New NRI home training prepares you for a rewarding career in America's newest high-technology field.

The wave of the future is here. Already, advanced robotic systems are producing everything from precision electronic circuits to automobiles and giant locomotives. By 1990, over 100,000 "smart" robots will be in use.

Over 25,000 New Jobs

Keeping this robot army running calls for well-trained technicians...people who understand advanced systems and controls. By the end of the decade, conservative estimates call for more than 25,000 new technical jobs. These are the kind of careers that pay $25,000 to $35,000 a year right now. And as demand continues to grow, salaries have no place to go but up!

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Now, you can train for an exciting, rewarding career in robotics and industrial control right at home in your spare time. NRI, with 70 years of experience in technology training, offers a new world of opportunity in one of the most fascinating growth fields since the computer.

You need no experience, no special education. NRI starts you at the beginning, takes you in easy-to-follow, bite-size lessons from basic electronics right on through key subjects like instrumentation, digital and computer controls, servomotors and feedback systems, fluidics, lasers, and optoelectronics. And it's all reinforced with practical, hands-on experience to give you a priceless confidence as you build a programmable, mobile robot.

Program Arm and Body Movement, Even Speech

Designed especially for training, your robot duplicates all the key elements of industrial robotics. You learn to operate, program, service, and troubleshoot using the same techniques you'll use in the field. It's on-the-job training at home!
Building this exciting robot will take you beyond the state of the art into the next generation of industrial robotics.

You’ll learn how your completely self-powered robot interacts with its environment to sense light, sound, and motion. You program it to travel over a set course, avoid obstacles using its sonar ranging capability. Program in complex arm and body movements using its special teaching pendant. Build a wireless remote control device demonstrating independent robot control in hazardous environments. You’ll even learn to synthesize speech using the top-mounted hexadecimal keyboard.

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NRI training uniquely incorporates hands-on building experience to reinforce your learning on a real-world basis. You get professional instruments, including a digital multimeter you’ll use in experiments and demonstrations, use later in your work. And you get the exclusive NRI Discovery Lab®, where you examine and prove out theory from basic electrical concepts to the most advanced solid-state digital electronics and microprocessor technology. Devised by an experienced team of engineers and educators, your experiments, demonstrations, and equipment are carefully integrated with 51 clear and concise lessons to give you complete confidence as you progress. Step-by-step, NRI takes you from the beginning, through today, and into an amazing tomorrow.

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WE’LL GIVE YOU TOMORROW.
Suites 14, Newport Beach, CA 92663.

The model rockets mentioned in the article are made by Estes Industries, Highway 50 West, Penrose, CO 81240, and use the P100 in their launcher to provide a sudden high-current surge to ignite the chemical engine. The battery is also being used in medical applications, ranging from the cardiac monitor in magnetic resonance imaging, to a portable defibrillator, to hospital thermometers.

Small quantities of the P100 and P500 batteries are available from Time Craft Industries, 1300 Galaxy Way, Concord, CA 94520. (In California, call 1-800-642-0232; those outside of California, should call 1-800-227-2480.)

FRED COHEN
PowerCard Corporation

TESLA, FATHER OF RADIO

I have followed with interest Radio-Electronics' "Antique Radios" column, but I was disappointed with the treatment of Tesla in the installment that appeared in the March issue. Far from being among the inventors "who worked with electricity, but were not involved with wireless," Yugoslav-born Nikola Tesla, as early as his lecture at the Franklin Institute, in Philadelphia, in March, 1893, suggested a system consisting of "an electrical oscillator, or source of alternating current," one of the terminals of which would connect to Earth, the other to "an insulated body of large surface." That, he thought, might be used to transmit "intelligence, or perhaps even power, to any distance....I am firmly convinced that this can be done and hope that we shall live to see it done."

Tesla continued, taking out several patents, and in 1899 gave a demonstration of radio remote control in Madison Square Garden, New York City. Model boats in a large tank were started, steered, and stopped by radio waves from a short distance.

If that is so, why then isn't Tesla hailed as the inventor of radio? Hugo Gernsback had the answer. In his article "Nikola Tesla, the Father of Wireless," written on the occasion of Tesla's death, (January 7, 1943) he says:

"By 1900 Tesla had patented a wireless system, much of which was used later to make commercial wireless possible....These very means were used much later by Marconi and others who appropriated Tesla's ideas.

"Tesla in due time brought suit against Marconi, but could not establish his patent rights in court and blamed his failure on the paucity of technical knowledge of the times, of the lawyers and the court. When, many years later, his language had become clear, even to a mediocre technician, his patents had run out. Nevertheless, there would have been no wireless transmission without Tesla's fundamental work."

Gernsback did not know it, but at that very time, proceedings that would rectify the injustice were under way. On June 21, 1943, the Supreme Court disallowed Marconi's fundamental patent, on the basis of "earlier work by Tesla" and others. It's a true pity that Tesla did not live six more months!

Not only did Tesla outline the concepts—he was active in developing the instruments used in practical work. He devised the rotary spark gap and was the inventor of the oscillating arc, later adapted and used by de Forest for phone and in much marine telegraphy. He pioneered the high-frequency generator, used by Fessenden in the first telephone broadcast, and which became the standard high-power transmitter until it was superseded by tubes in the 1920's.

FRED SHUNAMAN(former Editor, Radio-Electronics)

ENERGY STORAGE IN 2001

Here's an addendum to my article, "Energy Technology in the 21st Century," which began on page 107 of the May 1987 issue of Radio-Electronics:

Recently, a new superconducting oxide material has been discovered by two university research teams. That material maintains zero electrical resistance at temperatures as "high" as -150°F; contrast that with the maximum superconducting temperature of niobium-tin wire, which is -450°F, continued on page 29
Leader LCD-100 Portable DMM/Storage Oscilloscope

Here's a 200-kHz digital storage scope you can (almost) fit in your pocket.

HAVE YOU EVER WISHED FOR A COMPACT AND PORTABLE TEST instrument that combined the features of a digital multimeter with those of a storage oscilloscope yet weighed only about two pounds? Probably not—it sounds too good to be true. But Leader Instruments Corporation (380 Oser Avenue, Hauppauge, NY 11788) has developed just such an instrument: their LCD-100.

Not everyone needs an oscilloscope that can be held comfortably in the palm of his hand. But if portability is important to you, the LCD-100 is worth looking at. When you first see it, you’ll be tempted to say, "Gee, that's cute!" But when you look more closely, you’ll be impressed by what it can do.

Basic specifications

The scope has a bandwidth of 200 kHz, a vertical sensitivity of 10 millivolts/div, and a rated accuracy of ±4%. Its multimeter section offers autoranging measurements of resistance, voltage, and current. The input impedance is 1 megohm.

The oscilloscope display is a 64 × 192-pixel dot matrix LCD. The settings of the scope's controls are

A new Storage Oscilloscope with 5MHz sampling rate.

This instrument offers all the outstanding features of a state-of-the-art 20 MHz real-time oscilloscope. In addition, it provides digital storage capability for signals between 50ns and 5µs duration. Maximum memory is 1024x8 bits for each channel. A Dot Join feature permits linear interpolation between sample points. An X-Y recorder option and an optional GPIB interface allow full integration in automatic test systems. In many cases, the HM205-2 can easily replace considerably more expensive digital storage oscilloscopes.

Price incl. 2 Probes 888.–$

Demonstration of the excellent transmission performance of the HM205-2 in analog mode with a fast risetime 1MHz square wave signal. All HAMEG Oscilloscopes are specified to have less than 1% aberrations and overshoot.

This screen photo shows a 20kHz sine wave signal in storage mode. The screen resolution of 1024 x 256 points offers an outstanding display that can easily be compared to those found on analog instruments.

Write or call toll free 800 247 1241

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CIRCLE 62 ON FREE INFORMATION CARD
Dear Customer, From Drew Kaplan

Escort has ignored DAK’s second, one-on-one Maxon versus Escort radar challenge. And frankly, I’m fighting mad. I suppose they have a right to ignore me. But after referring to my challenge as only an “advertising gambit” and calling Maxon’s radar detector an off-shore, primitive, and bottom-end unit, I’d think they’d be glad to wipe us out in a head to head duel to the death.

But, I’m really mad for two other reasons.

**Mad Reason 1.** Road and Track Magazine held an independent general radar detector test in their September 86 issue. As far as I can see, Maxon beat Passport in Uninterrupted Alert, and Passport beat Maxon in Initial alert. Now to be fair, neither of us seem to have beaten the other by even 2 seconds at 55 miles per hour. So, we didn’t win or lose by much. And, Maxon’s $99° detector was tested against the $295 Passport, not the $245 Escort we challenged. What’s interesting is that Road and Track had nice things to say about Passport and even about Escort, which wasn’t even included in the tests any more.

Now, if you’ve been following DAK’s challenge, you know we’ve only been challenging Escort. If you’ve read Road and Track’s tests, you’ll be amazed when you read Boardroom Reports, which I’ve reprinted for you to the right. What’s really interesting is that it’s the exact same person in both publications.

Actually, Maxon did extremely well. Road and Track only used ‘over hill’ and ‘around curve’ tests because on straight-aways the differences weren’t worth describing. (Imagine that!)

It’s just as I’ve said in my challenge. I don’t think there’s much difference between Maxon’s and Cincinnati’s Radar detectors when it comes to sensing radar.

**THE CHALLENGE GROWS.**

In view of the opinions stated in the article in Boardroom Reports about the $245 Escort, DAK hereby adds the $295 Passport to our challenge.

**Mad Reason 2.** Did you ever hear about the cure for dandruff that was developed in the middle-ages? It was the guillotine. And frankly, I think you should be aware of Cincinnati Microwave’s advertising cure for the Rashid VRSS Collision Avoidance System.

The Rashid VRSS system, as described in Popular Science magazine, January 1986, sends out a radar signal on the K band ahead of your car. The good part is that it can help you avoid running into things higher than your front bumper. The bad news is that since it operates on K band, it sets off radar detectors.

Well, hats off to Cincinnati Microwave. I’ve tested the Passport against the Rashid unit and, as usual, they have done a splendid job. While every other detector I tested, including Maxon’s, was driven crazy, theirs didn’t utter a peep.

But then, my Maxon hasn’t uttered any peeps lately either and let me tell you why. I was on my way to the Far East to visit Maxon, so I asked Tom, a manager at DAK, to purchase and test the Rashid. Well, I ever hear from him. First the unit cost $558 plus about $100 to install. Then buying it and finding someone to install it took almost a month.

But the real reason he was unhappy was that the recommended method of installation involved cutting a 6½” hole in the front grill of his neat new car.

Well, much to my wife’s chagrin, it’s now installed in her station wagon.

After installation, it has to be set by an installer. He drives between 15 and 30 miles per hour toward a solid object. When the installer thinks he’s reached a safe stopping distance, he adjusts the warning alarms to sound. Then in the future, when a similar distance is reached, lights will flash and an alarm will sound. Of course, if you accelerate too quickly into a lane behind another car the same alarms can go off.

And, I haven’t figured out what to do if there’s a dog in the road, dirt on the radar sensor, or how to compensate for the different stopping distances encountered on dry, wet, icy or snowy roads.

**HINT IMPORTANT PART**

Speaking of advertising gambits, in virtually every magazine I pick up, I’ve been seeing Cincinnati’s Bad News for Radar Detector ads spelling out the obsolescence of all other detectors.

If it’s such an important feature that distinguishes them from us, there had better be some of these devices on the road, or Cincinnati Microwave’s credibility may just be on the road as well.

I will add $10,000 to my Escort/Passport challenge if Cincinnati Microwave can prove that there are even 1000 Rashid units on the road anywhere in the U.S. Oh heck, I’ll add $5000 if they can even find 500. (And, look at this.)

**NOTE:** There are several other potential collision avoidance systems on the drawing boards and each may have a DIFFERENT FINGERPRINT.

So, if you’re a current Escort or Passport owner, I suggest that you find out how many Rashid units there are and what Cincinnati Microwave will do about the “other” units before you pay $$$ to have your current detector upgraded.

Besides, with over 3,000,000 square miles in the U.S., even 1,000 units would work out to less than one unit for every 3,000 square miles.

If a major car company successfully sells a collision avoidance system, then Maxon will be ready. But, the car companies currently can’t even get consumers to pay $200 for air bags. So, you decide. Is it significant, or an advertising gambit?

Below is the NEW version of the challenge. Escort, a reply please!

---

**A $20,000 Challenge To Escort**

Let’s cut through the Radar Detector Glut. We challenge Escort & Passport to a one on one Distance and Falsing ‘duel to the death’ on the highway of their choice. If they win, the $20,000 check pictured below is theirs.

By Drew Kaplan

We’ve put up our $20,000. We challenge Escort to take on Maxon’s new Dual Superheterodyne RD-1 99° radar detector on the road of their choice in a one on one conflict.

Even Escort says that everyone compares themselves to Escort, and they’re right. They were the first in 1978 to use superheterodyne circuits and they’ve got a virtual stranglehold on the magazine test reports.

But, the real question today is: 1) How many feet of sensing difference, if any, is there between this top of the line Maxon Detector and Escort’s or Passport’s? And 2) Which unit is more accurate at interpreting real radar versus false signals?

So Escort, you pick the road (continental U.S. please). You pick the equipment to create the false signals. (Don’t forget our $10,000 Rashid challenge.) And finally, you pick the radar gun.

Maxon and DAK will come to your...
Challenge Continued

highway with engineers and equipment to

and yes, we'll have the $20,000
cHECK (pictured) to hand over if you beat
us by more than 10 feet in either X or K
band detection with the Escort, or by 2
seconds at 55mph with the Passport.

BOB SAYS MAXON IS BETTER

Here's how it started. Maxon is a mam-
moth electronics prime manufacturer.
They actually make all types of sophis-
ticated electronic products for some of
the biggest U.S. Electronics Companies.
(No, they don't make Escort's).

Bob Thetford, the president of Maxon
Systems Inc., and a friend of mine, was
explaining their new RD-1 anti-falsing
Dual Superheterodyne Radar detector
to me. I said “You know Bob, I think
Escort really has the market locked up.”
He said, “Our new design can beat theirs”.

So, since I've never been one to be
in second place, I said. “Would you bet
$20,000 that you can beat Escort” And,
as they say, the rest is history.

By the way, Bob is about 6'9” tall, so if
we can't beat Escort, we can sure scare
the know you what out of them. But, Bob
and his engineers are deadly serious
about this 'duel'. And you can bet that
our $20,000 is serious.

We ask only the following. 1) The public
be invited to watch. 2) Maxon's Engi-
neers as well as Escort's check the radar
gun and monitor the test and the results.

3) The same car be used in both tests.

4) We'd like an answer from Escort no
later than July 31, 1987 and 60 days
notice of the time and place of the con-

5) If Escort can prove that there are
1,000, or even 500 Rashid units in oper-
ation, we will present them with the
appropriate $10,000 or $5,000 check at
the beginning of the conflict. And, 6) We'd like them to come with a $20,000
check made out to DAK if we win.

HOW'S THIS FOR FAIR

Cincinnati Microwave will be deemed
the winner and given the check if either

Escort beats Maxon by 10 feet in both
uninterrupted and initial alerts, OR if
Passport beats Maxon by 2 seconds at
55mph in both uninterrupted and initial
alerts. So, DAK wins only if we beat both
Escort and Passport.

A tie will exist only if both the $295
Passport and $245 Escort fail to beat
Maxon's $99 Dual Superheterodyne
RD-1 Radar Detector.

SO WHAT'S
DUAL SUPERHETERODYNE?

Ok, so far we've set up the conflict.
Now let me tell you about the new dual
superheterodyne technology that lets
Maxon leap ahead of the pack.

It's a technology that tests each sus-
pected radar signal 4 separate times
before it notifies you, and yet it explodes
into action in just 1/4 of one second.

Just imagine the sophistication of a
device that can test a signal 4 times in
less than 1/4 of one second. Maxon's
technology is mind boggling.

But, using it isn't. This long range
detector has all the bells and whistles. It
has separate audible sounds for X and K
radar signals because you've only got
about 1/3 the time to react with K band.

There's a 10 step LED Bar Graph Meter
to accurately show the radar signal's
strength. And, you won't have to look at
a needle in a meter. You can see the Bar
Graph Meter with your peripheral vision
and keep your eyes on the road and put
your foot on the brake.

So, just turn on the Power/Volume
knob, clip it to your visor or put it on your
dash. Then plug in its cigarette lighter
cord and you're protected.

And you'll have a very high level of
protection. Maxon's Dual Conversion
Scanning Superheterodyne circuitry
combined with its ridge guide wideband
horn internal antenna, really ferrets out
radar signals.

By the way, Escort, we'll be happy
to have our test around a bend in the road
or over a hill. Maxon's detector really
picks up ambush go signals.

And the key word is 'radar', not trash
signals. The 4 test check system that
operates in 1/4 second gives you ex-
tr emely high protection from signals from
other detectors, intrusion systems and
garage door openers.

Note when the lid is up and X or K band
sounds explode into action, take care,
there's very likely police radar nearby.
You'll have full volume control, and a
City/Highway button reduces the less
important X band reception in the city.

Maxon's long range detector comes
complete with a visor clip, hook and
loop dash board mountings, and the power
cord cigarette adaptor.

It's much smaller than Escort at just
3½" Wide, 4¾" deep and 1½" high. But,
it is larger than Passport. It's backed by
Maxon's standard limited warranty.

Note from Drew: 1) Use of radar de-
tectors is illegal in some states.

2) Speeding is dangerous. Use this
detector to help keep you safe when you
forget, not to get away with speeding.

CHECK OUT RADAR YOURSELF
RISK FREE

Put this detector on your visor. When
it sounds, look around for the police.
There's a good chance you'll be saving
money in fines and higher insurance
rates. And, if you slow down, you may
even save lives.

If you aren't 100% satisfied, simply
return it in its original box within 30 days
for a courteous refund.

To get your Maxon, Dual Superheter-
odyne, Anti-Falsing Radar Detector risk
free with your credit card, call toll free or
send your check for just $999 ($4 P&H),
Order No. 4407. CA res add tax.

Special Note: Now that we're challenging
Passport, we've added an optional suction cup
windshield mount and extra coiled power cord.
(Sorry we can't afford to throw them in for free.)
They're just $59 ($1 P&H) Or. No. 4800.

OK Escort, it's up to you. We've got
$20,000 that says you can't beat Maxon
on the road. Your answer, please?

Escort and Passport are registered trademarks of Cincinnati Microwave. Rashid VRSS and Rashid Radar Safety Brake are registered trademarks of Vehicle Radar Safety Systems, Inc.
For Daisy Wheel, Dot Matrix & Ink Jet Printers

$899 Desktop Publishing Breakthrough

Imagine using a word processing and drawing program that lets you integrate charts and pictures that you ‘paint’ or ‘clip’ into your text. Well, if you use an IBM PC or Clone, now you can have graphically dramatic documents, from business or personal letters, to proposals, to organization charts, even with a daisy wheel printer.

By Drew Kaplan

It’s easy. It’s impressive. And, now your thoughts can be powerfully illustrated in both words and graphics.

After all, for illustrating abstract data and thoughts, nothing beats a dramatic chart or drawing. So, let your ideas leap off the page by using integrated text and graphics. Your thoughts are sure to make an impressive impact.

Whether you write letters, bank proposals, term papers, company manuals or news letters, you can forget complicated and expensive laser printing. And, you can forget complicated expensive desktop publishing programs.

Now for just $899, you can use your daisy wheel, dot matrix or ink jet printer to print normal test. Plus, you can integrate simply fabulous graphs and drawings into your creations.

INCREDIBLY EASY

Savtek, a brain trust group, has developed an easy to use yet incredibly sophisticated integrated word processing and graphics program.

Just create your letters, proposals, or reports as you would with any other word processor. In fact, if you already have a document created in virtually any other word processor, you can ‘grab’ it into Savtek’s instantly.

You’ll produce visually powerful technical papers and manuals with drawings and charts, and dramatic marketing reports with graphics. You’ll produce sales proposals with panache.

And since there’s no complicated training needed (if you can run a word processor, you can run Savtek), you’ll make great impressions, fast.

Anyway, once you’ve created the written part of your report, using Savtek’s sophisticated automatic word processing features, you’re ready to add pictures, charts and graphs.

Just select from the over 100 supplied changeable pictures or draw your own, using the automated ICON based drawing program.

Later, you’ll learn much more about the sophisticated drawing program that lets you draw, paint, fill, expand, reduce, copy, and move your pictures.

And, you’ll form squares, circles and triangles automatically. Anyone can draw with it because it’s totally automated and uses arrow keys and doesn’t require a mouse. But, read on.

Once you’ve selected a picture, the computer will produce an automatically sized box representing it. Just position the box wherever you want the picture to be in the text.

Like magic, the actual picture will appear and the text will automatically reformat itself around it.

And, speaking of reformatting, this program will automatically make page breaks and recalculate each page as you write or edit. If you make an addition to page 1 of a 10 page report, the effect will ripple through all 10 pages.

So, whatever length you’ve chosen for each page (including headers, footers and automatic page numbering), will automatically be preserved.

You’ll particularly like the cut and paste features of this word processing program which allow you to copy, move or delete sections of your text.

Of course you’ll have automatic Wordwrap, Hidden Hyphenation, Justified Smooth Right or Ragged Right text. Plus, you’ll have Find, Replace and Search.

And look how you can format your document. There are 5 page templates called rulers which allow you to automatically set up your page.

You can select any right and/or left margins, your tabs, one, two or three line spacing, and the number of blank lines at the top and bottom of your page.

Each of the 5 rulers comes with different default settings. But, you can adjust and save them or change them and even use several at one time on a page.

HOW DO THE PRINTERS WORK?

I use a daisy wheel printer because I like my letters to look personal. I’ve always had to switch to a dot matrix printer for graphs and illustrations.

Unfortunately, I couldn’t have my graphics on the same page as my text.

Now, because this program can use the period on the daisy wheel to create all the charts and graphic symbols you see within this ad, I don’t need to switch printers any more.

And while it doesn’t create the graphics as fast as a dot matrix, the quality is superb. Now my graphics can be impressively integrated into my text.

Note: Every single sample page shown in this ad, was printed out on my EXP 400 Silver Reed daisy wheel printer.

Note: This program does not produce two column news letters in a single action. Simply create a double length column and cut it when you’re finished.

No matter what printer you use, daisy wheel, dot matrix (with or without near letter quality printing) or ink jet (color or single color), you’ll have powerful looking documents to really present your ideas in the most effective manner.

DESKTOP PUBLISHING

Desktop publishing is about the hottest category of computer programming. It seems that everyone has discovered the impact of combining text and graphics. And very impressive presentations are just what Savtek’s ETG Desktop publishing system provides for you.

Imagine leveraging the capabilities of your own IBM or Clone, your own printer and your own keyboard to produce the documents you see on these pages, with nothing else to buy.

THE 1000 WORD PICTURE

First a confession. I can’t draw. That’s why you don’t see drawings in DAK’s catalogs. But I’ve been amazed at how creative I can be with this paint program.

It’s easy. You do everything with the arrow keys and the return key. By using the arrow keys you can draw in any direction with a choice of 12 brush shapes.

There’s an erase function to eliminate anything you don’t like. And here’s my favorite function. UNDO is a function that works throughout this program.

...Next Page Please
... Publishing Continued

It simply removes the last thing you did. So, no matter what you do wrong, you're a button away from removing it.

If you don't want a solid line, just spray an area. It's like using a spray can.

Let's say you want to connect two points with a straight line. Use the Angle Line. It produces a computer generated straight line between any two points.

What if you want a circle? Just touch the return key. Then use the diagonal arrow key to enlarge or reduce the circle. If you use the up/down or right/left arrows, you'll get an ellipse.

In the same way you can create squares, rectangles or triangles. And you'll be amazed how many things, from houses to technical drawings, are made up of squares, rectangles, circles and triangles.

But, that's not all. You can choose any of 32 background patterns to fill in enclosed areas or broad lines. And if 32 isn't enough, you can design your own.

There's so much more. You can juggle a picture. Imagine, turning it over or sideways with the touch of a button.

You can copy or move a picture or even part of a picture right on the screen. So, draw it once and copy it or move it.

But, here's my favorite. You can enlarge or reduce any picture or part of a picture right on the screen. So you can change its size equally, or you can stretch it out or make it tall and thin. Wow!

There are 12 included font/sizes. So you can have large or small type in your choice of styles within a picture or integrated with your text.

And, each of the 12 font/sizes can be shown on the screen and printed normally, in bold, in italic, in outline, or in shadow. Plus, you can write normally across the page, up the page, down the page or upside down.

Finally, you can zoom into any small section of the screen and edit your pictures, pixel by pixel. With this kind of power, you don't need to be an artist, just have the ability to push a button.

You can operate this Paint program independently. Or, you can access any picture from within word processing.

So, for banners and pictures, you can print directly from the Paint Program. Or, for everything previously described, simply access your pictures, captions, graphs or charts through the desktop publishing section.

This program is incredibly powerful, yet you'll be comfortable using it within just a few hours.

Every picture in this ad was created with this program. And, you haven't even seen the tip of the iceberg of its capabilities.

For example, picture on the screen, you can bring a second picture up and join them together.

WHO CAN USE THE SYSTEM

All you need is an IBM PC, AT, XT or 100% compatible with standard IBM CGA or EGA graphics capability. It must have at least 256K, and either two floppy drives or one floppy and a hard disk.

Below is a list of some of the dot matrix, ink jet and daisy wheel printers that have been tested with this program. If your printer is compatible with any of these printers, it should work too.

Special Note: Most dot matrix printers are Diablo 620/630 compatible, so they will work with this program.

Special Note: With a color printer you can print 3 colors plus black text.

CALL FOR LIST OF SAVTEK PRODUCTS

Call 800-272-9580 for a catalog of SAVTEK products. Or, contact your local supplier. Or, send in this coupon today to receive a free catalog of SAVTEK products.

Call 800-325-0800 For Toll Free Information, Call 8AM-5PM Monday-Friday PST

Call 1-800-272-9580 For Toll Free Information, Call 8AM-5PM Monday-Friday PST

To order SAVTEK's ETG Integrated Word Processing and Graphics Desktop Publishing System for your IBM PC or Clone, call toll free or send your check for the breakthrough price of just $8990 (S6 P&H) Order No. 4801. CA add tax.

