PE PROJECT FIRSTS!

Universal 4-Channel Matrix Decoder

DECODES QS AND SQ RECORDINGS AND BROADCASTS - PLUS "SURROUND SOUND" WITH VARIO-MATRIX SYSTEM

A Solar Energy Meter MEASURES SUN'S ENERGY

PLUS:

How to Determine CB Radio Communication Range

Annual Index of 1976 Articles and Columns

TEST REPORTS:

Technics SA 5460 Stereo Receiver
Sura N24H Stereo Cartridge
SBE Formula D "Touch-Com" AM CB Mobile

Sencore Portable Transistor/FET Meter

16-PAGE BONUS!

SPECIAL FOCUS ON DIGITAL ELECTRONICS

- How to Select a Hobbyist Microcomputer
- Build a Digital Auto Spy--Logic -- and more
THE COBRA 32XLR.
A TECHNOLOGICAL PUNCHTHROUGH.

Cobra has a reputation for punching through loud and clear. The new Cobra 32XLR, of course, continues the reputation. And creates another—for innovative design, superb engineering and technical superiority.

Start with the illuminated 4-in-1 meter. It tells you exactly how much power you're pushing out and pulling in. As well as monitoring your modulation in precise percentages. And measuring your punch with an SWR check. In short, the 32 XLR lets you keep an eye on your ears.

ScanAlert, Cobra's unique scanning system, continually monitors Channel 9 when you're on another channel. If an emergency comes up, the ScanAlert light goes on. And the incoming message automatically locks the receiver on the active channel.

The 32XLR's Digital Channel Selector is the very latest. With large LED numerals—for a read-out that registers clearly and quickly. Plus switchable "pulse block" noise blanking—that rejects short-pulse noise not normally blocked by other systems. Which makes it the most effective in the business. Finally, add automatic noise limiting, Dynamike Plus (with built-in power mike) and Delta Tuning.

The new Cobra 32XLR. It has virtually everything. And it has everything to do just one thing. Punch through loud and clear.

Punches through loud and clear.

Cobra Communications Products
DYNASCAN CORPORATION
6460 W. Cortland St., Chicago, Illinois 60635

For information on our complete line write for brochure #CB-2.
The Simple Answer
is
A Complex Solution.

Combine D3 with the slanted micro-fbers of the Discwasher brush—and you have the most functional, most convenient record care system in the world. At Discwasher dealers worldwide.
The small wonder
of the micro-world

Measuring just 11" wide x 11" deep x 5" high, and weighing a mere 7 pounds, the Altair™ 680b is a complete, general-purpose computer.

The secret to this revolutionary, small computer is its CPU board. This double-sided board fits along the bottom of the Altair case and plugs directly into the front panel board. It contains the new 6800 microprocessor, 1,024 bytes of RAM memory, a 256-byte PROM monitor, provisions for 768 bytes of additional PROM or ROM, and a single interface port with a Motorola ACIA serial interface adapter which can be configured either RS-232 or TTY. A five level Baudot interface option is also available.

The Altair 680b can be programmed from front panel switches, or it can be interfaced to a video display terminal, or teletype-write. Three additional circuit boards can be plugged inside the Altair 680b for further memory and interface expansion. The first of these boards is a 16k static RAM memory board.

Software already developed includes Altair 680 BASIC with all the features of the 8K BASIC previously developed for the Altair 8800. These include Boolean operators, the ability to read or write a byte from any input port or memory location, multiple statements per line, and the ability to interrupt program execution and then continue after the examination of variable values. This software takes only 6.8K bytes of memory space and a copy is included free with the purchase of the Altair 680 16k memory board.

Other software includes a resident two pass assembler. The Altair 680b is also compatible with Motorola 6800 software.

The Altair 680b is ideal for hobbyists who want a powerful computer system at an economic price. Altair 680b owners qualify for membership in the Altair Users Group, and like other Altair owners, they receive a complimentary subscription to Computer Notes and complete factory support.