Look at the 12 sample pages I created. You'll see graphs, pictures and charts mixed into my text. I even designed a logo for my newsletter. Just think about the impact you'll make when you present your ideas with a combination of text and graphics. And oh, it's so incredibly easy to use.

IBM is a registered trademark of International Business Machines.
**XEROX® 6064 PERSONAL COMPUTER**

**XEROX® ... They Set the Standards!**

For over 20 years Xerox® has been the world leader in office products and copying equipment. They have set standards that others can only imitate. The Xerox® 6064 Personal Computer was designed to meet the demands of business, professional, and personal computing today, and into the future! We are proud to offer this complete Xerox® System at a remarkably LOW price!

**Get the Xerox® Advantage!** The Xerox® PC offers you the advantage of running IBM® compatible MS-DOS so you can run the hundreds of business and professional software programs available today! And the Xerox® PC is easy to use! It’s designed to get you up and running as quickly as possible with computer-aided instruction and superior documentation covering all aspects of personal computing.

**Xerox® ... Service You Can Count On!** If you’re considering an IBM®-compatible, don’t be misled by price alone! The system we are offering is a complete system...very easy to hook up and use...and very affordable. But more than that, each system we sell is backed by Xerox® service and support. When you buy this system, your name and computer’s serial number is automatically registered with Xerox®. Should you need service or advice, a network of over 150 service centers stands ready to help you. Before you buy...compare! Xerox® is your best value! Check all these features:

- IBM®-PC/XT Compatibility.
- 256KB Memory Features an 8MHz Intel 8086-2 Microprocessor for Faster Speed, Less Waiting Time.
- Two 5 1/4" Floppy Disk Drives, 360KB Each.
- Seven Expansion Slots, Plus a Serial Port for Communications or Printer, and Parallel Printer Port.
- High-Resolution 640 x 400 Pixels. Monochrome Monitor, with 12" Diagonal, Non-Glare Screen, Swivel and Tilt Base.
- Standard 83-Key PC Keyboard with Mouse Interface (Mouse Not Included.)
- Comes with ScreenMate™, a User Friendly Guide to the Functions of the MS-DOS Operating System. ScreenMate™ is Menu Driven...No Need to Remember Complicated Commands!

**Complete Tutorial Software and Manuals Included:**

- Four Reference Guides.
- Four Software Programs: Two X-Cel™ Training Disks, Two Diagnostic Disks, GW™-BASIC Interpreter, and MS™, DOS/ScreenMate™ Operator’s Guide.
- Twenty Blank Disks.

**Over 150 Service Centers Nationally.**

**Manufacturer’s Limited 90-Day Warranty on Parts/Labor.**

**List Price**

$2224.80

**Priced At Only**

$999

**Memory Expansion Board for Xerox® 6064 Personal Computer:**

**List**

$249.00

**Priced At**

$129

SEND TO:
C.O.M.B. Direct Marketing Corp.
1405 Xenium Lane N/Minneapolis, MN 55441-4494

Send Xerox® Personal Computer(s) Item H-2483-7129-232 at $999 each, plus $49 each for ship, handling.

Send Xerox® Memory Expansion Board(s) Item H-2483-7128-978 at $49.00 each, plus $3.50 each for ship, handling.

(Minnesota residents add 6% sales tax. Sorry, no C.O.D. orders.)

Please call or write to inquire.

**Toll-Free: 1-800-328-0609**

Credit Card customers can order by phone, 24 hrs. a day, 7 days a week.
indicated on the left side of the LCD, leaving a 64 x 160 dot matrix to display the waveform on a 4 x 10-division graticule. The display measures about 4½ x 1½ inches and dominates the front panel of the LCD-100. (The entire front panel measures about 8¼ x 5½ inches, and the unit is 1½ inches deep.) The rest of the panel is broken into five major control groupings: vertical amplifier, sweep, trigger, memory, and DMM.

The vertical amplifier controls, on the bottom right of the panel include an AC-DC/GND input-coupling switch, a position control, and the vertical attenuator control. The vertical sensitivity can be varied from 10 mV/div to 20 V/div division.

The sweep controls of the LCD-100 are different from those of a conventional oscilloscope. The sweep rate can be varied (from 5 µs/div to 20 s/div in 21 steps) by using slow and fast pushbuttons. The selected rate is indicated on the scope’s display. An auto range button can be used to automatically select the timebase that provides an optimal display of input signals between 50 Hz and 200 kHz.

When the horizontal sweep is set at 50 ms/div or slower, the LCD-100 automatically switches to the roll mode, which turns the screen into a strip-chart recorder—without the paper, of course. If you see something on the display that you want to examine more closely, you can press the HOLD button to freeze the display.

The trigger controls include level, slope, and source, which operate as on any other scope. There are three trigger modes available: automatic, normal, and single-shot.

Now test and restore every CRT on the market... without ever buying another adaptor socket or coming up embarrassingly short in front of your customer... or your money back

with the new improved CR70 “BEAM BUILDER”™ Universal CRT Tester and Restorer Patented $995

Have you ever?
Thrown away a good TV CRT, data display CRT, or scope CRT that could have been used for another two or three years because you had no way to test or restore it?
Lost valuable customers because you advised them that they needed a new CRT when another technician came along and restored the CRT for them?
Lost the profitable extra $35 or more that you could have gotten for restoring a CRT while on the job and locked in the profitable CRT sale later?
Avoided handling profitable trade-ins or rentals because you were afraid you’d have to replace the picture tube when you could have restored it?
Had a real need to test a CRT on the job, but didn’t have the right adaptor socket or setup information in your setup book?

If any of these things have happened to you, CALL TODAY, WATS FREE, 1-800-843-3338, for a FREE 15 day Self Demo.

"BEAM BUILDER" is a trademark of Sencore, Inc.
The display position pushbuttons can also be used in the trigger mode to vary the amount of pre-trigger information—one of the benefits of digital storage scopes. It allows you to see transients that occur before the trigger.

Memory storage
Another advantage that the LCD-100 has over a conventional oscilloscope is the ability to store waveforms in non-volatile memory. In the field, that could prove to be a very convenient feature; the unit could be used as a sort of logging device, to store waveforms for later analysis. Conversely, reference signals could be stored before the unit was taken into the field for comparison against the device under test. An internal lithium battery holds the memory even when the main batteries die.

The LCD-100 isn’t only a digital storage scope: flipping a function switch transforms the scope into an autoranging DMM. Three input jacks (v, com, and mA/Ω) are located at the top right of the front panel. Three pushbuttons select either the voltage, resistance or current functions of the meter, and another pushbutton selects either AC or DC inputs (in the voltage and current modes) or standard or low-power resistance modes. The DMM has top ranges of 1000 volts DC, 750 volts AC (40 Hz–500 Hz), 320 milliamperes, and 32 megohms. Unfortunately, the the DMM section can’t be used at the same time you’re using the scope section, and it uses different probes.

We examined an early version of the LCD-100, and had only a preliminary instruction manual. Our rating chart, therefore, does not include a manual rating.

The LCD-100 will never replace your bench scope—but it doesn’t try to. Its $950 price should stop you from even thinking about buying it unless portability is the most important feature you need in a scope. As a portable scope, the LCD-100 is fantastic: It’s small, light, easy to use, and it’s designed for portability right down to its convenient carrying case.
and that’s quite a difference.

The new discovery should have a dramatic impact on the size and cost of superconducting coils. Household-sized units costing as little as $1500 are now feasible. Future developments may bring that cost even lower.

Dr. STEPHEN B. KUZNETSOV

ON ELECTRONS

I would like to make a comment on something in the March 1987 issue of Radio-Electronics. On page 61, in the article “The Evolution of VHSIC,” we read: “Electrons move through the IC at the speed of light.”

That is not true; only light travels at the speed of light. Electrons can be accelerated to very high speeds in a vacuum, but not to the speed of light. In a circuit, an electron’s motion is slower, because of collisions with atoms. Reducing the trace width moves the components closer together, thereby decreasing the number of time-consuming collisions.

JONATHAN E. DARMSTADT
Potsdam, NY

FROM A HOBBYIST

I have been a reader of the various Gernsback publications since 1946. They have gone through high and low periods of usefulness to both electronics professionals and hobbyists alike.

I would like to congratulate you on your present content and format. It is first rate: the magazine proves to be informative and impressive, without forgetting the hobbyist’s interests.

Particularly, I thank you for your PC Service feature. That innovative approach section makes it far easier for a hobbyist to fabricate his or her own circuit boards. I read several electronics magazines, and to my knowledge, Radio-Electronics is the only publication that has gone to the extent that you have done consistently, year after year, to help the builder. Keep up the good work and thank you.

J.L. BROWNING
Buena Park, CA

Walk “tough dog” troubles out of any TV & VCR in half the time... or your money back

with the exclusive, patented, VA62 Universal Video Analyzer...$3,295

Would you like to?

Reduce analyzing time: Isolate any problem to one stage in any TV or VCR in minutes, without breaking a circuit connection, using the tried and proven signal substitution method of troubleshooting?

Cut costly callbacks and increase customer referrals by completely performance testing TVs & VCRs before they leave your shop? Own the only analyzer that equips you to check all standard and cable channels with digital accuracy? Check complete, RF, IF, video and chroma response of any chassis in minutes without taking the back off the receiver or removing chassis plus set traps dynamically right on CRT too? Simplify alignment with exclusive multiburst pattern?

Reduce costly inventory from stocking yokes, flybacks, and other coils and transformers, for substitution only, with the patented Ringing Test. Run dynamic proof positive test on any yoke, flyback, and integrated high voltage transformer...in- or out-of-circuit?

Protect your future by servicing VCRs for your customers before they go to your competition? Walk out “tough dog” troubles in any VCR chrominance or luminance circuit — stage-by-stage — to isolate problems in minutes? Have proof positive test of the video record/play heads before you replace the entire mechanism?

Increase your business by meeting all TV and VCR manufacturers’ requirements for profitable warranty service work with this one universally recommended analyzer?

To prove it to yourself, CALL TODAY, WATS FREE, 1-800-843-3338, for a FREE Self Demo... or learn how the VA62 works first by calling for your free simplified operation and application instruction guide, worth $10.00.

Call Today Wats Free 1-800-843-3338

Sencore
3200 Sencore Drive
Sioux Falls, SD 57107 innovatively designed
605-339-0100 In SD Only with your time in mind.

CIRCLE 178 ON FREE INFORMATION CARD
NEw PRODUCTS

**RADAR DETECTOR**, the model G-300S uses microprocessor-based superheterodyne circuitry and a GaAs diode mixer to provide top sensitivity. That bonus extra edge provides maximum time for a driver to check speed and slow down if required.

Among its other features, the G-300S includes circuitry that analyzes incoming signals to eliminate false alerts. One circuit looks for and eliminates false alerts caused by other radar detectors in nearby vehicles. Another singles out the fixed frequency of police radar signals from random background signals. In urban areas, a six-second delay can be switched in to prevent triggering by weak X-band signals that may be caused by electronic door openers, security systems, etc. However, the unit responds instantly to strong signals. For full protection, full sensitivity is retained at all times for shorter range K-band signals.

Both audio and visual alerts are issued. The audio alert has a selectable volume level and features auto shut-off after four "beeps." It identifies the radar band via the alert’s tone. Visual alerts are issued using a bank of six LED’s. The LED’s flash in sequence, with the flash rate increasing as the radar source is approached.

Measuring only 3⅛" x 4¾" x 1", the unit is small enough to be carried around in a briefcase or a coat pocket; it can be easily hidden to prevent theft. The model G-300S carries a suggested retail price of $260.00—GUL Industries Corporation, 23970 Craftsman Rd., Calabasas, CA 91302.

**SATellite RECEIVER**, the model ESR924i, incorporates both an Earth-station receiver and an antenna-positioning system in one unit. It features priority view, which allows the user to pre-program up to 9 channels for instant viewing; parental lockout, whereby channels that parents do not want the children to explore can be locked out on the remote-control module; enhanced stereo,
which allows the user to choose either narrow or wide bandwidths for best audio reception; and positioning programmability, whereby the viewer sets the alphanumeric designations for the satellite wanted, and the dish moves into place automatically. The unit can be programmed for up to 21 channels.

The model ESR924i is priced at $980.00. — R. L. Drake Company, PO Box 112, Miamisburg, OH 45342.

MICRO-MINI RECORDER, records three hours (ninety minutes per side) on a special Angrom tape cassette (included). The unit has a detachable microphone for use with a tie clip. The recorder measures ¾ x 2 x 4 inches, and uses two AAA batteries. It also operates on AC power using an AC adaptor (which is included).

The Micro-Mini has two-speed capability with silent automatic stop; one-touch recording; tape counter, and many other features not found in other miniature recorders. Extras that come with the unit include tie-pin cord, microphone capsule, earphone, and carrying case.

The Micro-Mini is priced at

Excluding, triple patented dynamic cap and coil analyzing ... guaranteed to pinpoint your problem every time or your money back

with the all new LC75 “Z METER 2”
Capacitor Inductor Analyzer
Patented
$995

The “Z METER” is the only LC tester that enables you to test all capacitors and coils dynamically — plus, it’s now faster, more accurate, and checks Equivalent Series Resistance (ESR) plus small wire high resistance coils.

Eliminate expensive part substitution and time-consuming shotgunning with patented tests that give you results you can trust every time. Test capacitor value, leakage, dielectric absorption, and ESR dynamically; with up to 600 volts applied for guaranteed 100% reliable results — it’s exclusive — it’s triple patented.

Save time and money with the only 100% reliable, in- or out-of-circuit inductor tester available. Dynamically test inductors for value, shorts, and opens, automatically under “dynamic” circuit conditions.

Reduce costly parts inventory with patented tests you can trust. No more need to stock a large inventory of caps, coils, flybacks, and IHVTs. The “Z METER” eliminates time-consuming and expensive parts substituting with 100% reliable LC analyzing.

Turn chaos into cash by quickly locating transmission line distance to opens and shorts to within feet, in any transmission line.

Test troublesome SCRs & TRIACs easily and automatically without investing in an expensive second tester. The patented “Z METER 2” even tests SCRs, TRIACs, and High-Voltage Diodes dynamically with up to 600 volts applied by adding the new SCR250 SCR and TRIAC Test Accessory for only $148 or FREE OF CHARGE on Kick Off promotion.

To try the world’s only Dynamic LC Tester for yourself, CALL TODAY, WATS FREE, 1-800-843-3338, for a FREE 15 day Self Demo.

Call Today Wats Free 1-800-843-3338

SENCore
3200 SenCore Drive
Sioux Falls, SD 57107
605-339-0100 In SD Only

Innovatively designed with your time in mind.
RCA's SK Series Replacement Guide (SKG202E) is your one source for over 214,000 solid state replacements using 2,900 SK and KH types. Integrated circuits, thyristors, rectifiers, transistors, microprocessors — RCA has them all.

Likewise, RCA's Industrial MRO Guide (1K7862) lists over 4,000 devices that replace more than 21,000 JEDEC* and Commercial types. The Guide also includes Power MOS/FETs, QMOS Integrated Circuits, a combined index/cross reference, and a section on high-reliability devices.

Together, these RCA Guides provide fast, easy answers for 235,000 solid state replacement problems.

For copies, see your local RCA distributor. Or write: Sales Promotion Services, RCA Distributor and Special Products Division, 2000 Clements Bridge Rd., Deptford, NJ 08096-2088.

*Joint Electron Device Engineering Council

RCA SK Replacement Solid State
$179.00 plus $4.00 shipping and handling.—AMC Sales, Inc., Box 928, Downey, CA 90241.

**OPTICAL-CABLE FAULT LOCATOR.** The model 2138, handles single-mode fibers at 1300 nm wavelength up to 24-mile distances.

**CIRCLE 40 ON FREE INFORMATION CARD**

The locator has a dynamic range of 20 dB; attenuation can be measured to better than ±0.1 dB accuracy by positioning the dial cursors on the integral CRT display. The unit has ergonomic easy-to-use front-panel controls combined with a bright CRT screen and LCD. Splice- or connector-loss measurement is fully automatic.

Intended for use in the field, the portable device weighs only 17.6 pounds and measures 11.6" × 11.6" × 6". It can be powered from rechargeable batteries to provide a minimum of 3 hours’ continuous use.


**BAR-CODE READER**. The 300C, offers the user either single-code decoding or auto-recognition at the flip of a switch. In the single-code state, the unit decodes any one of the following: Code 39, the most common alphanumeric bar

**CIRCLE 33 ON FREE INFORMATION CARD**

with the SC61 Waveform Analyzer

Patented $2,995

If you value your precious time, you will really want to check out what the exclusively patented SC61 Waveform Analyzer can do for you. 10 times faster, 10 times more accurate, with zero chance of error.

End frustrating fiddling with confusing controls. Exclusive ultra solid ECL balanced noise cancelling sync amplifiers, simplified controls, and bright blue dual trace CRT help you measure signals to 100 MHz easier than ever.

Accurately and confidently measure waveforms from a tiny 5 mV all the way to a whopping 3,000 V without hesitation with patented 3,000 VPP input protection — eliminates expensive “front end” repairs and costly equipment downtime.

Make only one circuit connection and push one button for each circuit parameter test: You can instantly read out DC volts, peak-to-peak volts and frequency 100% automatically with digital speed and accuracy. It's a real troubleshooting confidence builder.

Confidently analyze complex waveforms fast and easily. Exclusive Delta measurements let you intensify any waveform portion. Analyze glitches, interference signals, rise or fall times or voltage equivalents between levels; direct in frequency or microseconds.

Speed your digital logic circuit testing. Analyzing troublesome divide and multiply stages is quicker and error free — no time-consuming graticule counting or calculations. Simply connect one test lead to any test point, push a button, for test of your choice, for ERROR FREE results.

To see what the SC61 can do for your troubleshooting personal productivity and analyzing confidence, CALL TODAY. WATS FREE, 1-800-843-3338, for a FREE 15 day Self Demo.

Call Today Wats Free 1-800-843-3338

3200 Sencore Drive

Sioux Falls, SD 57107

605-339-0100 In SD Only

innovatively designed

with your time in mind.

**CIRCLE 180 ON FREE INFORMATION CARD**
Today's world is the world of electronics. To be part of it, you need the right kind of training, the kind you get from Cleveland Institute of Electronics, the kind that can take you to a fast growing career in business, aerospace, medicine, science, government, communications, and more.

**Specialized training.**
You learn best from a specialist, and that's CIE. We're the leader in teaching electronics through independent study, we teach only electronics and we've been doing it for over 50 years. You can put that experience to work for you just like more than 25,000 CIE students are currently doing all around the world.

**Practical training.**
You learn best with practical training, so CIE's Auto-Programmed® lessons are designed to take you step-by-step, principle-by-principle. You also get valuable hands-on experience at every stage with sophisticated electronics tools CIE-designed for teaching. Our 4K RAM Microprocessor Training Laboratory, for example, trains you to work with a broad range of computers in a way that working with a single, stock computer simply can't.

**Personalized training.**
You learn best with flexible training, so we let you choose from a broad range of courses. You start with what you know, a little or a lot, and you go wherever you want, as far as you want. With CIE, you can even earn your Associate in Applied Science Degree in Electronics Engineering Technology. Of course, you set your own pace, and, if you ever have questions or problems, our instructors are only a toll-free phone call away.

**The first step is yours.**
To find out more, mail in the coupon below. Or, if you prefer, call toll-free 1-800-321-2155 (in Ohio, 1-800-523-9109). We'll send a copy of CIE's school catalog and a complete package of enrollment information. For your convenience, we'll try to have a representative contact you to answer your questions.

---

**Cleveland Institute of Electronics**
1776 East 17th St., Cleveland, Ohio 44114

YES! I want to get started. Send me my CIE school catalog including details about the Associate Degree Program. I am most interested in:
- [ ] computer repair
- [ ] telecommunication
- [ ] robotics/automation
- [ ] broadcast engineering
- [ ] medical electronics
- [ ] other

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Hundreds of Great Projects!

Would you like to build a miniature laser system or experiment with state-of-the-art optical fibers? You can master these and many other electrical circuitry challenges with this exciting new collection of columns (originally published in Popular Electronics. Communications. Electronic Design. or Modern Electronics magazine) by noted electronics author Forrest Mims III. All projects in this book were either designed by the author or adapted from manufacturers' application notes or other sources. Included are MOSFET analog & digital circuits, LED syllable decoder, optoelectronics, high-frequency communications, control & telemetry, radio control & remotely triggered camera, sensors, thermoelectronics, experimental circuits & more!

Forrest Mims' Circuit Scrapbook II $19.95 B-3001

Give your projects that pro finish at minimal cost!

SPEEDY BOXES

Quality plastic kit cases with PCB slots on all 4 sides; 4 screws & aluminum lid. Interior dimensions shown.

3" x 2 1/4" (H-2755) $1.95
3" x 2 1/4" x 1 1/2 (H-2753) $1.75
6 " x 3 1/4" x 1 1/2 (H-2751) $2.90

Same as above with ABS plastic lids (which add 3/16 to height)

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The 300C offers either an RS-232C serial or IBM keyboard interface, and the list price is $635.00, including a high-grade sealed-tip metal wand.—Peripheral Connections, 2190 W. 11th St., Eugene, OR 97402.

CAR VIDEO SYSTEM, the American Audio In-Dash Car Video System, features a stereo cassette player with auto reverse, AM-FM stereo radio, 50-watt sound system, digital readout, and digital clock, plus a 2" black-and-white TV set with zoom (enlarging the picture 30%) and a VCR input. The unit can be installed easily; for automotive in-dash applications, the system must be wired, so that the TV picture only works in the key's accessory position.

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The In-Dash Car Video System can be installed on any 12-volt system. It is priced at $299.00.—Boulder Electronics, 1325 Broadway - 222, Boulder, CO 80302.

PORTABLE PATTERN GENERATOR, the model LCG-409, is battery-operated and is designed to be a precision NTSC signal source for field adjustments to VTR’s, VCR’s, large-screen TV receivers and monitors, and other video systems, as well as for bench operations.

Housed in a metal cabinet measuring 8 x 3 x 10 inches, weighing approximately 6.6 lbs., including the four C cells for power, the unit features full-field 75% color bars, dot, crosshatch, and full raster sig-
continued on page 42
NEW IDEAS

Sound-effects generator

Here's a circuit that provides great fun for kids. It can generate a European police-car siren, bird noises, spaceship sounds, etc. In addition, it can be put to serious use as a doorbell, an alarm, etc. It's easy to build, uses readily-available parts, and is inexpensive.

How it works

A block diagram of the circuit is shown in Fig. 1. As you can see, the circuit consists of four parts: a binary counter, a D/A converter, a VCO, and an audio output amplifier. The speed at which the counter counts depends on the frequency of the output of the VCO, which in turn is determined by the output of the counter. That feedback loop is what gives this circuit its characteristic output.

Referring to the schematic in Fig. 2, the initial frequency of oscillation is determined by potentiometer R11. The VCO first oscillates at a relatively low frequency, and gradually picks up speed as the control voltage supplied by the D/A converter increases.

The D/A converter is simply the group of resistors R1–R8. When none of IC1's outputs is active, little current will flow into the base of Q1, so the VCO's control voltage will be low. As more and more counter outputs become active, base current increases, and thereby so does the VCO's frequency of oscillation.

The VCO itself is composed of IC2-a, IC2-b, Q1, and the timing network comprising D1–D4, C1, R10, and R11. The diode bridge functions basically as a voltage-controlled resistor.

The buffer amplifier is made up of the four remaining gates from IC2, all wired in parallel. Volume is sufficient for experimental purposes, but you may want to add an amplifier, speaker, or both.

Construction

Use any convenient means of wiring the circuit—point-to-point, wirewrap, etc. Layout is not critical; just be sure to connect the power supply to the IC's correctly.

Press S1; you should get a sound from the speaker. The sound you get will depend on the position of R11. To vary the effect, try tapping on S1.—Edwin B. Tupue
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continued from page 39

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The model 4444 is priced at $750.00.—ET&T Corporation, 3001 Redhill Avenue, 1-219, Costa Mesa, CA 92626.

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UNTIL RECENTLY, THE DIGITAL dashboard has been seen only in movies and custom show cars. Automobile manufacturers now incorporate digital displays in selected models, but only as an extra-cost option. But that leaves the rest of us in the dark—literally! So here's an inexpensive, easy-to-build tachometer for your car that displays engine speed in both analog and digital form. The circuit is versatile enough to be adapted for use as a speedometer; we'll show how to do so in a future issue.

Why did we provide both analog and digital displays? Mainly because a digital readout can be harder to read and interpret under rapidly changing engine speeds than an analog dial. After the circuit is calibrated, you can get a good idea of engine speed just by glancing at the gauge. After calibration, the digital readout will display accurately from 0 to 9990 RPM in increments of 10 RPM.

Theory of operation
The tachometer works by counting pulses from the distributor points for a period of time, and then scaling and displaying that number. The digital display has three significant digits; the forth (and least significant) digit always displays "0," so that RPM's can be read from the display directly.

Breaker-point frequency is determined by this formula:

\[ f = \text{RPM} \times \left( \frac{\text{Number of cylinders}}{120} \right) \]

For example, with a speed of 600 RPM on an eight-cylinder engine, breaker-point frequency is 600 \( \times \left( \frac{8}{120} \right) = 40 \) Hz. At 3000 RPM, it is 200 Hz.

Now let's use the 600-RPM value to establish how to display the correct value on the tachometer. With an input frequency of 40 Hz, the display must read 600. Because the least-significant digit is zero and the counter section controls only the three active digits, we need to end up with a value of 60 in our counter. With a time-base of 0.5 second (2 Hz), 60 pulses must be read within 0.5 second. Dividing 0.5 by 60 gives us 8.33 ms, the reciprocal of that is 120 Hz—the value we must feed the counter section to obtain the correct reading. So we must multiply the 40-Hz incoming frequency by 3. The circuit that does that will be described later.

Following the same procedure, we find that, to obtain accurate readings for a 4-, 6-, or 8-cylinder engine, the input frequency must be multiplied by a value of 6, 4, or 3, respectively.
Circuit overview
A block diagram of the circuit is shown in Fig. 1. After conditioning the noisy input signal, a PLL (Phase-Locked Loop) is used to multiply the incoming frequency by the value set by the cylinder-select switch (SI). The output of the PLL drives both the analog and digital sections that follow.

The BCD counter is the heart of the digital circuit; it counts the multiplied input signal. After a predetermined sampling interval, a latch pulse latches the number present in the counter at that instant. Immediately following the latch pulse, a clear pulse resets the counter so that counting may start from zero for the next sampling period. The readout is updated every 0.5 second. Figure 2 shows the circuit's timing diagram.

The latch and clear pulses that control the counter are derived from a crystal-controlled oscillator. The oscillator uses a 3.58-MHz TV color-burst crystal to generate a 0.5-second gate time that is stable over a wide range of temperatures.

To produce the analog display, the output of the PLL section is converted to a voltage by a frequency-to-voltage converter. That relative voltage is then displayed on a row of twenty LED's that are driven by a pair of bar-graph display-driver IC's.

Circuit description
The input-conditioning circuit, PLL, and timebase are shown in Fig. 3. Pulses from the points (or tachometer hook-up on an electronic ignition system), are fed through a coaxial cable to the input circuit. Waveshaping is accomplished by rectifying the pulses, filtering out spikes, and squaring the signal up by using a comparator with hysteresis. The input circuit limits the amplitude of the 200-300-volt pulses from the points to about nine volts in order to avoid damaging the PLL. Negative pulses are clipped by D1, and positive pulses are filtered by C1 and C2.

Pulses are next squared by IC1, an LM741 op-amp that functions as a comparator. The comparator uses positive feedback via resistor R6 to produce hysteresis, which helps square the signal.

The PLL section is made up of IC5 (a 4046), its associated circuitry, and IC6, a 4018 presettable divide-by-n counter. The setting of IC6 is what determines the PLL's multiplication factor. If IC6 is set to divide by 3, the output frequency of the PLL section will be locked at 3 times the input frequency. Switch SI determines the number by which IC6 will divide the PLL's output frequency.

The clock is built around an MM5369 17-stage programmable oscillator/divider (IC2); it uses a 3.58 MHz crystal to produce an output of 60 Hz. The 60-Hz output is then divided down to 2 Hz by IC3. The 50-millisecond latch pulse is produced by IC7-a; a delayed version of that pulse is generated by C11, C12, R14, R15, IC7-b, and IC7-c. The delayed pulse functions as the clear signal that was described earlier.

Now let's examine the digital display section (shown in Fig. 4). Counting, latching, and display multiplexing is done by IC9, an MC14553 three-digit BCD counter. The common-cathode LED segments are driven by IC8 (a 74C48); the LED's common cathodes are driven by the three PNP transistors (Q1-Q3).

The analog display (shown in Fig. 5) is based on a frequency-to-voltage converter IC12, an LM2917. It produces a voltage that is proportional to the frequency of the signal fed to its pin-1 input. That voltage is fed to the two bar-graph display drivers, IC10 and IC11, through potentiometer R34, which allows the display to be calibrated. The display drivers are cascaded to drive the 20 discrete LED's. Cascading is accomplished by referencing IC11's internal comparator reference voltage to the final reference voltage of IC10. Resistor R29 limits the amount of current the drivers must dissipate.

Construction
The tachometer is built on two PC boards, a display board, and a main board. The display board (Fig. 6) contains four seven-segment LED displays, twenty discrete LED's, and several current-limiting resistors. The main board (Fig. 7) contains the remainder of the circuitry. The PC boards can be made using the foil patterns shown in PC Service, or a set of boards with plated-through holes can be bought from the supplier mentioned in the Parts List. If you etch your own boards, be sure to solder both sides of the board wherever necessary. If possible, use machined-type IC sockets that don't have plastic bodies, as they can be soldered on both sides of the board easily.
PARTS LIST

All resistors are 1/4-watt, 5% unless otherwise noted.
R1—4700 ohms
R2, R3, R5, R12, R14, R15, R30, R33—10,000 ohms
R4, R7, R8, R10—100,000 ohms
R6—470,000 ohms
R9—22 megohms
R11—2.2 megohms
R13—1 megohm
R16, R17, R18, R27—1000 ohms
R19—R25—220 ohms
R26, R31—470,000 ohms
R28, R35—22 000 ohms
R29—50 ohms, 5 watts, wire-wound
R32—33,000 ohms
R34—10,000 ohms vertical trimmer pot
R35—2200 ohms

Capacitors
C1—0.22 µF disc
C2—0.022 µF disc
C3—0.01 µF disc
C4—10 µF, 16 volts, electrolytic
C5—33 pF disc
C6—22 pF disc
C7, C8, C15—1 µF, 16 volts electrolytic
C9—0.1 µF disc
C10—0.05 µF disc
C11, C12, C13—0.01 µF 001 disc
C14—0.022 µF mylar

Semiconductors
IC1—LM741 op-amp
IC2—MM5369 17-stage oscillator/divider
IC3—CD4518 dual synchronous up counter
IC4—CD4081 quad AND gate
IC5—CD4046 micropower phase-locked loop
IC6—CD4018 presettable divide-by-n counter
IC7—CD4001 quad NOR gate
IC8—74C48 BCD to 7-segment common-cathode display (Panasonic LNS160K, Digi-Key P351, P352, P353, & P354 may also be used)

Other components
S1—DP3T slide switch (CW Industries GP154-3013, Digi-Key SW115-ND)
XTAL1—3.58 MHz color-burst crystal
F1—1 amp slo-blow automotive fuse
P1—P2—0.1" 2-pin Molex connector

Note: The following are available from Dakota Digital, R. R. 1 Box 83, Canistota, SD 57012: Single-sided display board, $6.95; double-sided (with plated-through holes) main board, $12.95. All orders add $1.50 for shipping and handling. South Dakota residents and 4% sales tax.

When stuffing the display board, begin with the eight resistors and the three jumpers; then install the four seven-segment displays. Next, insert the twenty LEDs into their respective holes. Pay close attention to the polarity of the LEDs. The cathode for flat side goes toward the raw of holes at the lower edge of the board. After the LEDs have been set in place, carefully turn the board over and lay it down on a flat sturdy surface. Now position the LED's and the displays so they are the same height above the board. If they're not, the LED's must be inserted into their mounting holes further. After the LED's and displays are at the same approximate height, solder one lead of each LED to the board. Then turn the board over and align the LED's so they stand up straight and follow a smooth curve. Now finish soldering the LED's and set the display board aside.

The next step is to stuff the main board. Begin with the smaller parts: resistors and diodes. Next install the IC's. Because they're mainly CMOS IC's, the use of sockets is recommended, but not essential. If you don't use sockets, insert the IC's carefully, and solder only a few legs at a time to keep heat to a minimum. If sockets are used, install them now and insert the IC's later. Doing so will lessen any chances of static damage. Remember, if you don't use boards with plated-through holes, you'll have to solder most components on both sides of the board.

FIG. 3—THE TIMEBASE, INPUT CONDITIONING, and PLL circuits are shown here. Op-amp IC1 functions as a comparator that squares up the input signal for processing by the PLL.
Install the remaining components (capacitors, connectors, and transistors). The base or center leg of each 2N3906 is bent toward the flat side of the package; the transistor should rest about 1/4 inch off the board. Install the remaining parts on the board and double-check both boards for errors.

Mechanically, the boards are mounted back to back, separated by 1/4-inch stand-offs. Note that each PC board has a row of 35 holes along the lower edge. The boards were designed so that corresponding holes in each should be connected electrically using short pieces of bare wire. Trimmed resistor legs work admirably. If troubleshooting proves necessary, you can separate the boards by bending those wires carefully.

Before soldering the wires, connect the boards together using stand-offs and #6 hardware. Assemble the boards with the foil side of each facing that of the other. Then lay the assembly down and insert a bare wire through each hole in the top board and into the corresponding hole in the bottom board. Insert and solder several wires at a time, continue until all wires have been inserted and soldered.

**Testing**

After the two boards are stuffed and connected together, apply 12 volts to P2 using a power supply or battery. The three right-hand digits should display zero's, and the left-hand digit should show nothing. Also, no LED's should be lit. Now, using an audio-frequency function generator, apply a 9-volt peak-to-peak, 40-kHz squarewave to the junction of D4 (the 9-Volt Zener diode) and R2. If your generator cannot supply a squarewave with a DC offset, you may have to feed the test point through a 1K resistor and use a higher-amplitude signal.

Set the cylinder-select switch to 8. The readout should now display something close to 600. Change the cylinder-select switch to 6; the display should read 800. Last, set the switch to 4; the display should read 1200.

Now we'll calibrate the analog display. Set the cylinder-select switch to the setting you plan to use. Next, set the generator to the frequency that will produce the "redline" RPM reading for your engine (i.e., the speed above which the manufacturer recommends you not run the engine). For an eight-cylinder engine, that speed is typically 5000 RPM. When the redline reading is obtained on the digital readout, adjust R34 so the first red LED lights up. The tachometer is now calibrated and ready for installation.

**Installation**

First decide where the tachometer will be installed. You'll have to find a spot that provides a good view, that doesn't interfere with pre-existing components, and...
FIG. 6—STUFF THE TACHOMETER'S MAIN BOARD as shown here. Use clipped resistor leads to make the connections to the display board.

FIG. 7—STUFF THE DISPLAY BOARD as shown here. The flat side of each LED should point toward the bottom of the board. The two boards are sandwiched together, and corresponding pads on the boards are connected with short pieces of stiff wire.

Conclusions

The circuit can be used in a car, truck, boat, or wherever an accurate and reliable tachometer is needed. If you're interested in adding other digital display equipment to your car, see the July, August, and September 1983 issues of Radio-Electronics. Those issues contain circuits for displaying voltage, water temperature, and oil pressure in digital form. In addition, the circuit shown here can also be adapted for use as a speedometer—we'll show you how to do it next time.
Part 2

Last month, we showed you how to turn a car radio into a fine home receiver. But perhaps you're tired of hearing the same old music, news, and sports from your local stations. If so, take heart! This month we're going to show you how to build a shortwave converter that will let you hear the latest news from the places where it happens, while it happens. With it, you'll also hear the kinds of music and cultural events that are popular in many faraway places.

Our converter adapts any analog (dial type) AM car radio to receive international shortwave stations. It covers the two most popular bands, namely 49 (6 MHz) and 31 (9 MHz) meters, plus WWV (5 MHz); WWV is a frequency measurement service that also broadcasts time signals, making it great for setting your household clocks very accurately, among other things.

But why is using a converted car radio so important to this project? First, as outlined last time, those radios feature sensitivity and selectivity that is superior to what is offered by conventional home radios: a car radio modified for home use and outfitted with our shortwave converter will provide performance that is far superior to that of the low-cost multiband radios often seen at discount stores. Also, car radios are well shielded, so noise pickup is reduced resulting in quieter reception.

Considering those advantages, and the ease and low cost of converting a car radio to home use (as demonstrated last time), using a modified car radio for this project makes perfect sense.

Exploring the bands

If you've never listened to shortwave radio, you are probably wondering about the stations that you might discover and their programs. Of course, what you hear will vary due to broadcast conditions and what time of day you tune in; but here is a typical sample of what to expect: Radio HCJB (Ecuador), the BBC (UK) and Radio Deutsche Welle (Germany) offer music and news programs with a perspective not heard on U.S.-broadcast news reports. Other stations that you may find interesting include the Voice of Free China (Taiwan), Radio Havana Cuba (Cuba) and the Voice of America (U.S.). Those stations also offer music and cultural-affairs programs that are very entertaining. Surprisingly, those stations, and many more, were heard using only the equipment described here, plus a 4-foot antenna!
How it works

The circuit downconverts signals from WWV, 49 meters, and 31 meters to frequencies in the AM-broadcast band. With it, it is possible to tune in worldwide shortwave stations just like the conventional AM broadcasts you normally hear on your radio. A block diagram in Fig. 4 shows the basic details of the converter circuitry.

The shortwave converter consists of a mixer and crystal oscillator circuits. The mixer combines signals picked up by the antenna with a locally generated signal. The result is output signals in the 540-1600 kHz range; those are the frequencies that are normally received by the car radio.

The local signal is generated by the oscillator. Three crystals, 4 MHz, 5 MHz, and 8 MHz, are used to provide coverage of the bands previously mentioned. Selection of the appropriate crystal, and hence the band to be received, is done using a three-position switch, S2.

Now that we know how the converter works, let's examine the circuitry in a little more detail; a complete schematic is shown in Fig. 5.

Signals from an antenna are input to the circuit via J1, a five-way binding post. A three-pole switch, S1, is used to select or bypass the converter. When that switch is in the broadcast position, your radio will operate as normal; in the shortwave position, power is fed to the converter (via S1), and shortwave frequencies are then easily received.

Assuming that shortwave reception has been selected, signals first feed to a tuned circuit made up of L1, L2, and capacitors C1-C3. That circuit is set to pass only the frequency of interest and reject all others. The circuit is included to pre-
vent AM-broadcast signals from reaching the radio and causing interference. Capacitor C1 should be peaked for best reception once the circuit is fully assembled and tested.

The output across C3 is fed to the mixer circuit, which is built around Q1, a dual gate MOSFET that functions as an RF amplifier and mixer, thereby reducing the number of parts required.

The local oscillator signal from Q2 is also fed to the mixer, via capacitor C7. The mixer output appears across L3 and R4 and is coupled to the output via C6. Resistor R4 limits the output level; it is needed because strong signals could otherwise cause distortion in the radio.

The local oscillator circuitry is simple and straightforward. It uses a standard Colpitts oscillator circuit built around Q2, with C8 and C9 providing feedback for oscillation. Crystals XTAL1–XTAL3 provide the proper operating frequencies as described earlier.

That about does it for the theory. Let’s get started with construction.

Building the converter

The circuitry is simple, and easy to build, too. As we’ve shown, only two transistors and a few other assorted parts are used. While we’ve provided a PC pattern (see PC Service) and a placement guide (see Fig. 6), they are not strictly required. If you wish, you could wire up the circuit on a small piece of perforated construction board with good results. And best of all, no alignment of any kind is needed. That is great news for those of us who lack an RF test generator.

Probably the only hard-to-find part in the project will be variable capacitor C1. Those units are becoming scarce, because many of the original manufacturers are out of business. Try surplus stores for C1, or else substitute a higher-value unit. A 100-pF capacitor should work fine.

The semiconductors aren’t too critical. Other MOSFET’s, such as members of the 3N200 series, can be used if the RCA 40673 isn’t available; the RCA component is preferred, however, since it is overload-resistant. For Q2, most garden-variety silicon NPN transistors such as the 2N3904, 2N4124, and others, should work just as well.

The coils may be almost any type available, providing that the inductances are the same. The miniature units specified were used simply because they were handy.

As for the crystals, low-cost computer types were used here; there is no need to order them custom made and wait for delivery. You can use surplus units of slightly different frequencies, if desired; all that will do is to change dial calibration on the car radio. However, with the values specified, 5 MHz (WWV), 6.0 MHz (49M), and 9.0 MHz (31M) tune in at exactly 1000 kHz on the radio. That is desirable, because it makes finding specific frequencies easier.

Mowing on, the rest of the parts aren’t especially critical. But you should assemble the project in a metal project box to avoid pickup of local AM-broadcast signals.

The switches may be any combination of rotary or toggle types available.

Once you have all of the parts it’s time to start construction. Here are some suggestions to help you do the job:

At this point there are two possible routes: First, you can turn to PC Service and fabricate the board for this project shown there. Otherwise you can mount the components on a 1.5- × 3.5-inch piece of perforated construction board and use point-to-point wiring.

If you choose to go the PC-board route, a parts-placement diagram is shown in Fig. 6. Those using point-to-point wiring will find that diagram useful, too; for best results we recommend following roughly the same layout on the perforated construction board.

Start construction by winding coil L1. This is an easy task. Simply wind four turns of 28-gauge magnet wire over one end of L2. Then twist the wire ends together to hold the coil in place, secure the coil with nail polish, and let dry. Finish up by untwisting the wires and then tinning the ends.

Continue by installing the major components, such as the coils and crystals, on the board as shown. Then follow with the resistors and capacitors; be sure to keep all leads as short as possible. When done, install the semiconductors. Note carefully the tab positioning on Q1 and the flat side of Q2. Finish up by checking your work and correcting any errors.

Set the assembled board aside for a moment and prepare the aluminum box. Refer to Fig. 7 for a suggested panel layout, then drill your box accordingly. No dimensions are given for the layout because it will vary with the sizes of the parts you are using. Although not shown, you’ll also have to drill a mounting hole for J1, as well as a hole for the output cable and the power lead; those holes should be located on the rear panel. When all holes are drilled, mark the functions with pressure labels and coat the box’s exterior with clear plastic spray.

When the cabinet preparation is complete, mount C1, S1, and S2 on the front panel, and J1 on the rear panel. After that, install the board in the enclosure. Use ¼-inch spacers and 4-40 hardware to secure the board in place. Be sure to install the knobs, too. Note that on C1, the pointer should be in the 9-o’clock position when the capacitor plates are fully closed.

Wire the board to the cabinet-mounted components using using stranded hookup wire; be sure to cut each wire as short as possible. Don’t forget to install the bypass wire between S1-a and S1-b, and install a 3-foot length of hookup wire at S1-c for power. Feed that wire and a length of RG-59 coax through the rear-panel hole intended for that purpose. Solder the coax’s center conductor to S1-b and the braid to ground. Attach plug PL1 to the other end of the cable and you are finished!

Using the converter

The unit is easy to hook up. Simply plug PL1 into the antenna jack of your car radio. Then connect the power lead to the power supply (as described last month). After that, connect a short antenna to binding post J1. A simple antenna such as a 4-foot piece of hookup wire should be sufficient.

Set switch S1 to the broadcast position and turn on the radio; you should hear regular AM-broadcast stations as before. Then set the band switch, S2, to the WWV position and turn S1 to the short-wave position. Tune your radio carefully around 1000 kHz and you should hear the WWV time clicks at least weekly. Adjust C1 for maximum volume and then you are all set!

Reception on 49 and 31 meters works the same way. Set the band switch to the band of interest, then tune in stations from 1000 to 1600 kHz on your radio. Adjust C1 for maximum volume on each station. That’s all there is to it, so enjoy!
PHONLINK
INTERACTIVE REMOTE CONTROL

Rule the world by telephone!

GENE ROSETH

Part 2 Now that we know a little bit about how our telephone controller works, it's time to look at the circuit in greater detail. So let's get to work.

Circuit details

Figure 5 shows the microprocessor section. The EPROM (IC6) is enabled whenever a read is done to the Z80's memory (not I/O) space. Note that there is no RAM in the system; the abundance of Z80 registers and some careful programming have allowed us to dispense with RAM and associated address decoders.

The gates in the lower-left corner of the schematic (IC4-c-IC4-f, IC5-a, IC5-b, IC7-c, IC7-d) decode the I/O space for the speech synthesizer, the PIO, and the ADC. The Z80's clock input is driven via the clock output of the Touch-Tone decoder (shown in Fig. 6).

Figure 6 shows the analog interface circuitry. Data to the speech synthesizer and from the ADC is transferred via the data bus; data from the Touch-Tone decoder is transferred via the PIO. The control inputs of the analog switch are driven by the PIO and serve to connect the appropriate signal source to the telephone-line interface circuitry via terminal U13.

The speech synthesizer is a complex device that can be viewed as a storehouse of fundamental speech sounds called phonemes. The microprocessor causes the speech synthesizer to output individual phonemes along with appropriate delays to form complete words and phrases.

FIG. 5—THE CONTROLLER IS BASED ON A CMOS Z80; THE DESIGN USES NO RAM EXTERNAL TO THE Z80!
The ADC is a successive-approximation type; the resistive voltage divider connected to each of the first seven inputs (pins 1–5 and 26–28) is in the proper ratio to allow the microprocessor to translate a 0–5-volt input to a 0–100 percent output. For other input-voltage ranges, those resistors must be changed accordingly. The eighth input is connected to IC9, a precision current reference that produces a voltage proportional to ambient temperature.

Turning to Fig. 7, note first of all that there are two separate five-volt power supplies, one for the analog and one for the digital circuits. Now you know why the power connections to some IC’s in the previous figures are labeled ±Vdd and to others, ±VA. The analog and digital grounds are connected together, but only at one point: analog and digital ground runs around the board are separate.

The remainder of the circuitry provides the telephone-line interface. Line isolation is achieved through the use of optoisolators. Opto-isolator IC16 and its associated passive components comprise the ring detector. Each time a ring occurs, a negative-going pulse is generated at pin 5 of IC16; that pulse is applied to pin 2 of IC13-a. The output of that op-amp is then applied to the PIO where it can be detected by the CPU.

Driving the remainder of the interface is BRI, a fullwave bridge rectifier that ensures proper operation of the controller even if the controller is connected to the phone lines backwards. Relay RY1 serves as the hook switch, which is equivalent to the cradle switch on any telephone. The relay is controlled by Q1, which in turn is controlled via the PIO by the Z80.

A closed-loop feedback circuit is composed of IC12, IC17, IC19, IC13-c, and the C9/R16 lowpass filter; that circuit compensates for temperature drift. The data or voice signal is modulated onto the phone line by IC13-c and IC19, but the rest of the feedback loop is needed for stability and to optimize the operating point of IC19. The purpose of IC18 is to detect the disconnect pulse from the tele-

---

**WARNING**

PLEASE NOTE THAT, ALTHOUGH THE CONTROLLER PRESENTED HERE HAS BEEN DESIGNED TO MEET THE INTERFACE REQUIREMENTS OF THE TELEPHONE SYSTEM, IT IS NOT FCC TYPE-APPROVED. CONNECTION OF SUCH A DEVICE TO YOUR OPERATING COMPANY’S LINE IS SUBJECT TO THE REGULATIONS OF THAT COMPANY. IT IS YOUR RESPONSIBILITY TO ASCERTAIN THE PERTINENT REGULATIONS FOR YOUR AREA.

---

**TABLE 1—I/O CONNECTIONS**

<table>
<thead>
<tr>
<th>Function</th>
<th>Pin Number</th>
<th>SO1</th>
<th>SO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-cancel</td>
<td></td>
<td>31</td>
<td>1</td>
</tr>
<tr>
<td>function 2</td>
<td></td>
<td>29</td>
<td>2</td>
</tr>
<tr>
<td>Self-cancel</td>
<td></td>
<td>29</td>
<td>2</td>
</tr>
<tr>
<td>function 1</td>
<td></td>
<td>29</td>
<td>2</td>
</tr>
<tr>
<td>Output 4</td>
<td></td>
<td>27</td>
<td>3</td>
</tr>
<tr>
<td>Output 5</td>
<td></td>
<td>25</td>
<td>4</td>
</tr>
<tr>
<td>Output 1</td>
<td></td>
<td>23</td>
<td>5</td>
</tr>
<tr>
<td>Output 2</td>
<td></td>
<td>21</td>
<td>6</td>
</tr>
<tr>
<td>Output 3</td>
<td></td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Ground</td>
<td></td>
<td>*</td>
<td>8</td>
</tr>
<tr>
<td>Input 3</td>
<td></td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Input 2</td>
<td></td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Input 1</td>
<td></td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Input 4</td>
<td></td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td>Input 5</td>
<td></td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>Input 6</td>
<td></td>
<td>17</td>
<td>14</td>
</tr>
<tr>
<td>Input 7</td>
<td></td>
<td>19</td>
<td>15</td>
</tr>
<tr>
<td>+5 volts, 200 mA</td>
<td></td>
<td>33</td>
<td>16</td>
</tr>
</tbody>
</table>

*All even numbered pins are grounded.

**Note:** Pin 1 and pin 9 are not connected.
FIG. 7—THE POWER SUPPLY AND TELEPHONE-LINE INTERFACE are shown here. There are separate supplies for the analog and digital circuits.

Software
The controller’s software is written in Z80 assembly language; it comprises about 1800 lines of code. Due to space limitations, we can’t print the listing here, but we have posted it on our BBS. The file is called PHONLINK.AQM, and it has been squeezed, so you’ll have to unsqueeze it to use it.

LISTING 1

*ENTER8* MCOULE

ENTER8 LO A,04H ;PA5
OUT (SPCHPT),A ;PRE-DELAYS
OUT (SPCHPT),A ;
OUT (SPCHPT),A ;
OUT (SPCHPT),A ;
OUT (SPCHPT),A ;
LD HL,RTRN85 ;
JP ENTER ;"ENTER"
RTRN85 LO HL,RTRN86 ;
JP EIGHT ;"EIGHT"
RTRN86 LO HL,RTRN87 ;
JP TWO ;"TO"
RTRN87 LO HL,RTRN88 ;

phone exchange if the caller hangs up. That pulse causes an interrupt to the microprocessor, which then terminates the current session, re-entering the program near the top of the flowchart that was shown in Fig. 1 last time (Radio-Electronics, May 1987).
To get an idea of how we use the Z80’s registers rather than RAM to store subroutine return addresses, examine the routine in Listing 1.

The routine shown there causes the speech synthesizer to say “Enter eight to end or seven to repeat.” After executing several delays (by outputting a 4 to the speech port), the address of the routine that speaks the word Enter (RTRN85) is loaded in the HL register. Then the program jumps to the routine that pronounces the word.

That routine returns to the location pointed to by HL—the next line in the routine shown in Listing 1. It in turn calls the routine that speaks the word eight and continues in the same manner.

Construction

Use of a PC board is not absolutely necessary, but is strongly recommended, in order to minimize crosstalk and other problems. The commercially available PC board is double-sided, has plated-through holes, and is silk-screened, which greatly simplifies construction. Alternatively, you can etch your own board using the patterns shown in PC Service.

To stuff the board, follow the part-placement diagram (shown in Fig. 8). Observe all polarity markings and make sure that the transformer is mounted correctly! Mount IC20 (the 7805 regulator that supplies power to the digital circuitry) on the rear panel of your case, or some other heatsink. The power-on indicator (LED1) and the microphone (MIC1) should be inserted through holes in the front panel. Don’t forget to solder the two jumpers in the desired positions.