PRICES:
Altair 680b kit with complete, easy-to-understand assembly manual, operator's manual, and programming manual ........................................... $466
Assembled Altair 680b ........................................................................ $625
Altair 680b Turnkey model kit .......................................................... $395
Expander Card 680MB (required to expand 680) .............................. $24
Altair 680B6M 16k static RAM board kit with 680 BASIC ........................ $685
Altair 680 BASIC when purchased separately ...................................... $200
Baudot option .................................................................................. $42

MAIL THIS COUPON TODAY

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Price, specifications subject to change. Please allow up to 60 days for delivery.

NOTE: Altair is a trademark of MITS, Inc.
TURNING THE ELECTRONICS CORNER

The year 1976 has been a good one for persons deeply interested in electronics. I think the future might be even better—we are sitting smack in the middle of the electronics revolution that was promised a few decades ago.

As we turn the corner to 1977, we can see more clearly the fruition of many research and development projects of the past. Just think. Electronic digital watches were virtually unknown in 1972. In 1973 they cost a few hundred dollars when, around Christmas, PE introduced a kit for less than $70. They’re expected to sell for less than $20 in 1977. Similarly, microcomputers were at the $3000 level in 1974 when PE published plans for a kit that sold for less than $400.

There are other examples we could mention, but the important thing is that the imaginations of voracious consumers were captured by these enticing electronic products. This led manufacturers to increase their production levels of medium- and large-scale IC’s, thereby lowering their costs. As a consequence, product sales increased further, and the cycle of decreasing costs continued—to the benefit of the public.

Integrated circuits are making a host of products “smart.” Just watch things happen in ’77. For example, TV electronic games will be booming, thanks to inexpensive dedicated microprocessors. It’s predicted that this consumer product area will reach annual sales of 12-million units by 1980. New educational and programmable calculators will bow in ’77, taking advantage of lower-cost memory chips.

In another area, the use of home TV receivers as video terminals will become more apparent to many people in the new year. For example, the video disc is promised in ’77, and Japanese manufacturers are revving up for production of video tape cassette units (with a battle looming between JVC’s and Sony’s systems). A video jack, promised by some manufacturers, will lower cost of attachments. Hobbyist computer buffs already know that graphic display has come of age right now.

There are also modifications on the audio front that could well change the product mix in the future. These include the new Elcaset system that bridges the gap between present-day cassettes and open-reel tape. Then there are 40-channel CB transceivers.

It is anticipated that all major areas of consumer electronics will exhibit greater growth in the coming year. Of special interest is a market study by Venture Development Corp. of Wellesley, Mass., which predicts that the hobby computer market will show a 150 percent sales increase from 1975 (just under 7500 units) to 1976 (over 18,600 units). The study also indicates that this “promises to be nothing less than the leading edge of a consumer computer revolution.”

At this time of year, many people dream about some special “breakthrough.” I’m no exception. One of my wishes is for the acknowledgement from outer space of the hydrogen atom’s 1420-MHz frequency that earthlings have transmitted to outer space in a search for extraterrestrial life. The odds are almost insurmountable against making such a radio contact, of course. But just think of the excitement it would generate—and the projects we could all build and use. After all, one never knows what’s around the electronics corner.

Art Salsberg

Best Wishes for a Joyous Holiday Season
and a Happy New Year

Editorial
all the best to you

Look at 'em. Aren't they pretty? But, their real beauty is the way they'll turn your CB on! Because with a "Kriket®" external CB speaker, you can hear more clearly than you ever thought possible.

Who else makes a full line . . . to accommodate your every need? Isn't it about time somebody did?

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All AFS®/KRIKET® speakers are manufactured in the U.S.A. using American materials and craftsmen.

DECEMBER 1976
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Imagine a microcomputer

Imagine a microcomputer with all the design savvy, ruggedness, and sophistication of the best minicomputers.

Imagine a microcomputer supported by dozens of interface, memory, and processor option boards. One that can be interfaced to an indefinite number of peripheral devices including dual floppy discs, CRT's, line printers, cassette recorders, video displays, paper tape readers, teleprinters, plotters, and custom devices.

Imagine a microcomputer supported by extensive software including Extended BASIC, Disk BASIC, DOS and a complete library of business, developmental, and industrial programs.

Imagine a microcomputer that will do everything a mini will do; only at a fraction of the cost.

You are imagining the Altair™ 8800b. The Altair 8800b is here today, and it may very well be the mainframe of the 70's.