Interfacing

There are two basic approaches to interfacing the controller with external circuitry. The simpler method, which is suitable for small, low-power circuits, is to mount a small piece of perfboard inside the cabinet. The board can be secured to the top half of the cabinet with #4 screws. DIP connector SO2 on the main board allows an easy interface to the user board. The pinouts of SO1 and SO2 are shown in Table 1. The wires connecting the user board to the real-world inputs and outputs
All resistors are ½-watt, 5% unless otherwise noted.
R1—100,000 ohms
R2—250 ohms, 1%
R3—10,000 ohms, 1%
R4, R17, R24, R27, R32, R34, R35—10,000 ohms
R5—R8, R19, R36, R40, R42, R44, R46, R48, R50, R52, R55—33,000 ohms
R10, R15, R38—47,000 ohms
R11, R12, R14—1000 ohms
R13, R20, R21—220,000 ohms
R16, R28, R54—1 megohm
R18, R25—22,000 ohms
R22—330,000 ohms
R23, R30, R31, R33—100,000 ohms
R26—100 ohms
R29—150 ohms, ½-watt, 5%
R37—470 ohms
R39, R41, R43, R45, R47, R49, R51—51,000 ohms
R53—39,000 ohms
R56—150 ohms

Capacitors
C1, C6, C13–C15, C17–C22—0.1 µF, ceramic disc
C2, C8, C10—1 µF, 16 volts, electrolytic
C3, C4—0.022 µF, ceramic disc
C5, C11—10 µF, 16 volts, electrolytic
C7—2.2 µF, 16 volts, electrolytic
C9, C26—33 µF, 16 volts, electrolytic
C12—0.1 µF, 200 volts, disc
C16—4700 µF, 16 volts, electrolytic
C23—470 µF, 16 volts, electrolytic
C24, C25—22 pF, disc

Semiconductors
IC1—TMPZB440OP, CMOS Z80
(Toshiba)
IC2—8255A, PIO
IC3—SP0256-AL2, speech synthesizer
IC4—74C04, hex CMOS inverter
IC5—74C02, quad CMOS NOR
IC6—27C64, 8K CMOS EPROM
IC7—74C32, quad CMOS OR gate
IC8—ADC0809CCN, A/D converter
IC9—LM324Z, precision current reference
IC10—M-956, DTMF decoder (Teltone)
IC11, IC22—unused
IC12, IC15—TLC2171, op-amp
IC13—LM324, quad op-amp
IC14—4066, quad analog switch
IC16–IC19—4N32A, opto-isolator
IC20—LM7805, five-volt regulator,
TO3 case
IC21—LM7805, five-volt regulator,
TO220 case

The other method of interfacing is required when the application demands devices that are too big or too power-hungry to be mounted internally. Here a separate box should be built that contains its own internal power supply. The edge-card connector identified as SO1 in the schematics can be used to connect the controller to the interface box.

Construction aside, the type of circuit you'll need will depend on your inputs and outputs. Figure 9 shows ideas for several types of interfaces. Component values are not given for most of the circuits because those values can only be determined based on the voltage levels you'll be dealing with. But the circuits shown provide a good starting place.

Figure 9-a and Figure 9-b show two simple digital-output circuits. Neither can supply much current; the relay in Fig. 9-b should be a low-current type. The Fig. 9-a circuit is suitable for applications where isolation is unimportant; otherwise, use the Fig. 9-b circuit.

Figure 9-c and Figure 9-d show two simple analog-input circuits. As with Fig. 9-a and Fig. 9-b, the Fig. 9-c circuit is suitable for applications where isolation is unimportant; otherwise, use the Fig. 9-d circuit.

Last are circuits for transmitting digital data over the telephone lines. As shown in Fig. 9-e, the remote voltage of interest should be processed by a VCO (Voltage-Controlled Oscillator) so that a tone suitable for phone-line bandwidth (3000 Hz) will be generated. The signal applied to either of the converter's self-canceling inputs should be in the range of 50–100 mV p-p. As shown in Fig. 9-f, the tone can be recovered at the receiving end after suitable isolation and buffering by a voltage-to-frequency converter or a PLL (Phase-Locked Loop).
More on the electronics that makes our robot go.

Part 7 This month we'll continue our look at the robot's control electronics. You'll need to refer to the schematic that appeared last time ("R-E Robot, Part 6," Radio-Electronics, May 1987), so have it handy as we proceed.

Analog-to-digital converter

An Analog-to-Digital Converter (ADC) is required to convert information about the torque output of the drive motors and the state of the batteries to a digital signal that can be processed by the RPC (Robotic Personal Computer). Additionally, an ADC is needed to convert the outputs of environmental sensors to digital form; almost all such sensors have analog outputs.

Because it is easily interfaced with our microprocessor bus, the ADC we selected is the ADC0804 (National). That IC is self-clocking, uses an internal ratiometric reference, and needs only +5-volts DC to operate. The input-voltage range of that IC is adjustable; we've set it for 0 to +5-volts DC.

The ADC's input channel is selected using two 4051 8-channel multiplexers IC's. The input channels are allocated as follows. Two channels are connected to amplifiers monitoring each drive motor's current. Two channels are connected to the RERBUS (Radio-Electronics Robot BUS) connector; we'll discuss the structure of the RERBUS in a moment. Two channels are dedicated to internal heatsensing. Eight channels are available at the user connector for external sensors or other peripherals you may add later.

The desired input channel is selected by placing the appropriate data on the data bus and then writing it to IC4, the 74LS377 parallel latch discussed last time. About 200 µs later, the requested data is placed on the data bus by reading port 150H.

For example, let's assume that we wanted to check on the battery. Battery condition is monitored on channel 3. By selecting that channel we can learn of the state of the battery's charge; if it has dropped too low the appropriate action can be taken. The following line of computer code, written in FORTH, returns the state of the battery:

```
: BATT? 2 150 PC! 2 DELAY 150 PC@ .
```

Speaking of FORTH, we realize, of course, that we have not discussed the language in any detail yet. Undertaking such a task would require devoting several complete issues of Radio-Electronics, and the job would still be incomplete, at best. Therefore, for space reasons, we must assume that the reader is familiar with the language. On that premise, when we present FORTH routines in future installments of this series, we'll explain what the routine does in general terms, but not the function of each term or line.

RERBUS user interface

If circuit designers always knew in the beginning what would be needed in the end, the concept of a bus would never have been developed. Since we lack such foresight, however, a simple interface bus is provided to allow you to expand the robot easily and at low cost. That interface bus has been named the RERBUS; it uses 26-conductor ribbon cable that carries 8 data lines, 4 address lines, 2 control lines, and power.

The RERBUS interface is derived from IC7, a 74LS374 output latch. That latch was chosen over the 74LS377 used earlier because it has greater output drive capacity. The price of that added drive capacity is the need to add an additional or gate (IC15-b, 74LS32) to the clock line. A second 74LS374 (IC8) is used to buffer the address and control lines for the interface. Data is read from the interface using IC6, a 74LS541 octal buffer/line driver.

The advantage of that implementation is that we have complete control over the access time of any circuits connected to the bus. The read or write lines can be enabled as long as the external circuits require. That is particularly important when a flexible cable is used instead of a backplane because a flexible-cable bus requires slow access times because of its high inter-conductor capacitance.

Motor controllers

Before describing our motor-control
circuit, remember that we are dealing with DC brush-type torque motors. Those motors are characterized by poor speed regulation, lack of an integral tachometer, and, consequently, low-cost; the last characteristic explains why they were selected. Stepper motors with the torque capability we need would have been difficult to locate and would have cost much more. Brushless motors, though less expensive, require much support circuitry that they wind up costing as much to use as steppers. Servo motors with an integral analog tachometer could have been used, but they too are much more expensive than lowly torque motors. Remember, any automobile starter motor will deliver around 1/2 horsepower, just about what we need.

Motor controllers fall into two general classifications: linear and switching. In a linear controller, the terminal voltage of the motor is varied to keep the motor speed constant. A switching controller keeps motor speed constant by regulating the duty cycle of the power applied to the motor. Bear in mind that our motor controllers may have to handle up to 500 watts. Examining the power-dissipation requirements of typical series-pass transistors we see that there will be a power-dissipation problem if linear controllers are used. The worst case is at high-torque loads and low motor speeds. Then the series-pass transistors must conduct maximum current while withstanding nearly full battery voltage. The result is over 1 kW of power dissipation in the series-pass transistors.

A switching controller, on the other hand, is either fully conducting or fully off. In either case, power dissipated by the series-pass transistors is zero. Actually, it's very near zero. During transitions between off-to-on and on-to-off, power is lost, but the total dissipation is many orders of magnitude lower than that of a linear controller.

Some form of feedback is required in all motor-control circuits. That can be derived from an analog generator attached to the motor shaft, as is done with servo motors. Sometimes the motor itself is used as an analog tachometer by measuring the back EMF generated. In our case, optical encoders will be attached to the motor shafts to obtain motor-speed information. The information from the encoders is brought to the controller via connectors PL2 (right motor) and PL6 (left motor); it is decoded by a pair of 74L574 dual flip-flops (IC28 and IC29).

The final stage of each motor controller is the output driver. That stage must deliver the power to the motor. It must also be capable of reversing and stopping the motor. One method of doing that requires two power supplies of equal voltage and opposite polarity. The motor is connected to the positive supply to run in one direction and to the negative supply to operate in the opposite direction. That solution does not use batteries efficiently, so it is not used.

Another alternative would be to use an H bridge. In that scheme each motor is surrounded by four switches (transistors) that direct the current through the motor in the desired direction. Although efficient in terms of power usage, the circuit requires four high-power transistors and associated circuitry, all of which increases the cost.

Finally, the classic approach is to connect the motor to the center arm of two SPDT relays and to use the relays to establish the direction of the current in the motor. That approach is simple and inexpensive; it is the approach used in our robot.

**Design considerations**

It is important that the motor controller be able to operate as independently as possible. We could design a motor-control system in which a microprocessor controls the power delivered to the drive transistors and counts the incremental revolutions of the drive wheels. That is an ideal application for a slave processor, and, in fact, that is how the **HERO 2000** works. Unfortunately, however, developing a dedicated slave-microprocessor system for our robot was a luxury that we could not afford.

On the other hand, it is important that we do not load the RPC down with too many tasks. Therefore, our motor controller will have to be smart enough to operate without constant attention from the microprocessor.

We also need an accurate system that can keep track of how far the robot has moved. The drive wheels will be used to steer the robot, so, not only must the motors be capable of accurate differential actions, they must be well-behaved at low (maneuvering) speeds. The robot's arm has just one degree of freedom. The other two degrees of freedom are obtained from the base unit. Therefore, the motor controls must be able to move the unit in small forward, backward, or rotational steps to enable the arm to grasp its target.

The wheel-derived distance will be used as our first-approximation navigational system. However, no matter how accurate our wheel-based navigation is, there is no solution to the "bump in the road" problem. For example, if our robot were traveling in a straight line, maintained by equal distance traveled by each wheel, and one wheel went over a bump, the robot would turn towards the bump. That is because the wheel that went over the bump went farther to achieve the same linear distance that the wheel that missed the bump. In spite of that problem, it would simplify later problems if the robot were able to go where it is told reliably.

The motor controller designed for the robot meets those specifications. We have designed a totally digital, Phase-Locked Loop (PLL) motor-control system that uses a single pulse-width modulated tran-
The PLL
The key to the design of the motor controller is the use of a phased-locked loop. A block diagram of a PLL is shown in Fig. 1. Essentially, a PLL consists of a reference-frequency source, a frequency comparator and a variable-frequency signal that is produced using a Voltage Controlled Oscillator (VCO). In operation, the frequency comparator constantly compares the variable-frequency signal with the reference-frequency signal and adjusts the variable-frequency signal so that the two match.

By now you may be getting an idea about how our controller works. A reference frequency that is proportional to the desired speed is generated. That frequency is compared with the output of an optical encoder that is linked to the motor; the encoder plays the part of the VCO in this PLL. If the controlled voltage is lower than the reference voltage, the PLL circuit will turn the drive transistor on more; if it is higher, the PLL will turn the drive transistor on less.

A block diagram of the system is shown in Fig. 2. As mentioned, two such systems are required by the robot, one for each drive motor. To keep things simpler in the following discussion, we will examine the circuit for the left motor only; the right-motor controller works identically.

Reference frequency
The reference frequency is derived from the 80188 microprocessor clock (on the RPC) and one of the three independent timers of IC13, an 8253 programmable 16-bit counter. The clock signal is divided by 16 to produce a 500-kHz clock for the 8253. The 8253 then divides the input clock by a 16-bit number to produce an output frequency between 2 Hz and 250 kHz, depending on the number selected. That output is used as the reference frequency by the PLL. The reference frequency can be turned on and off via pin 11, G0, by writing to port 124H. When the reference frequency is off, the motor must stop completely.

Frequency comparator
The frequency comparator used by our PLL is the internal type-II comparator in the 4046 PLL, IC23. A sophisticated digital-memory circuit outputs a 1 (logic high) if the phase of the reference signal leads that of the controlled signal. A 0 (logic low) is output if the phase of the reference signal lags that of the controlled signal. As you can see, the circuit is actually a phase comparator. However, in our description we will continue to refer to the circuit as a frequency comparator because in our system it is used to control the frequency of the optical-encoder feedback signal rather than the phase.

The output of the frequency comparator is a pulse train whose duty cycle will vary from 0 to 100%, depending upon the difference in phase between the reference frequency and the optical-encoder outputs. The frequency of that pulse train will be equal to the reference frequency. If you examine the output of the 4046 with an oscilloscope while applying a load to the motor you will see the duty cycle of the comparator's output increase, but its frequency will remain the same.

Motor driver
Like the reference frequency, the motor driver is gated on and off via port 124H. When the driver is gated on, the output of NAND gate IC24-a drives transistor Q1 into saturation. That 2N3906 small-signal PNP transistor drives a Darlington pair. Note that rather than a single unit, in our circuit we use a Darlington pair fashioned from discrete transistors (Q2 and Q3). That approach is used because it offers you much flexibility in matching drive transistors and motors. The 2N3772 transistor used for Q3 in our circuit is rated at 30 amperes; that means it can deliver up to 1 kilowatt to the motor at the maximum recommended battery voltage (36 volts x 30 amps).

The motor is connected to the center position of two SPDT power relays. A single flyback diode, D2, protects the driver transistor from damage due to motor inductance. The use of two relays instead of an H-bridge output-driver circuit allows us to reverse motor directions, yet saves three expensive power transistors, several level-matching components, and three flyback diodes. Maximum dynamic braking of the motors is achieved when both relays are in the deenergized position, an important consideration when the robot is parked.

It is possible to perform regenerative braking with the circuit, wherein the kinetic energy of the robot in motion is used to generate electricity in the motor and charge the batteries. However, due to the complexity of the control algorithms and the small amount of energy recovered, we did not implement that feature.

Motor current is sensed at the 0.01-ohm resistor, R21, amplified and filtered by the LM358 operational amplifier, IC20, and presented to the ADC. In a given motor, the relationship between load and current is linear irrespective of motor speed. Once that relationship has been determined, the information can be used by the RPC to sense the grade or surface that the robot is operating on.

Shaft encoders.
We used a Hewlett Packard HEDS 6000 optical encoder for our robot. That unit has a quadrature output of 500 counts-per-revolution.

Note that the HEDS 6000 is one of the most expensive components in the system. You have two choices if you do not want to follow our lead in using that encoder. You can make your own encoder, either with or without quadrature outputs, continued on page 90
Part 5

ALTHOUGH STATIC (DC) measurements address a wider range of conditions and are easier to make than dynamic (AC) measurements, dynamic measurements are actually more realistic because they apply directly to normal usage.

As you recall from the first installment of this series, dynamic tests are performed by measuring a semiconductor's influence on an AC input signal when the device is operating under DC conditions. Let's take a look at why that is so and begin with an analysis of bipolar-transistor dynamic measurements.

Transistor gain

The dynamic parameter of primary interest to the design engineer and the hobbyist alike is undoubtedly hfe, which is called beta, and which is often represented by the symbol β. Commonly referred to as beta, hfe is the AC short-circuit forward-current gain of a bipolar transistor in the common-emitter configuration. In plain terms, hfe is the ratio of the change in collector current to a corresponding change in base current brought about by an AC signal. hfe can be expressed by the equation:

$$h_{fe} = \frac{\Delta I_C}{\Delta I_B}$$

where $I_B$ is the change in base current and $I_C$ is the change in collector current.

Keep in mind that the key word in the above equation is change. (The Δ symbol is used to indicate a change.) Let's say, for example, that a transistor is DC-biased with a base-emitter current of 1 mA, which results in a corresponding collector current of 50 mA. Those values are called the static conditions of the circuit.

The static conditions that determine the operating parameters of a transistor are established by a constant-voltage power supply across the collector and emitter, and a constant-current source for the base-emitter junction. A test circuit having those conditions is shown in Fig. 1. Meter M1 indicates base current ($I_B$), meter M2 indicates collector current ($I_C$). Resistor $R_L$ is the collector's load.

After noting the static base and collector currents, make a change in the base current and note the resulting shift in the collector current. For illustration, assume we apply an input signal of 1 mA to the base (in addition to the static 1 mA current, for a total of 2 mA) and see what happens. Assume that the increase in base current causes the collector current to increase from 50 mA to 100 mA.
AC-measurement circuit is shown. The constant-current generator connected from emitter-to-ground represents Q1’s base-emitter biasing; it eliminates having to clutter the illustration with the DC biasing circuit.) The test circuit measures \( h_{ie} \) by comparing the AC input voltage to the AC output voltage. The meter’s scale is specifically calibrated so that it directly indicates Q1’s \( \beta \). (The conversion between current and voltage is made in the voltage divider consisting of resistors R1 and R2. The values for those components were selected so that 10 mV appears across resistor R2 when 1 \( \mu \)A flows into transistor Q1’s base.)

A calibration level of 10 mV was chosen so that an \( h_{ie} \) in the range of 0 to 100 can be read directly from a meter (M1) that normally indicates 0–10 mV full-scale. The meter’s calibration works this way: Switch S1 is set to its CAL position and resistor R3 is adjusted so that meter M1 indicates full scale (10 mV). The switch is then set to its TEST position and the meter reading, which indicates the transistor’s \( \beta \), is noted. Keep in mind that a full-scale reading represents a beta of exactly 100.

The \( h_{ie} \) value obtained by that method will probably agree very well with \( h_{ie} \), the static (DC) gain parameter, but not every time or for every transistor. The parameter \( h_{ie} \) is frequency dependent and can fluctuate widely from the measured static (DC) values, a fact that is especially true of high-frequency transistors.

**Alpha gain**

Another commonly-used parameter is \( \alpha \) (alpha), which represents the AC short-circuit forward-current gain for a transistor operating in the grounded-base mode. Its nomenclature is \( h_{ie} \). While the \( \beta \) value is not as familiar to some as \( \beta \), it is often used to establish gain parameters for high-frequency circuits that require a grounded-base configuration.

Alpha can be determined in two different ways: either by direct tests, or by mathematical derivation from other parameters, such as \( h_{ie} \). The formula for converting \( h_{ie} \) into \( h_{ie} \), is:

\[
h_{ie} = \frac{-h_{ie}}{1 + h_{ie}}
\]

Be aware that the conversion only yields an approximation for \( \alpha \). Circuit factors such as distributed capacitance and inductance are not taken into consideration by the formula.

To arrive at a more accurate value for alpha, the transistor must be tested in a circuit such as the one shown in Fig. 3. Once again, the constant-current source in Q1’s emitter lead represents the biasing circuit. As before, the ratio between the input signal and the output signal is used to determine alpha. The formula is:

\[
h_{ie} = \frac{-h_{ie}}{1 + h_{ie}}
\]
HYBRID FUNCTIONS

The hybrid system of testing is a black-box method for analyzing system parameters. The parameters pertaining to bipolar transistors are listed in Table 1. It is usually possible to convert from one parameter to another mathematically without having to actually perform the test. The formula for converting $h_{fe}$ into $h_{fb}$, for example, is:

$$h_{fb} = \frac{-h_{fe}}{1 + h_{fe}}$$

<table>
<thead>
<tr>
<th>Element</th>
<th>$h_{11}$ Input impedance</th>
<th>$h_{12}$ Reverse voltage</th>
<th>$h_{21}$ Forward current</th>
<th>$h_{22}$ Output admittance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emitter</td>
<td>$h_{le}$</td>
<td>$h_{re}$</td>
<td>$h_{le}$</td>
<td>$h_{re}$</td>
</tr>
<tr>
<td>Base</td>
<td>$h_{lb}$</td>
<td>$h_{rb}$</td>
<td>$h_{lb}$</td>
<td>$h_{rb}$</td>
</tr>
<tr>
<td>Collector</td>
<td>$h_{lc}$</td>
<td>$h_{rc}$</td>
<td>$h_{lc}$</td>
<td>$h_{rc}$</td>
</tr>
</tbody>
</table>

$\Delta I_E = \frac{\Delta I_C}{\Delta I_E}$

By again establishing the transistor’s input signal at 1 µA, we can read the value of $h_{fb}$ directly from the meter.

The value of $h_{fb}$ is always less than unity. If that puzzles you, examine the test configuration in Fig. 3 more carefully.

<table>
<thead>
<tr>
<th>Element</th>
<th>$h_{11}$ Input impedance</th>
<th>$h_{12}$ Reverse voltage</th>
<th>$h_{21}$ Forward current</th>
<th>$h_{22}$ Output admittance</th>
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<td>$h_{lb}$</td>
<td>$h_{rb}$</td>
<td>$h_{lb}$</td>
<td>$h_{rb}$</td>
</tr>
<tr>
<td>Collector</td>
<td>$h_{lc}$</td>
<td>$h_{rc}$</td>
<td>$h_{lc}$</td>
<td>$h_{rc}$</td>
</tr>
</tbody>
</table>

Like $h_{11}$, the values of $h_{lc}$ and $h_{rb}$ vary according to the established $V_{f1}$, and $I_{f}$ values. Higher currents and lower voltages result in a decrease in gain. The transistor’s data sheet will show clearly under what DC conditions the $h$ parameters were measured. Otherwise, the data sheet would be useless.

Understanding the parameters

Parameters designated by the lower case $h$, such as $h_{le}$ and $h_{lc}$, are called hybrid parameters, meaning they are derived from a black-box method of testing and analyzing system parameters. Although we have concentrated on the $\alpha$ and $\beta$ hybrid $(h)$ parameters, data sheets often list other $h$ parameters. Individual $h$ parameters are integrated into four basic groups that are identified by numerical subscripts. They are:

- $h_{11}$ = input impedance
- $h_{12}$ = reverse voltage ratio
- $h_{21}$ = forward current ratio
- $h_{22}$ = output admittance

Each group represents a family of $h$ parameters. For example, $h_{le}$ and $h_{lb}$ both belong to the $h_{2}$ family of forward-current-ratio measurements, as does $h_{lc}$, the forward current gain in the grounded-collector configuration. (The second letter in the subscript of an $h$ parameter indicates the common element. For example, $h_{lc}$ means the collector is common.)

A box elsewhere in this article shows the relationship between the various $h$ parameters. The test circuits for $h_{le}$ and $h_{lb}$ have already been discussed. Test circuits for other parameters are shown in Figs. 4 through 6.

For all of the circuits, the indicating meter $M_1$, is identical to the one used in Fig. 1. The test frequency is 1 kHz, but 60 Hz should yield identical results in all but a few instances. By adjusting the the R1/ R2 voltage divider’s ratio to produce a calibration voltage of 10 millivolts, the $h$ value can be read directly from the meter.

Bear in mind that the $h$ parameters are DC dependent. In other words, expect a shift in values if the static current and voltage change.

Field-effect transistors

The field-effect transistor requires radically different test procedures because it more closely resembles a vacuum tube than it does a transistor. Consequently, many of the test parameters reflect vacuum-tube technology. For example, an FET’s gain is specified in $g_m$, a term that is borrowed from vacuum-tube terminology. Gain is listed as $g_m$ on the FET’s data sheet. It may also be listed as $g_{21}$, $g_{m2}$, or even $g_{m2}$. (Notice the similarity to a transistor’s $h$ parameters.)

The quantity $g_m$, which is often referred to as transconductance or admittance, is continued on page 90
Flip-flops are the basis of all digital circuits. Learn about the different types and practical applications for them.

RAY MARSTON

Digital IC’s can be classified into two basic types: gates and flip-flops. The latter are also known as bistable latches and memory elements. Many devices are based on flip-flops, including counters, dividers, shift registers, data latches, etc., as well as presettable up-down counters and dividers, and other devices.

In this article we will explain how several types of flip-flops work. Then we’ll go on to discuss several versatile CMOS flip-flops. Last, we’ll show many practical circuits that use flip-flops.

Basic principles

The simplest type of CMOS flip-flop is the cross-coupled bistable latch shown in Fig. 1-a. The circuit is built from two NOR gates; it has two inputs (usually tied low via pull-down resistors), and a pair of output of-phase outputs. The circuit works like this: If the SET terminal is briefly taken high, the Q output immediately goes high, and the Q output goes low. The cross-coupling between the two gates causes the outputs to latch in that state, even when both inputs are pulled low again. The only way the output states can be changed is by applying a high to the RESET terminal, in which case the Q output immediately goes low, and the Q output goes high. Again, cross-coupling causes the outputs to latch into the new state even when both inputs are pulled low.

Because of the latching action, the basic Set-Reset (S-R) flip-flop acts as a simple memory element that “remembers” which of the two inputs last went high. Note, however, that the output state cannot be predicted if both inputs go high simultaneously, so that must not be allowed to occur. Fig. 1-b shows the symbol of the S-R flip-flop, and Fig. 1-c shows its truth table.

The versatility of the basic circuit can be enhanced greatly by wiring an AND gate in series with each input terminal as shown in Fig. 2. That way high input signals can reach the S-R flip-flop only when the clock (CK) signal is also high. Therefore, when CK is low, both inputs of the flip-flop are held low, irrespective of the states of the SET and RESET inputs, so the flip-flop functions as a “permanent” memory. However, when CK is high, the circuit functions as a standard S-R flip-flop. Consequently, information is not automatically latched into the flip-flop, but must be “clocked” in; that’s why the circuit is known as a clocked S-R flip-flop.

Figure 3-a shows how to make the most important of all flip-flops, the clocked master-slave flip-flop. It’s built from two clocked S-R flip-flops that are cascaded and clocked out of phase via an inverter in the clock line.

It works as follows. When the CK input is low, the inputs to the master flip-flop are enabled via the inverter, so the SET-RESET data is accepted. However, the inputs to the slave flip-flop are disabled, so the data is not passed to the output terminals. Then, when the CK input goes high, the inputs to the master flip-flop are disabled, so the input data is latched in the outputs; simultaneously, the input to the slave flip-flop is enabled, and the latched data is passed to the output terminals. The symbol of the clocked master-slave flip-flop is shown in Fig. 3-b.

The clocked master-slave flip-flop can be made to toggle (or divide by two) by cross-coupling the input and output terminals as shown in Fig. 4-a. By doing so, SET and Q (and RESET and Q) are always at opposite logic levels. So when CK goes
low, the master flip-flop changes state. When \( \text{CLK} \) goes high, the slave flip-flop changes state. Note that the output states change on the arrival of the leading edge of each new clock pulse.

It takes two clock pulses to change the output from one state to another and back again, so the frequency of the output is half the frequency of the clock. The circuit is known as a Toggle (or type-T) flip-flop; its symbol is shown in Fig. 4-b.

**The D flip-flop**

The type-T flip-flop is a special device that functions only as a counter/divider. A far more versatile device is the Data or type-D flip-flop, which is made by connecting the clocked master-slave flip-flop as shown in Fig. 5-a. In that circuit, an inverter is wired between the \( s \) and \( r \) terminals of the flip-flop, so those terminals are always out of phase, and the input is applied via a single pin. Fig. 5-b and Fig. 5-c show the symbol and the truth table of the type-D flip-flop, respectively.

A type-D flip-flop can be used as a data latch by connecting it as shown in Fig. 6-a, or as a binary counter/divider by connecting it as shown in Fig. 6-b.

**The JK flip-flop**

Figure 7-a shows the basic circuit of an even more versatile clocked flip-flop, which is universally known as the JK-type. It can function either as a data latch, a counter/divider, or as a do-nothing element by suitably connecting the \( J \) and \( K \) terminals. The symbol of the JK flip-flop is shown in Fig. 7-b, and its truth table is shown in Fig. 7-c.

In essence, the JK flip-flop functions as a \( T \)-type when inputs are both high, and as a \( D \)-type when they're different. When they're both low, the outputs remain unchanged when a pulse arrives.

**Real-world devices**

The two best-known clocked CMOS flip-flops are the 4013 \( D \)-type and the 4027 \( J \)-type. Each IC contains two independent flip-flops that share power and ground connections. Figure 8-a shows the functional diagram of the 4013; the truth table of its clocked inputs is shown in Fig. 8-b, and that of its direct inputs is shown in Fig. 8-c. Corresponding diagrams for the 4027 are shown in Fig. 9-a, Fig. 9-b, and Fig. 9-c.

Note that both the 4013 and the 4027 have \( SET \) and \( RESET \) inputs in addition to the normal clocked inputs. For both IC's those terminals are direct inputs that enable the clocked action of the flip-flop to be overridden, in which case the device functions as a simple unclocked \( S-R \) flip-flop. For normal clocked operation, the direct inputs must be grounded.

The 4013 and 4027 are fast-acting, so it is important that their clock signals be absolutely noise-free and bounceless, and that they have risetimes and falltimes of less than five \( \mu s \). Both IC's clock on the positive transition of the clock signal.

**Ripple counters**

The most popular application of the clocked flip-flop is as a binary counter. Fig. 10-a shows how to connect the 4013 as a divide-by-two counter; Fig. 10-b shows the corresponding connections for the 4017. When clocked by a fixed-frequency waveform, both circuits give a symmetrical square-wave output at half the clock frequency.

As shown in Fig. 11, you can cascade several ripple counters (so called because of the way that clock pulses appear to ripple from stage to stage) to provide division by successive powers of two. Figure 11-a shows how to cascade two \( D \)-type flip-flops, and Fig. 11-b shows how to cascade two \( J \)-type flip-flops (to provide a division ratio of \( 4 \times 2 \) or \( 2^5 \)). In a like manner, Fig. 12-a and Fig. 12-b show how three stages can be cascaded to give a division ratio of \( 3 \times 2^5 \). In fact, an arbitrary number of stages can be cascaded, as shown in Fig. 13, to provide a division ratio of \( 2^n \) where \( n \) is the number of stages.

The circuits shown in Fig. 11–Fig. 13 are known as ripple counters, because each stage is clocked by the output of the preceding stage, rather than by a master clock signal. The effect, therefore, is that the clock signal seems to "ripple" through the counter chain. The problem is that the propagation delays of all the dividers add together and provide a delay that prevents the counter stages from clocking synchronously. Counters of that sort are in fact called asynchronous counters. If the outputs of the stages are decoded via gate networks, output glitches and inaccurate decoding can result.

**Long ripple counters**

Although 4013 and 4027 counters can be cascaded to give any desired number of stages, when more than four stages are needed, it's usually economical to use a special-purpose MSI ripple-carry binary counter/divider IC. Our next few figures show several examples.

The 4024, shown in Fig. 14, is a seven-stage ripple counter; all seven outputs are externally accessible. The IC provides a maximum division ratio of \( 128 \times 2^7 \). The
a 14-stage counter; all outputs except 2 and 3 are externally accessible. The 4020 provides a maximum division ratio of $16,384$ ($2^{14}$).

Figure 17-a shows details of the 4060. It is another 14-stage device, but outputs 1, 2, 3, and 11 are not accessible. A special feature of the IC is that it incorporates a built-in oscillator circuit. As shown in Fig. 17-b and Fig. 17-c, the device can use either a crystal or an RC network to set the frequency of oscillation.

The 4020, 4024, 4040, and 4060 ICs all have Schmitt-trigger inputs that trigger on the negative transition of each input pulse. All of those counters can be set to zero by applying a high level to the RESET line.

Glitches
A two-stage divide-by-four ripple counter, like that shown in Fig. 18-a, can have four possible output states; as shown in Fig. 18-b. Both outputs can be high, both can be low, one can be high and the other low, or the former low and the latter high. Before any clock pulses have been received, the $Q_2$ and $Q_1$ outputs are low. When the first pulse arrives, $Q_2$ goes high. When the second pulse arrives, $Q_1$ goes high and $Q_2$ goes low. On the third pulse, $Q_2$ and $Q_1$ both go high. Last, on the fourth pulse, $Q_2$ and $Q_1$ both go low again.
state, as shown in Fig. 18-c. Because the ripple counter is an asynchronous device, however, the propagation delay between the two flip-flops may cause glitches to appear in the decoded outputs, as shown in Fig. 18-d. Of course, those types of glitches are possible with any multi-stage ripple counter, and the greater the number of stages, the greater the total propagation delay becomes, and the greater the problem with glitches. The solution to the glitch problem is to use a clocked-logic device, which we’ll discuss momentarily.

Up and down counters.

A standard ripple counter counts up—the decoded outputs increase in value with each succeeding clock pulse. It is possi-

![Image of a circuit diagram](attachment:image.png)

FIG. 14—PINOUT OF THE 4024 seven-stage ripple counter is shown here.

![Image of a circuit diagram](attachment:image2.png)

FIG. 15—PINOUT OF THE 4040 12-stage ripple counter is shown here.

![Image of a circuit diagram](attachment:image3.png)

FIG. 16—PINOUT OF THE 4020 14-stage ripple counter is shown here.

Each of the four possible states can be decoded to provide four unique outputs by ANDing the outputs that are unique to each

![Image of a circuit diagram](attachment:image4.png)

FIG. 17—THE 4060's PINOUT is shown in a; several oscillator connections are shown in b and c.

![Image of a circuit diagram](attachment:image5.png)

FIG. 18—GLITCHES may be generated when decoding a ripple counter like that shown in a. The \( Q_1 \) and \( Q_2 \) outputs respond to the input signal as shown in b. When they’re combined as shown in c, a glitch may be generated, as shown in d.

Walking-ring (Johnson) counters

Ripple counters are useful where undecoded binary division is needed, but
It of the SYNCHRONOUS COUNTER is suitable for a divide-by-three counter. Note that the truth table shows the state of each flip-flop at each stage of the counting cycle. Remember that, when the clock is low, the “instruction” is loaded (via the r and k inputs) into the flip-flop; the instruction is carried out as the clock goes high.

So, at the start of the cycle, q2 and q1 are both low, and the “change state” instruction (JK code 11) is loaded into the first flip-flop. Then the instruction “set q2 low” (JK code 01) is loaded into the first flip-flop. When the first clock pulse arrives, the instruction is carried out, q1 goes high, and q2 stays low.

When the clock goes low again, new program information is fed to the flip-flops. Flip-flop 1 is instructed to change state (JK code 11), and flip-flop 2 is instructed to set q2 high (JK code 10). Those instructions are executed on the positive transition of the second clock pulse, causing q2 to go high and q1 to go low. When the clock goes low again, new program information is again fed to each flip-flop from the output of its partner. The counting sequence then repeats ad infinitum.

So in the walking-ring or Johnson counter, all flip-flops are clocked in parallel, but are cross-coupled so that the response of one stage (to a clock pulse) depends on the states of the other stages.

Walking-ring counters can be configured to give any desired count ratio. For example, Fig. 21-a and Fig. 21-b show the circuit and truth table respectively of a divide-by-four counter. Figure 22-a and Fig. 22-b show the circuit and truth table respectively of a divide-by-five counter.

The 4018

When synchronous counts greater than four are needed, it is usually economical to use an MSI IC rather than several 4027s. A suitable device is a 4018, a presettable divide-by-N counter that can be made to divide any whole number between 2 and 10 by cross-coupling input and output terminals in various ways. That IC incorporates a five-stage Johnson counter, has a built-in Schmitt trigger in its clock line, and clocks on the positive transition of the input signal. The counter is said to be presettable because the outputs can be set to a desired state at any time by feeding the inverted binary code to the Jam inputs (J–S) and then loading the data by taking pin 10 high.

Figure 23 shows how to connect the 4018 to give any whole-number division ratio between 2 and 10. No additional components are needed to obtain an even division ratio, but a two-input AND gate (a 4081, for example) is required to obtain an odd division ratio.

Greater-than-ten division

Even division ratios greater than ten can usually be obtained simply by cascading suitably scaled counter stages, as shown in Fig. 24-a–Fig. 24-d. Non-standard and uneven division ratios can be
A Synchronous Divide-by-Five Circuit is shown in a; its truth table is shown in b.

- **Table: Division Ratio vs Feedback Connections**

<table>
<thead>
<tr>
<th>Division Ratio</th>
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<tr>
<td>2</td>
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<tr>
<td>3</td>
<td>Q2 TO DATA</td>
</tr>
<tr>
<td>4</td>
<td>Q3 TO DATA</td>
</tr>
<tr>
<td>5</td>
<td>Q4 TO DATA</td>
</tr>
<tr>
<td>6</td>
<td>Q5 TO DATA</td>
</tr>
</tbody>
</table>

- **Figure 23:** To obtain an odd division ratio with the 4018, an external AND gate must be used.

- **Figure 24:** A division ratio of arbitrarily large size may be obtained by cascading divider stages and multiplying the division factor. In a, a divide-by-12 (2 \times 6) circuit; in b, a divide-by-36 circuit (6 \times 6); in c, a divide-by-50 (5 \times 10); and in d, a divide-by-1000 (10 \times 10 \times 10) circuit.

- **Figure 26:** Shows how to make a four-bit Serial-In/Serial-Out (SISO) shift register. A bit of binary data applied to the input is passed to the output of the first flip-flop on the application of the first clock pulse, to the output of the second on the second pulse, to the output of the third on the third pulse, and to the fourth (and final) output on the fourth pulse. The circuit can hold four bits of data at any given moment. The SISO register is useful for delaying binary signals, or for storing bits of binary data and unloading them (in serial form) when required.

- **Figure 27:** Shows how the previous circuit can be converted to a Serial-In/Parallel-Out (SIPO) shift register simply by using the output of each flip-flop. The circuit might be useful, for example, in converting data transmitted from a remote location in serial form to the parallel form used by computers.

Latches and registers

Now let's move away from counters and take a brief look at three other applications of the clocked master-slave flip-flop.
WE'VE BEEN SUBSTITUTE COMPONENTS in TV sets and radios since the first day we discovered it could be done. Though sometimes it's done to the detriment of good servicing, often a technician has no other choice. The following is an experience of that sort.

Flyback fireworks

A Wards color TV, model GGY-12983A, came in with symptoms of no picture or sound, and it smoked. A cursory inspection revealed that the horizontal transistor was okay and that the flyback didn't have any swollen places or cracks in its shell. However, when the set was fired up there were fireworks under the chassis in the area of the flyback.

The receiver was set on end to expose the full circuit panel. We immediately could see that a carbon path was burnt between two traces. Not being acquainted with this particular chassis, it was necessary to dig out the Sams folder. However, we were in for a surprise: Though the model was almost five years old it was still not listed.

The set's owner was a loyal customer, so since it was a quiet day we decided to search our folder file to see if we had servicing information for anything that was close to that chassis. Luckily, a similar one was found in Sams Photofact folder 2165-2; it was for a Wards model GNB-129/HAB. The component layout and the schematic numbering for the two sets were almost identical.

Now we could see that the carbon path ran from pin 7 of the flyback to the far side of a two-amp fuse, FS-501, located in the 117-volt line to pin 3 of the flyback. See Fig. 1.

It the set, those traces ran parallel, about 1/4-inch apart, for about three inches. Pin 7 is the return of the internal rectifiers in the flyback going to the 23.8-volt leg of the low-voltage power supply. The arc-over meant that excessive reverse current was flowing from the tripler section of the transformer.

Replacing the flyback was the only solution. No American manufacturer was listed so the part had to be ordered from Montgomery-Ward at list. The customer was notified of the estimate for repairs and he gave the go-ahead.

When it was received, the replacement transformer turned out to be a substitute. The original was part 50 3015344-02, type B. Their data sheet showed the substitute to be a 36183-0003, type B. The two parts appeared to be identical in every respect.

More problems

After the flyback was installed, excess solder and resin were cleaned from the solder terminals with a wire brush. Each soldered terminal was then carefully checked for resistance to the nearest circuit component.

Satisfied that there were no circuitry leakages, the receiver was fired up. When it came on without any apparent further problems, it was placed on the cooking bench to run for several hours. That's when the new symptom developed: There were now four and a half black vertical bars at the left side of the screen. There was also a faint streaking in the picture and raster. What happened?

After some head scratching, we remembered that a similar symptom had shown up once in a totally different brand. The cause had something to do with pulse feed.

An analysis of the circuitry revealed an RC network between the horizontal-output transistor, Q402, and pin 16 of the video/chroma processor, IC-900. That component is shown in Fig. 2.

Checking the horizontal pulse at the junction of R932, C460, and R469 with an oscilloscope showed that it was not normal; the pulse had excessive amplitude, and a sharp spike at its leading edge. continued on page 85
THE SOLDER SIDE of the Phonlink PC board is shown here.
THE COMPONENT SIDE of the digital tachometer.
THE COMPONENT SIDE of the double-sided Phonlink PC board.
THE SOLDER SIDE of the digital tachometer is shown here.
One of the most difficult tasks in building any construction project featured in Radio-Electronics is making the PCB board using just the foil pattern provided with the article. Well, we’re doing something about it.

We’ve moved all the foil patterns to this new section where they’re printed by themselves, full sized, with nothing on the back side of the page. What that means for you is that the printed page can be used directly to produce PCB boards!

Note: The patterns provided can be used directly only for direct positive photoresist methods.

In order to produce a board directly from the magazine page, remove the page and carefully inspect it under a strong light and/or on a light table. Look for breaks in the traces, bridges between traces, and in general, all the kinds of things you look for in the final etched board. You can clean up the published artwork the same way you clean up your own artwork. Drafting tape and graphic aids can fix incomplete traces and doughnuts, and you can use a hobby knife to get rid of bridges and dirt.

An optional step, once you’ve satisfied that the artwork is clean, is to take a little bit of mineral oil and carefully wipe it across the back of the artwork. That helps make the paper translucent. Don’t get any on the front side of the paper (the side with the pattern) because you’ll contaminate the sensitized surface of the copper blank. After the oil has dried a bit—patting with a paper towel will help speed up the process—place the pattern front side down on the sensitized copper blank, and make the exposure. You’ll probably have to use a longer exposure time than you are used to.

We can’t tell you exactly how long an exposure time you will need as it depends on many factors but, as a starting point, figure that there’s a 50 percent increase in exposure time over lithographic film. But you’ll have to experiment to find the best method for you. And once you find it, stick with it.

Finally, we would like to hear how you make our using our method. Write and tell us of your successes, and failures, and what techniques work best for you. Address your letters to:

Radio-Electronics
Department PCB
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Farmingdale, NY 11735

*His Shortwave Converter PCB board cannot be made using the direct-etch method.
IN OUR LAST REPORT WE RELATED THE unveiling of a VideoCipher-descrambling IC called the ZITS (Zero Information Turn-on System) or European Chip. We noted that it functions by snaring a VC2000 authorization (ID) number from the satellite data stream and adopting that number as its own. In effect, the ZITS chip appeared to be outside the GI-controlled authorization system; and when it was installed in a descrambler, a home viewer could access scrambled transmissions without having to sign up and pay for any services.

It turns out that the ZITS chip is a fraud; the facts behind the apparently amazing chip are quite bizarre. And there's a lesson here for us all.

The European Chip was first introduced to the home-dish industry at a technical seminar held in mid-January, shortly after GI introduced the new consumer VideoCipher descrambler, the 2100E, shown in Fig. 1. Anyway, the demonstration was impressive. A VideoCipher unit was unplugged from the AC power source, the internal lithium battery (which contains the unit’s ID) was disconnected, and nearly 100 pins on various IC’s inside the VC2000 were purposely shorted to ground to ensure that the unit was “brain dead.” Then the VC2000 was reloaded with three IC’s that not only restored operation, but the original factory ID as well.

The primary claim of the unit’s designers was that it did not have a real unit-ID number at all, and that, as the GI authorization system transmitted valid addresses (via satellite), the device read the data stream and picked off an address to adopt as its own.

They further claimed that, if the adopted address later became inoperative, the European Chip would simply search out another available address ID and adopt it as the unit’s new address.

Many who considered themselves acquainted with the inner workings of VideoCipher and the U7/U30 software were not satisfied with that explanation. They felt that if it worked at all, the unit had to have some other explanation.

Around the time of the first demonstration, a chip-scum originating on the West Coast began to surface. Someone had managed to extract an ID number from a VC2000. That number was then merged into a U30 EPROM using something the creator called a “loader chip.” The sellers of that system made claims similar to those of the Europeans: No authorization was required because the IC was adopting data-stream-transmitted ID numbers as its own. The IC from the West Coast turned out to be a fraud; upon analysis a unit-ID number removed from an “innocent” unit was found buried inside the operational unit. In other words, the wonder-chip from the West Coast was not actually adopting any number at all; it had its own number all along.

The Europeans used similar tactics; using programming jumps, the unit-ID number was hidden from normal view in an obscure location in the EPROM’s 16,384-byte address space. That was the end of the European Chip’s claim to fame, but the mystery did not end there.

The unit-ID number discovered in the West Coast chips turned out to be the same unit-ID number found in the European Chip. In fact, as more and more chips were uncovered all over the U.S. and Canada, they all had the same number buried in various locations in the EPROM. It turned out that a single VC2000, belonging to a consumer in the Midwest, was supporting thousands and thousands of clones!

Tracing the origin of the VC2000 in question was not difficult. A consumer, sympathetic to the scrambling battles, had loaned his VC2000 to a research group. After a month or so the unit was returned
to that person, seemingly intact. What he did not know was that, while the unit was out of his possession, the key was extracted and stored. Later, the key would be sold and re-sold, traded and re-traded, to perhaps a dozen or more clone suppliers all over the United States, and perhaps the world. The consumer continued to use his VC2000, unaware that his subscriptions to Showtime et al were also supporting a lively nationwide business.

The truth is that a unit's factory-installed ID number can be extracted by anyone who has key-extraction hardware and software. Extraction could even happen at an authorized distributor or dealer, because it's done with clip-on devices that leave no trail. Therefore the key can easily become a clandestine commodity traded without the knowledge of the innocent owner.

European extras

The European Chip was really a combination of both clone and musketeer technology. It relied upon the unit-ID number of an innocent box to turn on; then it used musketeer software to authorize not only the services that the innocent box actually subscribed to, but the balance of the services as well. Even the cable-only WOR service, which is not available to home-TVRO owners, was included in the European Chip service menu, because someone had discovered a two-byte change in the software that enabled reception of WOR.

Exposure of the European Chip (and others operating under various names) as a fraud sent shock waves through the descrambling underground. That's because the capture of a single IC in a family would reveal the master ID number for the entire family, and that would allow G1 to disable many systems simultaneously.

The danger of such discovery has always been a problem with clone devices, so most clone-cells have been self-limited to 50 or fewer users per clone master. But claims made about the European Chip caused people to be less cautious about protecting clone-cell size.

Meanwhile G1 has been tightening up on the flow of clone and musketeer IC's. Canadian musketeer suppliers have abandoned their system of shipping from Can-

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Unwanted sounds

YOU’VE JUST HELPED A FRIEND SET UP his new $5,000 audio system. For the first week or so he is extremely pleased; then the complaints start to come in. It’s not that he’s complaining to you, but that his neighbors are complaining to him. It seems that your friend’s new speakers—which are renowned for their deep, strong bass—are achieving a different sort of fame throughout his condo. The problem is described in slightly hysterical terms by the lady in the apartment below: “All I hear all night is this boom-boom-boom!” Even allowing for some hyperbole, the neighbor’s complaint is probably not unwarranted. Is there a solution?

Soundproofing.

Most people tend to confuse the techniques appropriate for soundproofing with those used for sound treatment. In general, the methods used for soundproofing (preventing noise originating inside a room from getting out—or noise from outside getting in) have little relevance to sound treatment (that is, adjusting the acoustic absorptive properties of a room). Soundproofing is by far the tougher problem.

Think of sound as vibrations of the air itself. Therefore, to keep sound out—or in—the first step is to make sure that insofar as is possible, all air transmission paths from one area to another are blocked. Those include seams around door edges, windows, ventilation ducts, etc. Most of the procedures used to prevent heat loss will also block sound. Measurements have shown that even the smallest air leakage path can defeat an otherwise effective sound-blocking approach.

Once the paths for airborne sound are located and eliminated—and that certainly isn’t always easy—then you must minimize the vibrations in solids, which also serve to couple sound from one area to another. When acoustic vibrations (sound waves) impinge on a surface, they are likely to cause it to vibrate. In fact, sound waves vibrating your ear drums are essential to the hearing process. Sound gets through walls in two ways: vibratory transmission through a solid and/or diaphragmatic action.

A child’s telephone consisting of two tin cans with a string stretched taut between them illustrates both principles in action. The acoustic energy from a voice causes the bottom of the can to act as a diaphragm that vibrates in response to the acoustic energy impinging on it. The mechanical vibration is transmitted by the taut string. At the receiving end, the vibrating string causes the receiving can’s bottom diaphragm to vibrate the air and to recreate, more or less, the original sound. In much the same way, the walls of a room can act as a diaphragm to “pick up” sound and couple it to the next room either through the air spaces between the studs, or through the studs themselves.

Eliminating the diaphragm

To eliminate diaphragmatic transmission, you have to eliminate (or dampen) the diaphragm. One very effective technique is to increase the mass of the walls in the transmission path so that they no longer are able to vibrate freely. For example, you can use heavy wall panels instead of thin ones and/or you can brace the panels with 2 × 4 studs at 10- or 12-inch intervals instead of using the standard 16-inch spacing. Or instead of studs and panels between interior rooms, you can use brick, concrete, cinder blocks, etc.; all of which are excellent barriers to impinging airborne vibration. However, anyone who has ever used a string telephone—or communicated to a building superintendent in the basement by hammering on a radiator—knows that solids can also serve as excellent sound-transmission paths.

To minimize such transmission, one can build up a wall or door using sandwiched layers of dif-
different types of materials to take advantage of the fact that vibration tends to be attenuated when traveling through the interfaces of different materials. (The double-glass windows with internal spacing used in recording-studio control rooms function on that principle.) Tests have shown that even the screws or nails used to hold panels to studs can provide transmission paths. For that reason, cementing panels in place with the mastic material commonly used to mount ceiling tiles is a preferred technique when resistance to sound transmission is important.

An excellent sound-isolating wall-construction technique has been described by Owens-Corning Fiberglass Corporation. Shown in Fig. 1, it consists of staggered vertical 2 x 4’s on a 4 x 6 sole plate arranged so that the two sides of %-inch gypsum board partition wall are independently supported. Another 4 to 10 dB of sound attenuation can be achieved by filling the spaces between the walls with fiberglass insulation batting.

A one-inch layer of sand between closely spaced panels or beneath a false floor also forms an excellent inert high-mass sound barrier. For the same reason, sheet lead is used industrially as a popular sound-shielding material, either by itself or bonded to other materials.

Note that the lower frequencies, because of their greater energy content, are the ones that are most readily transmitted through walls and floors, and are therefore the most difficult to isolate or absorb. That’s the reason why only the low “boom, boom, boom” (rather than the full audio range) was heard by the lady downstairs—and probably in other adjacent apartments. The higher frequencies, which are readily absorbed and blocked by acoustical tile and other absorbing materials, seldom get through to the neighbors unless there is a direct air-leakage path such as an air shaft. You can see how the the nature of the leaked sound provides a good clue as to the transmission path. If no highs are heard, air transmission is probably not at work.

Decoupling the speakers
At this point, it should be apparent that eliminating low-frequency transmission through walls or floors is no simple matter. For most people, and particularly apartment dwellers, the need for massive construction or reconstruction probably eliminates most of the available techniques right at the outset. For that reason, the very best place to cut down vibratory transmission is right at

continued on page 84

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**ELENCO PRODUCTS AT DISCOUNT PRICES!**

<table>
<thead>
<tr>
<th>Description</th>
<th>Price</th>
<th>Code</th>
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FIG. 2
ANTIQUE Radios

Restoring a classic

Starting with this column, we are going to change the focus of our discussions somewhat. In the past, we have primarily been interested in the history and evolution of radio, though we have also looked at topics ranging from cabinet styles to servicing. Now, we are going to look inside the radios themselves, including automotive radios, and study their circuitry. We'll also look at early Hi-Fi and FM circuitry, and early TV circuitry. Those whose interest is in restoring antique radios to operating condition will find these articles invaluable.

Radio of the month.
We'll start our look at early-radio electronics with the General Electric A-53. That model, which was produced in 1934, was very popular in its day. The one in my own collection is shown in Fig. 1. While I've had the set a long time, it has never worked. Also, I have never attempted to restore it. Now, we'll take an in-depth look at the radio's circuitry and then try and restore it together.

One reason that I've shied away from restoring that radio is that it is obviously not in its original condition. There is a hole in the cabinet front where the band switch should be, and another hole, midway up on the right-hand side of the cabinet, where nothing should be. Looking at the rear of the set, on the back apron of the chassis is a jack and a switch that clearly are not part of the original circuit. See Fig. 2. They likely are part of a phono-input circuit that was added by a previous owner.