The Altair 8800b is a second generation design of the most popular microcomputer in the field, the Altair 8800. Built around the 8800A microprocessor, the Altair 8800b is an open ended machine that is compatible with all Altair 8800 hardware and software. It can be configured to match most any system need.

MITS' plug-in compatible boards for the Altair 8800b now include: 4K static memory, 4K dynamic memory, 16K static memory, multi-port serial interface, multi-port parallel interface, audio cassette record interface, vectored interrupt, real time clock, PROM board, multiplexer, A/D convertor, extender card, disc controller, and line printer interface.

MITS' peripherals for the Altair 8800b include the Altair Floppy Disc, Altair Line Printer, teletypewriters, and the soon-to-be-announced Altair CRT terminal.

Introductory prices for the Altair 8800b are $840 for a kit with complete assembly instructions, and $1100 for an assembled unit. Complete documentation, membership into the Altair Users Club, subscription to "Computer Notes," access to the Altair Software Library, and a copy of Charles J. Sippl's Microcomputer Dictionary are included. BankAmericard or Master Charge accepted for mail order sales. Include $8 for postage and handling.

Shouldn't you know more about the Altair 8800b? Send for our free Altair Information Package, or contact one of our many retail Altair Computer Centers.

mits 2450 ALAMO S.E. ALBUQUERQUE, NEW MEXICO 87106 (505) 243-7821
Redesigned front panel. Totally synchronous logic design. Same switch and LED arrangement as original Altair 8800. New back-lit Duralith (laminated plastic and mylar bonded to aluminum) dress panel with multi-color graphics. New longer, flat toggle switches. Five new functions stored on front panel PROM including: DISPLAY ACCUMULATOR (displays contents of accumulator), LOAD ACCUMULATOR (loads contents of the 8 data switches (A7-A0) into accumulator), OUTPUT ACCUMULATOR (Outputs contents of accumulator to I/O device addressed by the upper 8 address switches), INPUT ACCUMULATOR (inputs to the accumulator from the I/O device), and SLOW (causes program execution at a rate of about 5 cycles per second—for program debugging).

New, heavy duty power supply: +8 volts at 18 amps, +18 volts at 2 amps, -18 volts at 2 amps, 110 volt or 220 volt operation (50/60 Hz). Primary tapped for either high or low line operation.

New CPU board with 8080A microprocessor and Intel 8224 clock generator and 8216 bus drivers. Clock pulse widths and phasing as well as frequency are crystal controlled. Compatible with all current Altair 8800 software and hardware.

**altair 8800-b**
1-MHZ COUNTER IC SOURCE

The 14583 Schmitt trigger IC used in the "Low-Cost 1-MHz Frequency Counter" (August 1976) is a Motorola part. It can be obtained from any large OEM dealer that distributes Motorola parts or for $1.69 plus 25¢ postage from the following address—Norman Huffnagle, 7511 Village Green Dr., Orlando, FL 32807.

DIGITAL SPEEDOMETER COMMENTS

In the article “Build a Digital Speedometer For Your Car” (September 1976), the opening states that the speedometer cable turns 1000 revolutions per mile travelled. If the speedometer cable is connected directly to the wheel, this means that the wheel must make 1000 revs per mile. The average radius of a wheel is about 13", which means that its circumference is 81.68". There are 63,360" in a mile (5280 x 12). If we divide 63,360" by 81.68", we obtain 773.7 revs per mile. To have 1000 revs per mile, the diameter of the tire would have to be 20".—Edward J. Picardi, Philadelphia, PA

The speedometer cable is not connected to the wheels. It goes to the transmission through a gearing system. Most cars use 1000 revs per mile, although this may differ from one make to another. We assumed 1000 revs per mile, but we also stated in the paragraph on adjustment that you can make the timing adjustment on a measured mile.