While we are concentrating on the electronics, we cannot ignore the cabinet. It too will need to be restored if the radio is to become something worthy of showing off. As far as the cabinet on our A-53 goes, I've seen worse, but I've also seen better. It will take at least two days to make the veneer patches and refinish the entire cabinet. One of the patches will be used to cover up the added hole. Of course, the grill cloth will have to be replaced.

Determining condition
One thing that you might be wondering about is how I determined that the radio does not work. Obviously, the answer is that I tried it!

The safest route to follow in determining whether or not a radio will work is to test every part, and to look for shorts and opens before plugging the unit in. Many readers have written me saying that they indeed do that each and every time. Unfortunately, human nature being what it is, I am sure many more of you do not. Even if I strongly urged you to follow that route, few of you would, as most are just too impatient to see if our new find works. I must confess, it too fit that description in many instances.

In lieu of testing, you should at the very least examine the radio carefully to uncover any obvious problems. I call that determining whether or not the radio is in "apparent safe operation condition." Among other things, see if all the tubes are present and in the right place. Check the integrity of the line cord. Look for bare wires, or ones that appear to be unconnected. Finally, check the chassis bolts. If several or all are missing, it is likely that someone once tried to fix the radio but did not complete the job. If you see the slightest sign of trouble, do not plug the radio in until you have completely examined and tested the radio. Otherwise you risk further damaging your prize at the very least, and possibly exposing yourself and others to dangerous electrical shocks.

Determining that your radio is in
"apparent safe operating condition" doesn't mean that other safeguards can be disregarded. When plugging in the radio, use an isolated, fused receptacle. Also, while the set is plugged in, don't handle the cabinet or chassis, and don't "stick your face" into the back of the cabinet to see if the tubes are lit.

**Getting to work**

As we've said, one reason we did not previously restore our A-53 was that it has been considerably altered, or mutilated, depending on the skills of whoever made the modifications we noted. Restoring 50-year-old radios to their original condition offers enough problems without having to also figure out how someone else's circuits are supposed to work.

Nevertheless, the radio is still a good choice for restoration. For one thing, as you can see from the schematic in Fig. 3, its use of superheterodyne circuitry identifies the A-53 as one of the better radios of its period. Further, despite its "man-made" defects, the cabinet is in relatively good shape.

Examining the circuit we see that it is a two-band unit. The missing band switch consists of S1-S4, and it is used to switch from the broadcast band to the 2.6-6.9-MHz shortwave band. The signal from

(Continued on page 84)
Marconi lucked out.

One of the obstacles faced by early radio pioneers was a lack of understanding about the ways radio signals propagate, and how outside factors, such as the ionosphere, affect that propagation. Had Marconi attempted to push a signal across “the big pond” earlier in the day, or a few days earlier or later, he would most likely have failed and the development of radio communications would have been delayed several years. The Titanic would have gone to the bottom with no one the wiser.

Marconi simply lucked out. “Skip” was unknown, as was its cause, its effect, and its relation to frequency. Let us all thank the gods that “the band” was open on the memorable day that Marconi tried to span the Atlantic.

Another factor that was misunderstood by early pioneers was the significance of antenna length. They believed that the longer the antenna the better the reception. (Of course, antennas work the same for transmitting as they do for receiving.) While long wires do provide higher gain than do short wires, to many users that gain works in mysterious ways, often causing a weaker signal to be received at a specific location.

Early broadcasters soon understood the vagaries of the long-wire antenna. Unfortunately, many hobbyists and shortwave listeners still do not; poor reception, solely due to using a too-long wire, often is the result.

The term long wire is really relative. Although an antenna must be at least $\frac{1}{2}$ wavelength long at 3.5 MHz to be considered a long wire at any frequency, in modern times we consider anything greater than $\frac{1}{2}$ wavelength at the desired frequency to be a long wire.

Antennas longer than $\frac{1}{2}$ wavelength have unusual sensitivity patterns. That’s what causes high-gain TV antennas to poop out on signals arriving at a 90° angle, where gain should be greatest. The long-wire effect is also what causes multipath interference (TV ghosting) from water towers, tall buildings, and hills that are well off in the distance and to the side of the antenna.

Different directions

The problems with long-wires are that they have more than one major lobe (maximum sensitivity), and that the precise angle of the lobe is determined by the length of the wire. To keep things simple, for this discussion we will not get into “doughnut” sensitivity patterns nor vertical radiation/reception angles (vertical angle being the effect that beams your antenna’s signal to Mars instead of to some place on Earth). We will concentrate on horizontal radiation—the sensitivity (radiation) pattern as it would appear if we were in the heavens looking down on the antenna in question.

Our reference antenna is the half-wavelength dipole shown in Fig. 1. That antenna, as you can see, has two lobes, yielding a sensitivity pattern whose maximum lies on a line that’s at a right-angle to the wire itself.

Now let’s assume that we want a stronger signal from the antenna, so we stretch a wire across several backyards for an overall length of $\frac{1}{2}$ wavelengths at the desired frequency, as shown in Fig. 2.

As you can see, we now have four lobes, each more sensitive than the lobes of a half-wavelength antenna. But there is no such thing as a free lunch. The antenna cannot create gain; it simply compresses the width of the lobe, taking energy from the sides of the lobe and concentrating it along the lobe’s axis. Notice that the $\frac{1}{2}$-wavelength antenna in Fig. 2 is essentially dead to signals arriving directly into the antenna (at a 90° angle).
If a shortwave listener was interested in receiving signals arriving at a right angle, simply extending the wire "for more gain," would instead result in a weaker received signal. To achieve higher gain, the wire would have to be repositioned so that one of the lobes was aimed at the desired station.

But many users report superior reception at all times when they switch to a long-wire. How can that be?

Often, the improvement is not due to improved sensitivity but to diversity reception, and the listener simply perceives better performance. Diversity reception has nothing to do with antenna gain. Instead, it comes about because different regions of a long-wire antenna respond differently to different phase relationships; those relationships are constantly changing because of changing ionospheric conditions. The effect is called selective fading. As the received signal fades out because of phase changes on one part of the antenna, it increases on another. The overall effect is an apparent improvement over the half-wavelength antenna, which has its maximum sensitivity to only one phase relationship.

At even longer wavelengths the antenna creates major and minor lobes; Fig. 3 shows the sensitivity/radiation pattern for a two-wavelength antenna. Notice that we now have a total of eight lobes, with the major lobes getting closer to the wire's axis.

If you could make the wire sufficiently long, the major lobes would flatten to 20° from the wire's axis. Also, the lobes would be so narrow that at 33° from the axis the
antenna would have essentially no sensitivity.

Now, what does all that ancient theory on antennas have to do with modern technology? Simply go outside and look at your TV antenna. If it's the typical "all channel" moderate to deep-fringe model, many of the elements are long wires at the higher frequencies. Instead of having maximum forward at 90° to the elements, on some channels the maximum gain is out to the sides.

That is what explains unusual multipath ghosting. Imagine, if you will, that your city's master transmitting antenna is on a mountaintop due north of your receiving location, and that there is a water tower located to the northeast, some 10 miles away. As usual, you aim the receiving antenna directly at the transmitting antenna, and all channels are received with more than adequate signal strength. But one of the higher VHF channels has two distinct, widely separated images. Here's why: At that channel's frequency, the antenna is several wavelengths long. Because of that, a major lobe extends to the northeast, rather than due north (forward). Therefore, the reflected signal from the tower is actually being received with greater strength than the direct signal from the broadcasting antenna. To avoid such situations, better antenna installers adjust an antenna for best picture rather than by compass heading, even when they can literally see the transmitting antenna from the receiving site.

It's very difficult to change the rules of the game, no matter how ancient they are. At any frequency, a longer antenna is not necessarily a better one. R-E

the speaker system itself, by minimizing its physical coupling to the floor or wall. You can do that by "floating" the offending speakers on structures built up of plywood and foam glued together as shown in Fig. 2. Alternately, a single 4-inch foam slab can be used.

As mentioned earlier, vibration tends to get decoupled when traveling between different materials such as the wood and foam layers. This is in addition to the losses in the foam itself. Make sure that there's sufficient clearance so that the ½-inch decorative plinth (A) does not touch panel (B) or the floor. The parts labeled (B) and (C) are ½-inch plywood, and the foam should be fairly dense and at least an inch thick. Some trial and error will probably be necessary before everything fits together properly. Keep in mind that isolation will be lost if any part of the plinth or the speaker touches the floor.

Any audiophile readers who believe in the "advantages" of speakers or speaker stands that use floor spikes for improved bass, should keep in mind that mechanical coupling to the floor is likely to cause the floor structure itself to vibrate and contribute coloration to the sound of the system. Although some people apparently like the sound of resonating floorboards, I prefer that my speakers sound straight (as designed), thank you. Of course, spurious vibration should be avoided in both the stands or the speaker cabinets themselves, but that is a different matter that is best handled by the cabinet manufacturer's bracing and damping.

The bottom line is this: There really aren't any simple after-the-fact fixes you can apply to existing structures to minimize sound-coupling between rooms, apartments, or floors. But if you block the higher frequency sounds with thermal-insulation techniques and use speaker mountings that prevent bass coupling to the building structure, you certainly can help minimize problems—not to mention complaints. R-E

the antenna is coupled to the control grid of the 6A8 converter and oscillator tube via the RF coil. (Note that the value of that coil, and the others in the schematic, are specified in ohms. That is not a misprint. In those days manufacturers often identified the coils in a schematic in that way to make servicing easier. By checking the resistance of the coil against the rating, a serviceman could spot open or shorted units.) The 6A8 serves two functions: local oscillator and mixer. Tuning is accomplished using a dual-ganged variable capacitor, which is designated C3 and C4 in the schematic. The rear part of the capacitor, C3, is used to tune the receiver to the desired frequency. The front part of the capacitor, C4, is used to tune the local oscillator so that, when mixed with the incoming signal in the 6A8, an IF of 465 kHz results.

The IF amplifier, which is built around a 6K7 tube, differs somewhat from more modern sets. The difference lies mainly in the design of the two IF transformers. The IF-input transformer has a tuned primary and a tuned secondary. The coils themselves sit within a shield located on the top of the chassis. However, their trimmer capacitors are located on the underside of the chassis. Turning to the IF-output transformer, only the secondary is tuned and the entire circuit is located on the underside of the chassis.

The output of the IF amp is coupled via the IF-output transformer to the detector stage, which is built around a 6J7. Volume is controlled in the radio by varying the IF gain using R7, which is a potentiometer, and R8, which is a fixed unit. Those resistors are located in the cathode circuit of the 6K7. Note the 1 megohm resistor (R4) in the grid circuit of the detector; that resistor is also connected to the grid return of the 6K7. Its purpose is to prevent overloading the 6J7 in the event that the volume control, R7, is turned up when a strong signal is received.

continued on page 110
The excessive amplitude and the spike were obviously upsetting something in the video processor.

Essentially, the RC network is there for amplitude reduction and wave shaping, so that seemed like a logical place to start. First, R472, a 150K, 1/2-watt unit, was removed and replaced with a 120-pF capacitor. Since at that stage we were only doing some experimenting, and our whole approach could be wrong, the added component was just “tacked” in.

Since that little network physically lies just ahead of the flyback and very close to the focus lead emerging from the transformer it was important to make sure that the components were dressed well away from the focus lead. There was just about an inch of space for that. Making sure everything was clean and secure for a test run, the receiver was tuned up.

At least we were in the ball park. The black bars were still present but in a sort of hazy way, with that half bar still present near the center of the screen. And the streaking was still there, with much less brightness. Instead of reducing the pulse we had expanded it until over-blanking was taking place.

The next step was to reduce the value of the capacitor by about half, say, 62 pF, and remove C460 completely from the circuit. That brought the brightness back to near normal and, for the most part, removed the black bars. But the half bar still was winking at us and the streaking still was present.

Next, R469, a 150K 1/2-watt resistor, was removed from the circuit and a 100K 1/2-watt unit was put in its place. That change completely removed and and all traces of the black bars. The modified circuit is shown in Fig. 3.

One last hurdle

Now to find the cause of the streaking. It looked like some sort of outside interference, but none of the other sets were being affected.

With a flashlight and magnifying glass the shadowy areas around the flyback were thoroughly investigated. Just when we were about to knock off for the day we noticed what appeared to be a crack in R966; see Fig. 1.

That resistor was removed and, sure enough, it was split. And it was open. The streaking was capped by the return of the internal rectifiers of the flyback acting through that resistor back to the low-voltage supply. When the flyback failed, it probably took that resistor with it. Replacing R966 resolved the streaking problem and the set has worked fine ever since.

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**TROUBLESHOOTING TV**

continued from page 70

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**CABLE TV SPECIALS**

**CONVERTERS**

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<thead>
<tr>
<th>JERROLD:</th>
<th>JSX-3 DIC — 36 Channel Corded Remote</th>
<th>$149.**</th>
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<td></td>
<td>JSX-3 DIC — 36 Channel Set Top</td>
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<td>SB-3 — ‘The Real Thing’</td>
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<td>Z-TAC Cable Add-On</td>
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<td>VIEW STAR:</td>
<td>EVSC-2010 — 60 Channel Wireless —</td>
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<tr>
<td></td>
<td>with Parental Lockout</td>
<td>$99.**</td>
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<td>EVSC-2010 A-B—Same as above with</td>
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<td></td>
<td>A-B Switch</td>
<td>$109.**</td>
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<td>View Star 2501 — 60 Channel Wireless</td>
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<td>with Volume</td>
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PROBING THE SHADOWY AREAS near the flyback revealed a cracked resistor. It proved to be the cause of the mysterious streaking.

**FIG. 3—DELETING C460, R469, and R472 and adding a 100K resistor and a 62-pF capacitor cured the black-bar problem. Modifying the circuit as described in the text cured the problem; the modified circuit is shown here.**
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Instrumentation amplifiers

INSTRUMENTATION AMPLIFIERS ARE high-performance, high-gain op-amps used in applications that require precise, low-level signal amplification with low noise, accurate, closed-loop gain, and very low drift. The AD625, from Analog Devices, is a new precision programmable-gain instrumentation amplifier designed especially for:

1. Circuits requiring non-standard gain values not easily obtained from earlier instrumentation amplifiers such as the AD524 that featured programmable gains of 1, 10, 100, and 1000; and the AD624, with gains of 1, 100, 200, 500, and 1000.

2) Circuits requiring low-cost, precision software-programmable gain, and especially where low noise, low drift, and a high Common-Mode Rejection Ratio (CMRR) are desired.

The AD625 is a cost-effective device that uses three external resistors to set gain to any value from 1 to 10,000. Performance limitations are due mainly to those external resistors. The gain error contributed by the device is less than 0.5% and the temperature error is less 5ppm/°C. The CMRR is independent of feedback resistor matching.

A software-programmable gain amplifier can be designed around the AD625 by using a switch network such as a CMOS multiplexer. The on resistance of the switching network is not in the signal path, so the AD625 can provide 12-bit precision and can be programmed for gains between 1 and 10,000 in user-selected steps.

The AD625 provides highest precision with input offset voltage drift below 0.25µV/°C, output offset voltage drift below 15 µV/°C, and maximum nonlinearity of 0.001% when gain is unity. All grades of the AD625 provide a 25-MHz gain-bandwidth product, 5V/µs slew rate, and 15 µs settling time.

The AD625 comes in three accuracy grades (A, B, and C) for industrial (−25°C to +85°C) temperature range, grades I and K for commercial (0 to +70°C) temperatures, and grade for temperatures in the −55°C to +125°C range.

A block diagram of the AD625 is shown in Fig. 1. A differential voltage appears at the outputs of A1 and A2. That voltage, AV, is the product of the differential portion of the input voltage times the gain, or as shown,

\[ AV = 2(R_F/R_C) + 1 \]

Amplifier A5 is a unity-gain circuit that removes any common-mode signal from the output signal, which appears at pin 10.

The transconductance of the preamp input stage is determined by the value of R_C. Transconductance and gain increase as R_C decreases. That has three major advantages. 1) It makes very high open-loop gain possible; 2) The gain-bandwidth product increases with gain, thereby optimizing frequency response. 3) Input-voltage noise is reduced to a value that is determined by the collector current of the input transistors.

The reference terminal (pin 7) may be used to offset the output up to ±10 volts, for floating output loads or coupling to a circuit with an isolated ground.

The sense terminal (pin 11) is the
feedback point for the output op-amp. Usually it is connected directly to the output at pin 10. But, if heavy load currents are drawn through long leads, voltage drop in the lead resistance can cause errors. To eliminate those errors, the sense terminal can be connected directly to the load. Doing so places the lead's IR drop inside the feedback loop.

Typical IC instrumentation amplifiers can swing ±10 volts across a 2000-ohm load. However, when more current must be delivered to a heavier load, an output current-booster amplifier can be connected between the AD625 output and the load. In such a configuration the sense terminal would be connected to the “high” end of the load, thereby including the booster amp in the feedback loop.

Only three external resistors are needed to select any gain from 1 to 10,000. The gain accuracy and gain temperature coefficient are determined primarily by the external resistors. The gain-sense current is insensitive to common-mode voltage, so the CMRR of the resistor-programmed AD625 is independent of the match of the two feedback resistors, Rf. A value of 20K is normally used for Rf. Values above 20K are not recommended because gain errors referred to the output increase with increased feedback resistance. Values below 10K can cause instability. See Table 1 for resistor values that can be used to set several gains with errors of only ±0.5%.

Further technical and applications data on the AD625 (including programming by microprocessor) are included in the New Products section of the Analog Devices 1986 Update and Selection Guide. Write to Analog Devices, Two Technology Way, Norwood, MA 02062-9106.

**Ku-band amplifier modules**

The new MC5875A, MC5875B, and MC5876A, MC5876B are modules developed for mass-production of low-cost Ku-band satellite data-link receivers. Both are two-stage GaAs FET/hybrid-IC amplifiers designed to be cascaded to provide excellent noise (2.5 dB) and gain (33 dB) performance over the 11.7 to 12.2-GHz band. Both the low-noise module (A) and the gain module (B) come in hermetically sealed packages.

Both devices from NEC are available from the exclusive North American sales agent, California Eastern Labs. For data and other information write California Eastern Laboratories, 3260 Jay Street, Santa Clara, CA 95054.
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or you can investigate the use of incremental shaft encoders.

With the quadrature system, two pulse trains, 90° out of phase, are produced. Motor-direction information can be obtained by examining the relationship of the two waveforms; that is, to see which one is leading and which one is lagging. With proper decoding, spurious counts that may occur when the robot stalls or the motor shaft vibrates will be rejected.

A non-quadrature optical-feedback system can be implemented simply by attaching a disk with holes drilled around its circumference to the motor's back-shaft. A simple optical encoder can then be used to keep track of shaft rotation in the conventional way. Be sure that you drill as many holes as possible, for improved low-speed performance. You will have to condition the encoder's output signal to match TTL levels; that can be done with an LM393 comparator.

A quadrature encoder can be made from two optical sensors positioned so that the output waveforms are 90° out of phase. The sensors are properly positioned when the distance between the optical centers is such that when one hole is centered on one encoder, another hole is covering 50% of the other encoder. With a typical system using 0.25-inch sensor spacing, the hole pattern consists of 3/4-inch holes on 3/4-inch centers. That results in 12 holes on an 1.43-inch radius. That hole pattern is sufficient to give satisfactory feedback for operation at all but the lowest speeds.

Once again, the outputs of the two optical encoders should be conditioned with LM393 comparators. The circuit is then interfaced with the controller board and the output signals are decoded.

Terminal count

The progress of the motor is monitored using two counters of the 8253. One counter is clocked by the forward progress of the robot; the other counter is clocked by the reverse progress.

As mentioned, one of the features of the 8253 is that it is programmable. By loading the appropriate control word into the IC, the counters can be set to operate in one of six modes. For example, to generate the reference frequency we set up one of the 8253's counters to divide by a 16-bit number. That is the IC's mode 2. Here, we need to set up the remaining counters to operate in one of the IC's other modes, interrupt on terminal count (mode 0). In mode 0, the output goes high when the accumulated count has reached a value programmed into the counter. That output may be connected to a digital input for polled operation, but is connected to an interrupt input on the RPC for interrupt-driven operation. The counters can be interrogated by the RPC at any time during motor operations to ensure that the motor has not stalled or is not vibrating.

That's all for now. Next time we'll show you how to build and mount the board. We'll also look at some software considerations.

### SEMICONDUCTOR TESTING

**continued from page 63**

Defined as the forward transfer ratio in the common-source mode. It is expressed as:

\[ Y_{f}\text{s} = \frac{\Delta I_D}{\Delta V_{GS}} \]

where \( I_D \) is the drain current and \( V_{GS} \) is the gate voltage for an FET in a common-source configuration. A basic test circuit for \( Y_{f}\text{s} \) is shown in Fig. 7.

**FIG. 7—Basic \( Y_{f}\text{s} \) test configuration for FETs.**

To measure \( Y_{f}\text{s} \), the gate is first DC-biased with a voltage and the resulting drain current \( I_D \) indicated by meter M2 is noted. Then, the input voltage is changed and the resulting change in the gate voltage \( V_{GS} \) measured by meter M1, and the change in drain current measured by M2 are used to calculate \( Y_{f}\text{s} \).

Again, we must emphasize the word change. The static conditions under which the measurements are made are not anywhere near as important as the values of any changes.

Bear in mind that \( Y_{f}\text{s} \) is not a gain factor, per se. Rather, it describes the maximum possible gain. Generally, the larger the \( Y_{f}\text{s} \) value the greater the gain. Junction FET's have a fairly high forward transconductance, typically ranging from 4,000 to 10,000 µhos. MOSFET (Metal-Oxide Silicon Field Effect Transistor) gains tend to run higher, and dual-gate MOSFET gains are higher yet, wherein values up to 20,000 µhos are not uncommon.

**Dual gates**

Dual-gate MOSFET's can be tested in three different ways. In the first kind of test we apply a signal to one of the gates and connect the unused gate to the drain. By alternating the signal gate (by reversing the gate connections) we create a second distinct test configuration. In some cases, a voltage may be applied to the unused gate during the test; if so, that information is listed on the data sheet.

The third test configuration ties the two gates together and treats them as one. That is the test most commonly used with dual-gate MOSFET's, and its result is shown on most data sheets. While the arrangement yields the highest \( Y_{f}\text{s} \), it also results in decreased bandwidth.

**Variations in \( Y_{f}\text{s} \)**

Technically, \( Y_{f}\text{s} \) represents a resistive value that is influenced by the biasing voltage on the gate, which in turn influences the drain current, \( I_D \). In spite of the variations in \( Y_{f}\text{s} \), the device's manufacturer arrives at a representative \( Y_{f}\text{s} \) value by applying a DC bias voltage to the transistor and by maintaining the input signal at 100 mV or less, a configuration that yields the highest \( Y_{f}\text{s} \) value. Practically, however, that configuration serves little purpose, because with no DC bias on the gate the output signal may be severely distorted.

The effect of temperature on variations in gain should not be overlooked. As the ambient temperature increases, the leakage component through the semiconductor also increases, which affects \( I_D \), which, in turn, affects \( Y_{f}\text{s} \). In all cases, the tests are made at 25°C. When tests are performed at elevated temperatures the results are listed separately in the data sheet.

Next month we'll look into the fascinating world of operational amplifiers.

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**R-E ROBOT**

**continued from page 60**

SEMICONDUCTOR TESTING

**continued from page 63**

**SOURCES**

The following are available from Vesta Technology, 7100 W. 44th St., Wheatridge, CO 80033 (303-422-8098): Bare RE-Robot controller board, $41; assembled and tested RE-Robot controller board, $200; bare RPC board, $41; assembled and tested RPC, fully populated for the robot function, $294. Add $8.00 shipping per board ordered. Colorado residents add appropriate sales tax. Mastercard and Visa accepted.

Optical encoders (100 counts/revolution, quadrature output) are available from EMC Corp., 373 Hillsboro Way, Goleta CA 93117 (805-968-3060) for $40 each. California residents must add appropriate sales tax.

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RADIO/ELECTRONICS

90
DESIGNING PC BOARDS ON YOUR PC

New programs make it easy

THE KEPROM
Sinking the software pirate
97 DESIGNING PC BOARDS ON YOUR COMPUTER
CAD systems can make the job almost easy.

100 THE KEPROM: SINKING THE SOFTWARE PIRATE
A new type of hardware protection.

91 EDITOR'S WORKBENCH
Hardware: Microsolutions' Matchpoint PC
Software: Software Masters' Visible Computer: 8088
Etc.: New computer products
We've got reviews of several exciting products this month, including a well-done 8088/assembly-language tutorial and a disk-conversion package that allows you to read Apple disks on an IBM (or compatible) machine, along with brief spots on new releases of several industry standards. However, before getting to our reviews, we'd like to take time out to examine the chaotic state of IBM operating systems.

IBM'S NEW OPERATING SYSTEM(S): THE M & M'S

From the user's standpoint, there are two kinds of operating systems: command-line based and icon based. Apple's Macintosh, based to a great extent on work done by a research subsidiary of the XEROX Corporation, is an icon-based system, the IBM-PC is a command-line based system.

Much ink has been spilled arguing the merits of one system over the other, but few would argue that icon-based systems are more appropriate for beginning and occasional users, and that command-line-based systems are more appropriate for medium and advanced users who are willing to forego the ease of use of the icon system for the speed of the command-line system.

The IBM-PC (and its close relatives) to date have used an operating system that is command-line based. However, it seems likely that the next generation of IBM/Microsoft operating systems will be oriented toward a Mac-style interface. The problem with that type of interface is simple: the 8088 microprocessor used in the IBM-PC, the IBM-PC XT, and millions of clones is too slow to handle a full graphics interface like Microsoft Windows.

However, the IBM-PC AT has a higher-powered microprocessor (the 80286) that allows Windows to run at acceptable speed. And the latest member of the 80xxx family, the 80386, is even more powerful than the '286, so raw performance of Windows can theoretically improve by a factor of ten or so.

There's another problem. The '286 and '386 IC's can run standard MS-DOS applications as-is, but a large part of the inherent power of those microprocessors is thereby left untapped. On the other hand, the current generation of MS-DOS applications programs simply can't use the advanced features of the new IC's. What kinds of features? The M & M's: Memory and Multitasking. How much memory? Megabytes, gigabytes, terabytes (literally!) of memory. Multitasking? Why? So that you can run several programs simultaneously, and so that programmers can run several parts of the same program simultaneously.

Why would you want your computer to do more than one thing at a time? If all you use the machine for is to write letters to Aunt Sally and balance your checkbook, you don't need the M & M's. But if you do CAD, or manage large spreadsheets or databases, or do circuit design and analysis, then M & M's will become not optional but necessary as the next generation of software learns how to use the new hardware.

Why? Because, for example, the typical CAD program on an unenhanced PC runs slow. Speed may be acceptable on a '286 machine, but even then you don't get the snap out of it that you can get with, say, a well-designed wordprocessor on an '88 machine.

But speed isn't valuable in and of itself; it's a means to an end. And the kinds of things a fast microprocessor can be used for may surprise you. For example, how would you like to use a CAD program that had separate background processes that kept various views of the screen up to date? No more thirty-second screen redrives, switching views would happen instantaneously.

Or how would you like to use a circuit design/analysis program that allowed you to enter components graphically, and in the background kept track of voltages and currents at all nodes? So if you needed to bias a transistor to a certain point, given the output of the preceding stage, the circuit would calculate resistor values instantaneously, and, based on that information, start calculating values for the next stage.

How about a wordprocessor that did real-time spelling checking, disk saves (in the background, of course) every five minutes or 2000 keystrokes? And (everybody's favorite) how about running a spreadsheet, a database manager, a communications program, and a wordprocessor simultaneously?

You can't do any of those things in an acceptable manner on the present generation of PC's (IBM or otherwise). The hardware is here (sort of), but the software isn't. Computers (UNIX-based systems and engineering workstations, for example) have been around for some time that can do multitasking, but the hardware is high-priced, and the software (especially the user interface) is in many ways less functional than what is available for PC's.

So where does all of that leave IBM and Microsoft? They're supposed to release new hardware and software by the time you read this. The new hardware probably will include a low-priced PC that will compete with foreign clones and with the PC compatibles released by Commodore and Atari. The new hardware will probably also include a '386 machine; indeed, IBM would be foolish not to get something to market quickly, because it has been reported that Compaq is selling 10,000 '386 machines per month! Last, there may be something in between, perhaps another '86 machine.

New DOS

The new hardware is going to be nothing more than a high-priced bookend without software to take advantage of it. And, fortunately, Microsoft is slightly more open
about internal development than IBM, there has been some indication that DOS as we know it may split into three different operating systems.

At the lowest level we'll see some sort of extension of DOS 3. Speed may be enhanced, and some sort of graphics-based (not necessarily a full icon-based) user interface with more-comprehensible error messages and a built-in help system will be added. Both IBM and Microsoft have emphasized that the new DOS 3 will be much friendlier than (and compatible with) past versions, but hopefully the command-line interface will be retained. In any case, the new DOS 3 will be unable to take advantage of the M & M's, so don't expect to be able to run bigger spreadsheets or do multitasking. Power users will probably shun the new DOS because the graphics and help systems will eat up valuable system RAM and slow overall operations down.

At the next level we'll see an operating system for the '286 (which is used in the AT and in many accelerator cards), one that will allow specially-written programs to take advantage of the M & M's. However, 886-DOS (also unofficially called A-DOS, Advanced-DOS, DOS 5.0, and other names) will not allow traditional applications (those that can use only 640K of memory and those that write directly to video RAM) to use more memory or to do multitasking. Only new or adapted programs will be able to take advantage of the M & M's.

The '386 IC has a special mode that allows it to run multiple traditional applications simultaneously. The new '386 operating system (control program) will exploit the multitasking capability, but, like 886 DOS, will not allow traditional applications to access more than 640K of contiguous RAM. However, each traditional application will think it has a complete 640K machine at its disposal. But no particular application will be able to take advantage of extended resources (the M & M's) by itself. In addition, 386-DOS will be able to run other operating systems simultaneously, so it should be possible to build a UNIX-based engineering workstation that could run DOS applications in a UNIX window.

Apple and IBM

Meanwhile, Apple has introduced two new Macintosh computers, one of which (the Macintosh II, shown in Fig. 1) uses a CPU (the 68000) that can compete directly with the '386. More significant is the fact that Apple has finally realized two things: (1) IBM is a force to be reckoned with, and (2) an open-architecture machine with expansion slots and good technical documentation (like the IBM-PC and like the original Apple II) is good for business in that it encourages third-party innovation.

The new Macintosh II is an open-architecture machine that will run IBM Software (with the addition of a plug-in card containing an '88 or compatible microprocessor). In addition, Apple has ported UNIX to run on the machine, and there have already been good reports about the machine from the academic community (UNIX's traditional stronghold). It's likely, at least in the high end of the market, that Apple will finally be able to compete with IBM (i.e., with the forthcoming '386 machine).

Similarly, Commodore's recently announced A2000 has a keyboard that looks remarkably like the new IBM keyboard, and a plug-in co-processor card that runs IBM software. Inside, the A2000 has four slots that accept IBM-compatible expansion cards.

Conclusions

The point is that IBM is slowly moving toward the ease-of-use features that Apple brought to the PC world, and Apple (as well as Commodore) is moving simultaneously toward IBM compatibility and the large base of quality software and hardware that exists to serve the IBM market. Perhaps the Hatfields and McCoys can make up after all.

For users, these are all good signs. We'll get software that is more powerful, more kinds of hardware to run it on, and, as different system designs converge, we'll have less trouble moving from system to system. And just as the M & M's will bring increased power to advanced users, that additional power will also be useful in creating "friendly" graphics-oriented systems for beginners and occasional users. So don't let anyone tell you that the average user doesn't need a '386 (or a 68020), he may need it more than the power user!

IBM has been hurt by the invasion of the Clones, but IBM (like few other companies) has the resources to develop the next generation of hardware and (with a little help from its friends) systems software. Whatever IBM does, it always takes the Clone makers six months to a year to catch up—and by then IBM is working on something new. So, even if it has lost some market share, IBM is still calling the shots.

**FIG. 1**

**MICROSOLUTIONS' MATCHPOINT-PC**

Except by means of an expensive hardware emulator, it has not been possible to interchange disk files between Apple II and IBM-compatible computers. Currently, for the remainder of this review we'll use the term IBM to cover both IBM-made machines and clones.) Small businessmen with years of data generated on an Apple discovered that those files had to be recreated if the computer system was upgraded to an IBM. Similarly, the educational system, which has an enormous installed base of Apples, discovered that teachers could not prepare work at home on an IBM because even simple BASIC programs and text files could not be read by the school computers, and vice versa.

Although software that can convert virtually any CP/M or TRSDOS file to the MSDOS format (and vice versa) has been available for several years, it was not available for the Apple II. Of the more than 100 brands of computers that are commonly used for education and business, only the Apple was foreclosed from the MS-DOS world.

But Apple/IBM incompatibility has finally been resolved by a device called the MatchPoint-PC, made by MicroSolutions (132 West Lincoln Highway, Dekalb, IL 60115). It's a hardware/software package specifically designed for reading and writing on an IBM, disk files written in AppleDOS and ProDOS, Apple Softcard CP/M, and just about any other CP/M format. The hardware part is a half-length controller board (Fig. 2) that you install in an otherwise unused slot. It connects between the IBM's floppy-disk controller and its floppy-disk drives. A cable (which is supplied) that will match either card-edge or header-type controller terminals con-
rects the MatchPoint-PC to the existing controller. The computer's original cable is moved from the controller to the MatchPoint-PC, thereby placing the MatchPoint-PC between the disk controller and the disk drives.

The supplied software, which consists of a program called MPOINT and a special version of Uniform—a "universal" CP/M disk format/read/write program that can handle more than 100 different disk formats—sets up the operating conditions for foreign (non MS-DOS) disk formats.

Running the MPOINT program allows the interface to recognize Apple II disk formats, and temporarily adds five new commands to MS-DOS. They are: ACOPY, ADEL, ADIR, AlNIT (which formats a disk), and ATYPE. All commands function just like their MS-DOS equivalents (COPY, DEL, DIR, FORMAT, and TYPE).

How to use it

In normal operation, the MatchPoint-PC is totally transparent; the computer functions exactly as it always did. In fact, placing an Apple DOS or ProDOS disk in a drive will result in a read error message.

However, MPOINT allows the computer to recognize a single physical drive as two logical drives. For example, assume that MPOINT is configured so that drive B: will be the Apple-compatible drive. When the command DIR B: is entered the computer will recognize only MS-DOS disks in drive B. But if the command ADIR B: is entered, the MatchPoint-PC hardware automatically treats drive B: as an Apple drive and reads in the Apple disk's directory in short, the mode in which drive B: operates is automatically determined by the command you use. Figure 3 shows the ADIR screen display of an Apple disk on an IBM computer.

FIG. 3

Here's another example. The command ACOPY B: WORK.TEXT A: will copy the Apple file WORK.TEXT from drive B: to an MS-DOS disk in drive A: You could, of course, do it the other way around—MS-DOS (A:) to Apple (B:)

Uniform

By using the Uniform program, drive B can function as a CP/M drive (Apple or otherwise) using the next higher drive designator. If your computer has two physical drives (A: and B:), drive B: will double as CP/M drive C:. If your computer already has a drive C: (a hard disk, perhaps), the created CP/M drive will be drive D:

If that's confusing, perhaps a few examples will straighten things out. Assume the computer has two disk drives, A: and B:. If the selected Uniform mode is CP/M, the command COPY C: WORK.TEXT A: will copy the Apple Softcard CP/M file WORK.TEXT from drive C: (physical drive B:) to MS-DOS drive A:. And even though drive B: functions as CP/M drive C:, it also functions as MS-DOS drive B:.

Although an IBM computer can read Apple disk files, it cannot run binary programs. BASIC programs might be convertible, depending on how many machine-specific statements are used. Graphics programs, for example, will be particularly difficult to translate. Only ASCII text and data files are truly interchangeable between Apple and IBM machines. For example, SuperCalc files in an Apple CP/M format could be converted and then used on an IBM version of the program.

Unidos

There is one exception to the rule of binary file incompatibility, and that is when MatchPoint-PC is used with Uniform and an additional program called Unidos (also sold by MicroSolutions), which is a 280 emulator for IBM machines. It allows an IBM to run 280 and 8080 CP/M programs. The catch is that the CP/M program runs much slower on the IBM than it would on a true 280 machine because Unidos is only an emulator. So, for example, if you're upgrading from a CP/M to an IBM machine, you can continue to run your old CP/M software on the IBM.

Half-tracking

Although MatchPoint-PC works extremely well and with little trouble, its Apple/IBM compatibility is limited by something known as "half-tracking," which refers to disk data written between tracks on the disk. Basically, it's as if the disk drive's read/write "read, instead of stepping from track to track, stepped between tracks first. Half-tracking is used by some copy-protected Apple II software, which locates data or special encoding between the conventional tracks—in the half-tracks. IBM-type drives cannot step to the half-track location, hence, they cannot read nor write a half-track diskette. So, if you have Apple disks that are half-tracked, they will not be read by the MatchPoint-PC system. That's the only limitation we've found in MatchPoint-PC.

The MatchPoint-PC package, which includes the hardware interface, MPOINT, and UNIFORM retails for $195. For orders and further information write directly to MicroSolutions.

I bought my first personal computer, a single-board 6502 machine, in 1979. After hooking the board up to a power supply, with shaking hands I turned it on. Not much happened—no smoke, anyway. The six-digit seven-segment LED display showed a row of zeros. After staring at those zeros a while I realized I was in trouble—big trouble. I had just purchased the most expensive gadget (about $250) I had ever seen—and I didn't know the first thing about how to use it! It had no BASIC in ROM (one would be forthcoming), nor even an assembler, so programs had to be assembled by hand. And that was a difficult proposition for someone who had never even heard of hexadecimal numbering! It took me months just to learn how to add two numbers together!

Times have changed since 1979. Now anyone who wants to learn about microprocessors and machine and assembly language programming can do so without going gray in the process. How? With The Visible Computer: 8088, a disk-based self-teaching guide by Software Masters, PO Box 3639, Bryan, TX 77805.

The Visible Computer comes with a single floppy disk and a 350-page book. The disk contains more than 50 demonstration programs and a special program, called TVC, that functions as a combination assembler, debugger, and 8088 simulator. You can use TVC to run the demonstration programs, programs you write yourself, and commercial MS-DOS programs.

A beginner won't use TVC right away; he'll start off reading the book. The book contains 34 chapters and several appendices that cover number systems, basic logic (AND, OR, etc.), machine language, the stack, looping, arrays, the 8087 math co-processor, interrupts, and more.

The book is well-written and well-illustrated; new topics are introduced at a rate that should be acceptable to most aspiring assembly-language programmers. The author (who is not named) has an irreverent style that will make you chuckle more than once. For example, Chapter 2 ("Alternate Numbering Systems") starts off like this: "If you bought 'The Visible Computer with the hope that it would somehow save you the effort of climbing Mount Hexadecimal,
Simulating the 8088

TVC is an 8088 simulator written mainly in Pascal. It comes up on-screen with several windows (starting in the upper left corner and working clockwise): the control window, the flags window, the status window, the disassembly window, and the processor window. See Fig. 4. Beneath the windows is the monitor area. Normally you enter commands in the monitor area, the results of those commands are displayed in the various windows.

The commands used to control TVC are similar to the corresponding commands in the MS-DOS DEBUG program, so if you already know DEBUG you’ll have no trouble using TVC. On the other hand, if you don’t know DEBUG, you can use TVC to learn it, and doing so is valuable, because most MS-DOS debuggers are based on DEBUG’s command set.

Of course, TVC has a number of unique commands that allow you to step through programs step by step, examine and alter memory, assemble and disassemble programs, etc. The feature we like best is the simulator. You can set it up to display the machine state at one of several levels. The most detailed level (4) allows you to see what’s happening inside the 8088 machine cycle by machine cycle. Or you can set it to stop between each instruction, or not at all.

You can also generate “interrupts” during simulation by pressing keys at the keyboard. A special command allows you to set the interrupt number that is generated. For example, to simulate an interrupt 9, you would issue the command INTR 9. Then, when you pressed a key during simulation, a pseudo-interrupt 9 would be generated.

To protect the beginner from himself, TVC has a privilege mode that must be entered via a special command. In non-privileged mode, the user is prevented from writing to system memory, output ports, etc.

Other commands allow you to load and save files, activate a calculator (that allows addition, subtraction, multiplication, and division, and conversion between hex, decimal, and binary numbers, etc.).

All in all, The Visible Computer: 8088 provides a remarkably painless introduction to the 8088 microprocessor and assembly-language programming. So we heartily recommend it, a bargain at $79.95.

Software Masters also publishes versions of the package that teach the 6502 microprocessor. Contact them for details.

**ASHTON-TATE, DBASE III PLUS**

The last Ashton-Tate product we had occasion to use (some four years ago) was dBASE II on a CP/M machine. The program has evolved a great deal in those four years, dBASE III Plus (which runs only on IBM and compatible machines) is much polished and much enhanced over the previous version. For example, there are many many new programming commands and network support, but the more significant changes have occurred in the user interface.

dBASE III Plus has five user support systems: a disk-based tutorial; a program that helps you build a simple database automatically; another program that gives dBASE III Plus a menu-driven front end, extensive on-line help; and two thick manuals. The manuals constitute the weak link in the support system because it’s hard to locate desired information quickly.

dBASE III Plus is de facto standard in the microcomputer world. It’s a powerful product with many features, so it’s a serious contender for any moderately complex database management job. The program lists for $695 from Ashton-Tate (90101 Hamilton Ave., Torrance, CA 90502).
It hasn't been long since the most sophisticated thing you could do on a home computer was save the Earth from an alien invasion. More practical (and more mundane) jobs like word processing, database management, and CAD were the exclusive property of mainframes and workstations. Why? Because they needed lots of memory to work, and enough speed to provide a solution before the problem becomes obsolete.

However, the last several years have seen such a tremendous increase in computer technology that the difference between micro and mainframe machines is becoming more one of semantics than anything else. LSI and VLSI IC's have advanced microprocessors to the point where today's home computers are orders of magnitude more powerful than the mainframes used ten years ago. The bus width, instruction set, speed, and register structure of a modern CPU provides the perfect hardware environment for a new generation of sophisticated software.

One of the beneficiaries of this advance in computer power is the printed-circuit board designer. Anyone who has laid a board out by hand knows that routing traces is really a matter of repetitive trial and error. After the circuit design is finalized and the size and shape of the board have been defined, connecting all the components properly entails doing a great deal of experimenting. There are many standard guidelines to follow, and every designer has his own bag of tricks, but there's no getting around the fact that the whole job is tedious, time consuming, and often incredibly boring.

The good news is that now there are several commercial printed-circuit board layout programs available for the home computer. But before you rush out to buy one, keep in mind the fact that there are vast differences in price and performance among them. How can you decide which is right for you? Keep reading. In this two-part article we are going to examine the features of several popular programs in detail. But before getting into specific features of specific programs, we're going to discuss the basics of PC-board design. That way, if you're new to CAD (Computer-Aided Design), you can get a feel for what it's all about. We'll talk about specific programs (those shown in Table 1) next time.

The basics of CAD
Laying out a PC board (by hand or by computer) is not a random process; you must have definite information at hand, and you must follow rational procedures.

1. The circuit design must be finalized. You must know how the components are supposed to be connected, which signals are going off-board, sizes and shapes of on-board connectors, etc.
and, most important of all, how well the routing program was written to begin with.

The basic router is the "point-to-point" variety. When you use one, you indicate, for example, which two pins you want to connect, and the program tries to connect them. The interactive approach lets you control the order of traces, and it does all the tedious trial-and-error work for you. You can certainly lay out a board that way, but you'll have to be involved in every single step.

In a sense, the point-to-point router is a technician's version of "computer art" software. Using a computer art program, you would indicate two points on the screen and then connect them by entering the appropriate coordinates on a keyboard, by moving the cursor with the keyboard's directional (arrow) keys, by moving a mouse or joystick, or by drawing a line on a graphics tablet. Depending on the device or method used to create the line, the points would be connected by a straight line or by one having irregularities. The interactive basic router doesn't work much different, it just insures the connecting lines won't be irregular. Also, keep in mind that the more complex the board, the more difficult the job will be.

Remember that, there's much more to laying out a board than just making connections. For example, let's say you start at one corner of the layout and begin laying down traces. As the board fills up, it gets harder and harder to find paths to connect the pins. At some point you realize that you can simplify the routing of many traces by redoing much of the work you've already finished. So if you were doing everything by hand, you'd turn your pencil upside down and start erasing traces. That's exactly what you have to do with software that does point-to-point routing.

In fact, that's the biggest limitation of a point-to-point router. It doesn't know how or when to make the judgement that it's better off re-doing some work than sticking with a design and trying to work around it. That type of software only knows how to tie two points together—it can't optimize trace routing of the entire board.

To do that, you need software that's several orders of magnitude smarter: what's called an auto-router.

**Automatic trace routing**

An auto-router knows when it makes sense to throw away earlier parts of the layout. You can sit down and tell it how you'd like to tie particular pins together (that's called pre-routing), or you can let it handle the whole job by itself. It takes both connection and placement information from files (called netlists) and sets about doing the entire layout from start to finish. All you have to do is give the auto-router the name of the job and start it up.

The success rate of an auto-router depends, among other things, on how flexible it is. A versatile program will provide you with many options so you can tell it what the layout parameters are, how much time to spend on an individual trace, how convoluted the path of any one trace can be, at what point it should consider redoing work it's already done, etc., etc. The bottom line is that, the more control you have over the rules the auto-router follows, the more chance there is that it will route your board in a satisfactory manner.

**Feeding the router**

No matter how sophisticated the router is, it's only one part of a complete PC-board layout package. You need some way to give it the information it must have to do the job. That information includes the following:

1. The components you're using.
2. How they're connected together.
3. The board's physical characteristics.
4. Where the parts are placed on the board.
5. The type of hardcopy output you want.

The way a PC-board layout program collects all that information is critical, because the data-gathering part of the package is usually the one the user spends the most time with.

The simplest approach is to provide a way to enter data in symbolic form via the keyboard. The data file thus created lists which pins are connected together. The shape of the board and its
TABLE 1—PROGRAMS DISCUSSED

<table>
<thead>
<tr>
<th>smARTWORKS</th>
<th>The Wintek Corporation 1801 South Street Lafayette, Indiana 47904-2993 $895.00 Copy Protected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project: PCB</td>
<td>DASoft Designs Systems, Inc. P.O. Box 8088 Berkeley, California 94707-8088 $950.00 Hardware Locked</td>
</tr>
<tr>
<td>The Autoboard System</td>
<td>The Great Softwestern Company, Inc. 207 W. Hickory St. Suite 309 Denton, Texas 76201 $2500.00 Requires AutoCAD</td>
</tr>
<tr>
<td>AutoCAD</td>
<td>Autodesk, Inc. 2320 Marinship Way Sausalito, California 94965 $2850.00 (Version 2.5 or above)</td>
</tr>
<tr>
<td>smARTCAD</td>
<td>Creative Electronics 925 Fairwin Ave. Nashville, Tennessee 37216 $395</td>
</tr>
</tbody>
</table>

component layout can be handled in the same way. You have to establish some sort of coordinate system and use it to indicate both the edges of the board and the location of each component. That data could be entered from the keyboard just as the circuit data was. The problem with this method is that it's slow, non-intuitive, and prone to hard-to-detect errors.

**Graphics editor**

Using a database manager or word processor to build the files needed by the router is one way to solve the problem, but a much slicker (and friendlier) way to get the job done is to use a graphics editor as the router's front end. It's much easier to draw the schematic and the board than it is to describe them. After all, everybody knows that one picture is worth a thousand words—to say nothing of hours and hours of work, as well.

The idea is to use software that knows how to translate graphic images (drawn by you) into the tabular data needed by the router. The approach is terrific from the user's point of view, but it's an enormous problem for programmers, because designing a graphics system is not something you whip out between breakfast and lunch.

Among other things, you have to contend with graphic display standards (or lack thereof), digitizers, printers, plotters, and the rest of the I/O can of worms. It's one thing to manipulate graphic data in memory, but getting that data out in a useful form is difficult, because there are almost as many I/O standards as there are peripherals on the market. And even after the I/O problems are solved, the software designer still faces the job of translating graphic data into files that can be read by the router.

**The router**

Most commercial PCB-board software allows you to enter data via a graphics editor, and most gives you some provision for editing the netlists that are produced. If you pay attention to what you're doing, you can be reasonably sure that the router will work on exactly the circuit and layout you have in mind. What the router will produce, however, is something else altogether.

When you route a board by hand, the job is over when you put the last trace on the board. But with a router, the job's finished when it's completed as many traces as it can. The difference is more than merely semantic. Even if you're using the world's most sophisticated software, there's a good chance that the router won't be 100% successful. You'll still have to route a few traces by hand, and

**Even though it's a good JCB, this layout was obviously hand-drawn. Next month we'll do the layout by computer.**

when you reach that point, a good graphics editor becomes extremely important.

By the time the router finishes doing what it can, most of the traces will have been 'aid out, so adding the missing ones can turn out to be a tough job. In fact, if the graphics editor isn't very powerful, it can be an impossible job. You'll have to move and stretch many existing traces to be able to fit in the missing ones. And more than likely you'll want to re-route some of the work done by the router, because some of the paths it may have overlooked more obvious routes. The reason for this is that the router doesn't think the way you do; obvious is a relative term.

**Getting hardcopy**

However, the software goes about collecting and processing the data, eventually the layout must be put down on paper. It's all well and good to be able to take your circuit and generate a file that contains a description of the routed board, but the whole point of using a computer is lost if you can't get the answers out in a format you can use.

Just as you can enter data in several ways, you can get hardcopy output in several ways. You can send the image to a printer or a plotter and produce drawings for photochemical board production. Or you might want it in a data coordinate format to use with a numerical-control drilling machine. There are other options too, including files that can be processed further by other programs. And you must know before you start what you want by the time you're finished. So if you're considering a particular program, make sure it can provide the kind of output you want.

Next time we'll look at the capabilities of several programs. 10
Sinking The Software Pirates

JEFF HOLTZMAN, TECHNICAL EDITOR

Millions of dollars are lost every year because software pirates copy use, and sometimes distribute popular computer programs. Until recently the usual method of protecting software from unauthorized distribution has been to provide that software on floppy disks that are copy-protected, or on special "key" disks that must be present whenever the program is running.

However, copy protection has not proven to be an effective means of halting the unauthorized usage and distribution of computer programs. Legitimate users find key disks inconvenient, but even more important, a number of companies sell programs that can copy so-called copy-protected disks with ease.

Intel Corporation (3065 Bowers Ave., Santa Clara, CA 95051) has come up with a hardware solution to the problem of copy protection. The solution involves use of two or more 27916 key- access EPROM's (for KEPROM's, for short). A factory-fresh 27916 functions just like a 27128 EPROM, the 27916 comes in a 28-pin package that is identical to that of a 27128. The 27916's pinout is shown in Fig. 1.

Inside, the 27916 contains 16,384 eight-bit bytes that may be programmed and erased using standard equipment and procedures. In addition, however, as shown in Fig. 2, the 27916 contains special circuitry that locks the KEPROM—that prevents all but a 528-byte boot area from being accessed until a special authentication sequence has been carried out. The authentication sequence involves the two-way transfer of an internally generated, 32-bit random number that is encrypted according to a designer-defined 64-bit key. If, after the transfer, the originating and receiving KEPROM's have not decrypted the same number, their memory arrays remain locked and unusable. Otherwise each function just like a standard 27128 EPROM until the next power-down, or until a special reset code is received.

There are a number of ways of using the KEPROM's security features. Probably the most useful is to store the system's boot code in a KEPROM. Then, if the proper handshake sequence is not performed, the system will not come up. A limited number of users might have plug-in cartridges (computer game cartridges, for example), each of which would contain a KEPROM with the correct key. When a user inserted his cartridge, he would be able to boot the system. To perform that type of boot, both KEPROM's must have access to the data and address buses, as shown in Fig. 3.

A software publisher (like Microsoft) would find it difficult to use a KEPROM security system with present-day machines and a BASIC language program, for example. It takes two KEPROM's to perform the authentication handshake, so the BASIC cartridge should contain one KEPROM, and the other should be mounted on the system board. However, no present-day personal computers contain their boot software in KEPROM form. Retro fitting might be possible, but, to be most useful, a KEPROM-based security system must be designed in from the beginning.
FIG. 2—BLOCK DIAGRAM OF THE 27916 reveals that half of the IC (shown to the left of the dashed line) is very similar to a standard EPROM. The other half (shown to the right of the dashed line) contains the extra logic, control, and memory cells.

FIG. 3—A KEPROM-BASED SYSTEM requires normal access to the data and address buses.

**Configurations and states**

A 27916 may be configured to operate in one of three different ways: as a 27128 EPROM, as a 27916 KEPROM, and as a 27916 Key Manager. As a 27128, no authentication process need be executed at power-up. But as a KEPROM or a Key Manager, the authentication process must be executed at power-up. As a Key Manager, the device can control as many as 1024 KEPROMs. In that configuration, the device holds 1024 eight-bit keys, so half of the 16,384-byte address space is unavailable for system and application software. Two programmable bits (that are not located in the regular 16,384-byte address space) determine the device’s configuration.

When a 27916 is configured as a KEPROM or as a Key Manager, it can be in one of three different states: originator, recipient, or memory. It can enter the memory state only after the authentication process has been completed successfully. The two other states are used during authentication, which we’ll discuss more fully below.

**Memory map**

As shown in Fig. 4, the 27916 has a number of overlapping memory locations. As shown in Fig. 4-a, when a 27916 is in the memory state, and pin 94 is at a TTL high or low, the entire 16K of memory address space is available for normal read-only use. However, location 401 (all addresses are specified in hexadecimal notation) also contains a command register that controls the 27916’s state. The possible states are listed in Table 1.

When a 27916 is in Originator or Recipient states, several other registers become accessible. Location 400 is an input/output register that is used to transfer the encrypted keys between two KEPROM’s by bit. Locations 402 and 403 contain an optional key number that is used as an index, in a Key Manager system, to the proper key (of 1024 possible keys). Location 404 contains a Ready register that is used to synchronize key-bit transfers.

**TABLE 1—COMMAND REGISTER CODES**

<table>
<thead>
<tr>
<th>Hex Value</th>
<th>Command</th>
</tr>
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<tbody>
<tr>
<td>04</td>
<td>Enter Memory State</td>
</tr>
<tr>
<td>09</td>
<td>Enter Recipient State</td>
</tr>
<tr>
<td>31</td>
<td>Enter Originator State</td>
</tr>
<tr>
<td>29</td>
<td>Reset Default Recipient</td>
</tr>
<tr>
<td>31</td>
<td>Reset Default Originator</td>
</tr>
<tr>
<td>0B</td>
<td>Enter Recipient (Key-Manager Test)</td>
</tr>
<tr>
<td>33</td>
<td>Enter Originator (Key-Manager Test)</td>
</tr>
<tr>
<td>2B</td>
<td>Reset Default RE (Key-Manager Test)</td>
</tr>
<tr>
<td>33</td>
<td>Reset Default OR (Key-Manager Test)</td>
</tr>
</tbody>
</table>

Several additional registers become available when pin 94 (address line 9) is raised to 15 volts, as shown in Fig. 4-c. These locations need only be accessed during the manufacturing cycle, so you don’t have to worry about 15-volt signals on your 5-volt system bus! Location 00 contains a manufacturer’s code, and location 01 contains a device code. That information can be used by automatic programming machinery to select the proper programming voltages and algorithms.

Further, with pin 24 at 12 volts, a command mask register (location 401) and a programmable delay count register (location 405) can be written to. The delay count register determines the speed at which the authentication handshake occurs, legal values and corresponding handshake times are listed in Table 2. Slowing down the handshake process makes it more difficult for a would-be pirate to decode the sequence of operations.

The Command Mask Register controls the 27916’s configuration.
FIG. 4—MEMORY MAP OF THE 27916 reveals that when the device is in the memory state (a), all 16K of memory is available as usual. But in the originator and recipient states (b), only the boot areas and the control registers are accessible. In either state, by connecting pin 24 to 12 volts, the delay count, command mask, and ID bytes are accessible (c).

TABLE 2—PROGRAMMABLE DELAY CODES

<table>
<thead>
<tr>
<th>Hex Value</th>
<th>Approximate Handshake</th>
<th>Handshake Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1F</td>
<td>10 sec.</td>
<td>Slowest</td>
</tr>
<tr>
<td>3F</td>
<td>6-8 sec.</td>
<td>Slower</td>
</tr>
<tr>
<td>7F</td>
<td>3-5 sec.</td>
<td>Slow</td>
</tr>
<tr>
<td>FF</td>
<td>0.15 sec.</td>
<td>Fast</td>
</tr>
</tbody>
</table>

TABLE 3—COMMAND MASK CODING

<table>
<thead>
<tr>
<th>Hex Code</th>
<th>Configuration and Default State</th>
</tr>
</thead>
<tbody>
<tr>
<td>E0</td>
<td>Locked Key-Manager—Default Recipient</td>
</tr>
<tr>
<td>E1</td>
<td>Not Locked Key-Manager—Default Recipient</td>
</tr>
<tr>
<td>E2</td>
<td>Locked KEPROM—Default Recipient</td>
</tr>
<tr>
<td>E3</td>
<td>Not Locked KEPROM—Default Originator</td>
</tr>
<tr>
<td>E4</td>
<td>Locked Key-Manager—Default Originator</td>
</tr>
<tr>
<td>E5</td>
<td>Not Locked Key-Manager—Default Originator</td>
</tr>
<tr>
<td>E6</td>
<td>Locked KEPROM—Default Originator</td>
</tr>
<tr>
<td>E7</td>
<td>Not Locked KEPROM—Default Originator</td>
</tr>
</tbody>
</table>

(KEPROM, 97128, or Key Manager). It, by the way, is the third register that can be accessed at location 401, the normal memory cell and the command register are the other two. Legal values and corresponding configurations are shown in Table 3. Bit 0 of the Command Mask Register is the lock bit, bit 1 is the manager bit. If either bit is programmed with a value of 0, the 27916 cannot be read without first executing an authentication sequence. If the manager bit is programmed with a value of 0, the 27916 enters the Key Manager configuration. The lock bit is erasable, but the manager bit is not. Hence the Key Manager configuration is permanent.

The authentication handshake

The overall system boot-up process is outlined in Fig. 5. First the two 27916s must be reset by writing the appropriate reset code (as shown in Table 1) to the command register. One 27916 goes into the originator state, and the other goes into the recipient state, according to the contents of their command masks (as shown in Table 3). The originator then generates a 32-bit random number and places it in its ready register. The CPU reads a byte from the IO register, pulls the recipient's ready register, and transfers the byte to the recipient when it is ready. Although an entire eight-bit byte is transferred, only one bit is significant, so 32 separate transfers must take place to transfer the entire key.

The recipient encrypts the number according to its key, and then sends that number to the originator, using the same type of polling sequence. The originator then encrypts the original number and compares the two encrypted numbers. If they are equal, which they will be if the originator's and the recipient's keys are identical, the recipient can be placed in the memory state. Then the two devices swap roles and the process repeats. If the numbers match, the new recipient can be placed in the memory state.

The key

The key used to encrypt the random number is 64 bits long, hence there are about $10^{64}$ possible keys. That fact alone makes it difficult for the would-be pirate to attempt to determine the key. The eight key bytes are programmed into memory locations 408-40F. After the 27916 is configured as a KEPROM or a Key Manager, the key bytes are completely inaccessible to the outside world.

Usage considerations

First the 27916s normal memory space should be programmed, keeping in mind that the first 512 bytes must be used to perform the authentication sequence. The upper bytes of the 27916 (3FFC-3FFF) are also reserved for use with microprocessors like the 6502 whose reset and interrupt sequences use vectors in that area.
FIG. 5—FLOW CHART illustrates the proper boot-up sequence to enable the originator and recipient EEPROM's.

Then the Programmable delay counter should be programmed, if desired, and verified. The key (and the key number, if used) are programmed and verified next. Only then should the command mask be programmed. After that, the device will be locked, and access to its contents can only be gained after an authentication handshake. The Delay Counter, the Key bytes, the Key number and the command mask are programmed more or less the same as normal, but pin 24 (A9) is connected to a 12 volt source.

As for hardware considerations, Intel recommends connecting a 0.1 µf capacitor between vcc and ground near each 27916, and one 4.7 µf tantalum capacitor for every eight 27916's to compensate for voltage drops due to PC-board inductance. The 27916 has a 250 nsec access time, so it should be fully compatible with standard EPROM circuits and layouts.

Intel recommends that the 27916 in which the boot code is located should be soldered, and perhaps glued, to the PC board.
How safe is a KEPROM?

It might be possible, using a scanning electron microscope and other highly sophisticated equipment, to take a 27916 apart and duplicate the code it contained. Few people have access to that sort of equipment, but for military and other security-sensitive uses, the possibility that a KEPROM could be disassembled must be taken into account.

Another way of cracking a KEPROM involves using a logic analyzer. One could be attached to the system bus of a target computer and used to record the contents of the various memory devices in a system as they were accessed. But even if the complete contents of a locked memory system were obtained, they would not be useful without knowledge of the key, and the key is never present on the output pins after the lock bit has been cleared.

To understand why, suppose someone were able to duplicate the contents of a plug-in KEPROM cartridge. If those contents were duplicated in a 27128 EPROM and plugged in the cartridge port, the authentication handshake would fail, because the 27128 would not echo the encrypted random number.

You might think that the recovered contents could be transferred to a blank KEPROM, and the key somehow discerned. But how? It would take (literally) centuries to try all possible 10²⁴ keys one by one. Other methods using statistical analyses could be tried, or the key might be arrived at by cracking the encryption algorithm, but both are highly unlikely to yield results.

It’s ironic that, just at the time when major software publishers like Microsoft and Ashton-Tate are dropping floppy-disk copy protection, Intel has developed the 27916. Whether those publishers will adopt hardware protection remains to be seen. It’s highly unlikely that users will be happy using plug-in cartridges.
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<td>18 ($51.30)</td>
<td>19 ($54.15)</td>
<td>20 ($57.00)</td>
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<tr>
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<td>23 ($65.55)</td>
<td>24 ($68.40)</td>
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<td>29 ($82.65)</td>
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<td>32 ($91.10)</td>
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<td>35 ($99.75)</td>
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SCIENTIFIC Atlanta cable converters (original units), models—8500 and 8550, remote control, $150.00. Total orders accepted $255.00 Guaranteed. N.A.S., (213) 631-3552.

DO IT YOURSELF TV REPAIRS

NEW...REPAIR ANY TV...EASY. Retired service-cman reveals secrets. Write Research, Rt. 3, Box 610B, Colville, WA 99114.

CABLE TV DESCRAMBLERS

CABLE television converter, descrambler and wireless remote control video equipment accessories catalog free. CABLE DISTRIBUTORS UNLIMITED, 116-C Main Road, Washington, AR 71862.

EPROM PROGRAMMING


PRINTED CIRCUIT BOARDS


THANKS FOR HELPING TO KEEP UNITED WAY IN BUSINESS.

JUNE 1987

109
HOW THIS RAKE CAN SAVE YOUR LIFE

This simple garden tool is a firefighter. It can help you clear away brush and leaves that act like kindling around your home. And you.

So if you live near the forest, do a little raking. And that's not all. Landscape your home with a fire retardant plant like ivy. Use spark arrester screens on your chimney and vents. And put fire retardant material on your roof and underneath your house where it is exposed.

Because a forest fire burns more than trees.

Remember. Only you can prevent forest fires.

A Public Service of the Ad Council, the USDA, Forest Service and your State Forester.

ANTIQUE RADIO
continued from page 84

Finally, the output of the detector is capacitively coupled to the 6f6 power-amplifier pentode. The output from that pentode's plate circuit is coupled to the loudspeaker voice coil by T2.

Note the R-C network consisting of R12, C28, and C27, along with its associated switch, S5. That is a two-position tone control used to tailor the sound to the owner's preference. Such controls were not always included in radios of the period (or modern radios for that matter). As a result, the circuitry was often added by the owner. Details for doing that were available in Gernsback's Radio Craft and other electronics magazines of the day. One hint relating to that control: One of the things you should be sure to do once you've removed the chassis from the cabinet is to clean S5. Dirt on that switch can cause scratchy sound.

Next time we will get to work on restoring our radio.

R-E

GREAT VALUES • FAST SHIPPI NG • QUANTITY DISCOUNTS

YAMATO 4001 3/4 DIGITAL MULTIMETER

The YAMATO 4001 is a 3/4 DIGIT COMPACT DIGITAL MULTIMETER. Its compact size, large 3/4 digit LCD display, and 4000 count resolution make this a must-have tool for anyone who needs accurate and reliable measurements.

Professional Color Light Controller SM-328

FEATURES:
- 10000 display resolution
- Independent input channels, 10 voltage and 2 currents
- Built-in clock and calendar
- Auto power-off function

Only $199.95

TALKING CLOCK

Clocks that really tell you time!

TA-1000

Only $49.95

80W + 80W DC LOW TIM PRE-MAIN AMPLIFIER

OFFICE HOURS: MON. - FRI.
9:30 to 5:00
SAT.
10:00 to 5:00
(PACIFIC TIME)

RADIO-ELECTRONICS

Circle 93 on Free Information Card
### Unusual LEDs

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>Super-Bright Red. Outputs 300 mcd #274-006 ... 3.95</td>
</tr>
<tr>
<td>(2)</td>
<td>Blinking Red. MOS driver and a red LED combo. Can drive several LEDs in series #276-006 ... 1.19</td>
</tr>
<tr>
<td>(3)</td>
<td>Blinking Green. #276-003 ... 1.19</td>
</tr>
<tr>
<td>(4)</td>
<td>Bar Graph Display. Ten bright red segments #276-081 ... 2.99</td>
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### Sound Wars!

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
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<tr>
<td>(1)</td>
<td>Tri-Sound Siren. Wiring options create three different 80 db outputs. 3 VDC. #273-072 ... 5.95</td>
</tr>
<tr>
<td>(2)</td>
<td>Pulsing or Continuous Piezo Buzzer. Screwdriver terminals. 4 to 28 VDC. #273-068 ... 6.95</td>
</tr>
<tr>
<td>(3)</td>
<td>Electromechanical Buzzer. Extra loud! 12 VDC. #273-069 ... 1.89</td>
</tr>
</tbody>
</table>

### Save With Our "Hotline" Order Service

**Save Postage!** Our warehouse sends your order directly to the Radio Shack near you. We pay the shipping cost. **Save Time!** Delivery time on most items is one week. Special offer on your next order to the Radio Shack near you.

**Your Radio Shack store manager can Special-Order thousands of parts and accessories not listed in our catalog—tubes, linear and digital ICs, diodes, transistors, crystals, phono cartridges, and more. There's no minimum order requirement for this service!**

### Resistor Kits

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
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<tbody>
<tr>
<td>(8)</td>
<td>1/2 Watt 5% Carbon Film. Set of 100, 13 values. 10 ohms to one meg. #271-051 ... 1.98</td>
</tr>
<tr>
<td>(9)</td>
<td>1/2 Watt 1% Metal Film. Set of 50, 12 popular values from 10 ohms to one meg. #271-039 ... 2.49</td>
</tr>
<tr>
<td>(10)</td>
<td>1/2 Watt 5% Carbon Film. Big 100 piece set! 54 values, 10 ohms to 10 megohms. #271-312 ... 7.95</td>
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### 12V Transformers

<table>
<thead>
<tr>
<th>Description</th>
<th>Type</th>
<th>Volts</th>
<th>Current</th>
<th>Cat No</th>
<th>Each</th>
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<td>120 VAC primaries.</td>
<td>Mini</td>
<td>12V CT</td>
<td>120A</td>
<td>270-364</td>
<td>79c</td>
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<td></td>
<td>Std</td>
<td>110V CT</td>
<td>120A</td>
<td>270-365</td>
<td>89c</td>
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<tr>
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<td>H-D</td>
<td>110V CT</td>
<td>120A</td>
<td>270-366</td>
<td>1.89</td>
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### Ceramic Capacitors

**Low As 39¢ Pkg. of 2**

<table>
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<tr>
<th>Value</th>
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<tbody>
<tr>
<td>0.01</td>
<td>270-207</td>
<td>40c</td>
</tr>
<tr>
<td>0.02</td>
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<td>270-209</td>
<td>49c</td>
</tr>
<tr>
<td>0.03</td>
<td>270-210</td>
<td>59c</td>
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<tr>
<td>0.04</td>
<td>270-211</td>
<td>69c</td>
</tr>
<tr>
<td>0.05</td>
<td>270-212</td>
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</tr>
<tr>
<td>0.1</td>
<td>270-213</td>
<td>89c</td>
</tr>
<tr>
<td>0.2</td>
<td>270-214</td>
<td>99c</td>
</tr>
<tr>
<td>0.3</td>
<td>270-215</td>
<td>1.09</td>
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### Tool Set

**Mini 'Gators**

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<th>Description</th>
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<tr>
<td>Panel-Mount. For 1/4&quot; x 1/4&quot; lugs. UL recognized.</td>
<td>270-036</td>
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<tr>
<td>Includes 21 taps.</td>
<td>270-374 ... 1.19</td>
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**Fuse Holders**

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<th>Description</th>
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<td>DPDT Center off position, 6 amp.</td>
<td>275-653 ... 2.49</td>
</tr>
<tr>
<td>On/Off Labeling Plates.</td>
<td>275-300 ... 69c</td>
</tr>
</tbody>
</table>

### IC Breadboards

**Standard Modular Socket.** Total of 550 plug-in points. Accepts DIPs, discrete and 30 to 22-gauge solid wire. Two bus strips. Two or more snap together for more complex designs. 2 1/2 x 6" #276-175 11.95 -Watt 5%.

**Cooling Fans**

<table>
<thead>
<tr>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>AC Fan heats the enemy of electronic equipment. Use our quiet fans to increase airflow and extend the life of your computer, ham or hi-fi components. 4&quot; x 12 VAC. #273-241 ... 16.95</td>
<td></td>
</tr>
<tr>
<td>DC Fan heats the enemy of electronic equipment. Use our quiet fans to increase airflow and extend the life of your computer, ham or hi-fi components. 3&quot; x 12 VAC. #273-132 ... 7.95</td>
<td></td>
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</table>

### Tantalum Caps

**Low As 49¢ Each**

<table>
<thead>
<tr>
<th>Value</th>
<th>Cat No</th>
<th>Each</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01</td>
<td>270-207</td>
<td>40c</td>
</tr>
<tr>
<td>0.02</td>
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<td>99c</td>
</tr>
<tr>
<td>0.3</td>
<td>270-215</td>
<td>1.09</td>
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</table>

### Multi-Testers

**LCR Digital VOM**

<table>
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<tr>
<td>Low Freq AC</td>
<td>272-122</td>
</tr>
<tr>
<td>DC</td>
<td>272-123</td>
</tr>
</tbody>
</table>

**6995**

Folds Up For Travel

A remarkable value! You select the function. It selects the correct range. Features include automatic shut off when case is closed, auto polarized, de-tented hinge for best viewing angle, timesaving “beep” continuity test mode, plus 10-amp DC and AC current ranges. Fused and overload protected. With leads and owner’s manual. Batteries extra. #22-193
NOW YOU CAN BUILD AN IBM PC/XT COMPATIBLE!

IBM Special No. 2
Includes 9 items above... $499.95

NEW!

IBM Special No. 2
Includes IBM AT style keyboard with touch
table joystick (KB5160, see below) and all the above items (except KB83).

Regular List $604.50
Weight: 48 lbs.

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Includes IBM AT style keyboard with touch
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Regular List $604.50
Weight: 48 lbs.

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IBM PC/XT/AT Compatible

Turbo 4.77/8MHz Motherboard

75% faster than the IBM PC while in
Turbo mode. Turbo mode switch selectable
through either software or hardware.

Expands to 640K (comes with zero-K)
DTR/ERS/5B06 BIOS included.

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Turbo mode. Turbo mode switch selectable
through either software or hardware.

Expands to 640K (comes with zero-K)
DTR/ERS/5B06 BIOS included.
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We warehouse 60,000 items at American Design Components — expensive, often hard-to-find components for sale at a fraction of their original cost! You'll find every part you need — either brand new, or removed from equipment (RFE) in excellent condition. But quantities are limited. Order from this ad, or visit our retail showroom and find exactly what you need from the thousands of items on display.

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THERE'S NO RISK.
With our full 90-day warranty, any purchase can be returned for any reason for full credit or refund.

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COMMODORE COMPUTER
Commodore VIC 20 CPU board & mechanical keyboard guaranteed not to work. (For parts only.)

item #12144 $14.95 RFE

MECHANICAL KEYBOARDS . . .

115 VAC 27 CFM MINI FANS
50/60Hz
12W. Low noise level fans can be mounted for blowing or exhaust. 1" Thin; contains 9 plastic blades. Dim.: 2 1/2" sq. x 1 1/2" deep. Mfr – Tobishi #8921815. item #10960 $7.95 New 1 1/2" Standard; contains 7 metal blades. Mfr – Riven #53425. item #59708 $5.95 New

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55/100 CFM
8V. Can be mounted for blowing or exhaust. Aluminum housing, brushless, ball-bearing type. 1" Thin: 5 plastic blades with feathered edges. Mfr – Centaur #12085/4001. item #7541 $19.95 New 1 1/2" Standard: 5 plastic blades. Mfr – Centaur #7542/4001. item #12199 $14.95 RFE

DC SUBMINIATURE SOLDERLESS CONNECTORS, CRIMP TERMINALS
(Mfr – TRW)

<table>
<thead>
<tr>
<th>Description</th>
<th>8-Pin</th>
<th>15-Pin</th>
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DATA DRIVE
item #6642 $19.95

PRINT POWER SUPPLY
item #6642 $14.95

ASCII KEYBOARD
item #6643 $19.95

CONTROLLERS (set of 4)
item #7013 $9.95

ADAM CASSETTES
 item #7886 $19.95

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 item #9999 $99.00 New
PC 8300 HOME COMPUTER
(Advanced version of the Timex 1000)

- Includes 10 full-length expansion slots (not membrane): Contains 2K of RAM. Reverse video, 2B0A, 8 MHz processor. ROM BK BASIC, Graphics capability sound music, TV or monitor. Joy stick input oper in 15 VAC. Includes AC adapter, TV cable, and pair of cassette cables. Will run prerecorded tapes for Sinclair/Mex 1000.

Input: -15V Power Supply: 120VAC

190W DISK DRIVE POWER SUPPLY

Accessories

- 16K RAMPACK upgrade: $9.95 New
- 32K RAMPACK upgrade: $19.95 New
- COLOR PACK: $19.95 New

NS 87P50D-11 MICROCOMPUTER

- 6-bit single chip unit. Emulates 8048/49/50. Piggyback configuration. Allows you to plug in EPROMs. 2718, 2716, and 2732. Features: XROM, 5V.

80-16 bios. 4K direct access memory, 256 bits on chip ROM. 11 Mhz max. freq.

Item #8899: $29.95 New

ANALOG to DIGITAL CONVERTER


Item #7052 (IPD, tested/prot): Originally $130.00 - Special: $33.95

COMPUTER & GAME ACCESSORIES — ELECTRONIC COMPONENTS — INTEGRATED CIRCUITS — OPTICS

AT-STYLE COMPUTER CABINET

- Contains 10 full-length expansion slots (excludes). With room for an external 5 1/4" disk drive. Has 3 half-height drive slots. Rear on/off switch, notched to hold in power supply (not incl.), and security switch w/ key.

Item #12266: $49.95 New

AMERICAN DESIGN COMPONENTS

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<thead>
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<th>PART NUMBER</th>
<th>DIMENSIONS</th>
<th>DISTRIBUTION STRIPS</th>
<th>TERMINAL STRIPS</th>
<th>TIE POINTS</th>
<th>BINDING POSTS</th>
<th>PRICE</th>
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<td>WBU 06</td>
<td>38 x 5¾&quot;</td>
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<td>WBU 208-1</td>
<td>8.25 x 9¾&quot;</td>
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<td>4</td>
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Get more, for less. It's a simple definition of value. For DMMS, value means finding the combination of capabilities that meets your needs at the right price. Without losing sight of accuracy and reliability. If you want more functions at a low price, Beckman Industrial's Circuitmate™ Digital Multimeters are the best value around.

From the pocket-sized DM20L, to the DM850, with true RMS capability and accuracy to 0.05% +1 digit, Circuitmate DMMS give you the functions you need.

For instance, the DM20L, puts both a Logic Probe, a transistor gain function (hFE), and a full range of DMM functions in the palm of your hand. For only $69.95.

Then there's the DM25L. Where else does $89.95 buy you a Logic Probe, capacitance measurement, transistor gain function (hFE), and 24 DMM ranges including resistance to 2000 megohms? Nowhere else.

When high accuracy counts, there's the DM800 with a 4 1/2 digit display. The DM800 also gives you frequency counting. A full-function DMM, and more, doesn't have to cost over $179.95. If it's a Circuitmate DM800.

Or, for a few dollars more, get true RMS (AC coupled) to let you accurately measure non-sinusoidal AC waveforms, and all the capability of the DM800, in the DM850.

Of course, there's a whole range of Circuitmate DMMs and service test instruments, including the DM78 autoranger that fits in a shirt pocket, yet gives you a full size 3 1/2 digit, 1/8" readout. Not to mention a complete line of accessories like test leads, current clamps, even probes that can extend your DMMs range and sensitivity. All designed to work flawlessly with your Beckman Industrial Circuitmate DMM.

**DM20L Pocket-Size w/Logic $69.95**
- TTL Logic Probe: 20MHz
- HfE (NPN or PNP) 1 range (1000)
- DMM: Input Impedance—10 Megohms
- ACA/ACA-5 ranges (200μA to 2A)
- Ohms range (2 ohms to 2000 Megohms)
- Continuity beeper
- Data Hold display

**DM25L Capacitance, Logic, hFE $89.95**
- TTL Logic Probe: 20MHz
- HfE (NPN or PNP) 1 range (1000)
- Capacitance: 5 ranges (2nf to 20μf)
- Continuity beeper
- Anti-skid pads

**DM850 True RMS**
- 4 1/2 digits. DCV accuracy is 0.05% +3 digits
- True RMS
- Frequency counter to 200kHz
- Data Hold display capability
- Continuity beeper
- Built-in bail
- Anti-skid pads
- Price: DM850 (True RMS) $219.95* DM850 (Average) $169.95*

See your Beckman Industrial distributor and discover more DMM performance. For less.

*Suggested list price (USD) with battery, test leads and manual.