In reading the Speedometer article, I happened upon several design errors. First, IC2 through IC7 are TTL devices that operate only between 0" and 70°C, which means that during the winter months the speedometer will have to be warmed up before it will operate. Secondly, IC10 regulates the supply voltage between 4.70 and 5.30 volts, while the 7400 series ICs require voltage regulation between 4.75 and 5.25 volts.—Kevin J. Byer, Sr., Johnstown, PA

TTL devices do not freeze and will operate below 0°C. The barrier voltage increases somewhat with temperature reduction, but the IC’s will operate where a human being can tolerate the temperature. The operating voltage range for TTL devices is from about 4.7 to 5.3 volts. The output of the 309 regulator can range from 4.8 to 5.2 volts, with a typical of 5.05 volts. Once the system is turned on, power dissipation inside the 7400 IC’s will heat up the chips; hence, there will not be much of a "warm-up" time. Of course, if you prefer better low temperature devices, you can use the 5400 series IC’s that operate down to −55°C.

In the Speedometer article, you mention two ways to make the final adjustment. However, I feel that I have a way that is easier and better. I connected a 4-digit tach to my car and then started the engine and got it up to the rpm I wanted for the mph I wanted to go. I then made my final adjustment, using the formulas rpm = (mph x gr x 336)/td and mph = (rpm x td)/(gr x 336), where gr is the gear ratio of the rear end and td is tire diameter.—Richard Perry, Everett, VA

We have not tried this one, but it looks like it should work.

AN ELFIN TYPO

I have been very impressed by your careful editing of the articles on building the COSMAC "El" (August and September 1976). I found only one typographical error: In Part 2, Fig. 1 shows a 4058 IC, whereas the text refers to a CD4508 and Fig. 2 shows 4508’s, whereas the text refers to 4058’s.—George E. Smith, Homel Heights, Ontario, Canada

The correct number in both cases is CD4508.

HOME BREW CLARIFICATION

The article "Guide to Home Brew Phono Preamp Design" (September 1976) is helpful, but raises two questions. First, at the bottom of the first column on page 63, reference is made to R6, R10, and Rz in Fig. 5, which does not have resistors with these designations. Secondly, in the second column on page 63, it is stated that tone controls can easily be added to the Fig. 7 circuit. Where should the controls go and what component values should be used?—Carl Hartman, Newport Beach, CA

The 240-ohm, 100K, and 2.4K resistors in Fig. 5 refer to R6, R10, and Rz, respectively. The tone controls can be connected to the output (wipers of the volume controls). To prevent impedance problems, unity-gain op amp buffers can be used with passive RC networks. Or, active filters can be used.

"EXPERIMENTER’S CORNER"

I was just rereading parts of the June 1976 POPULAR ELECTRONICS and happened to glance at the Experimenter’s Corner. The article on the TTL NAND gate is the most understandable I have read in PE.—U. Vandrei, Ontario, Canada

Out of Tune

In "Build the Ultimate Metronome" (July, p. 57), R2 should go to pin 11 of IC2, not pin 10, and R6 should go to pin 11 of IC5, not pin 10.

In "Power-Failure Alarm" (June, p. 55), Q2 is shown as an npn transistor, whereas the 2N2621 is a pnp device. Any general-purpose npn transistor will work.

POPULAR ELECTRONICS
All SBE 23-channel CB units have a 40-channel future.

With all the talk about 40-channel CB units tomorrow, why should you buy SBE 23-channel units today?

Simple. We just give you the chance to buy today with tomorrow in mind. Which is what the SBE FUTURE-40 CB UPDATE PROGRAM is all about. Here's how it works: We're including a special Future-40 Certificate with all SBE 23-channel units. It entitles the SBE buyer to update his 23-channel unit to 40 channels within 1977.

You send in the certificate, we'll set up the update of your unit to a full 40 channels. All, for a reasonable charge, depending on the model involved.

Simple as that. All in all, the SBE Future-40 CB Update Program is aimed to hit those people who'd like to buy now, but are a bit confused about what's around the corner. And thinking ahead, about what's around the corner, that's what SBE is all about.
The HP-91 scientific portable printing calculator
$425.00*
The HP-91 is a completely portable scientific calculator with integrated printer. Now you can generate a permanent record of each calculation to document your work, in the office, or at a job site in the field.
- Lightweight briefcase portability. Operates on battery power or AC.
- Full range of scientific and arithmetic functions complete with printed record.
- Built-in, sophisticated, quiet thermal printer.
- Extra large, easy-to-read display.
- Four dozen built-in functions and data manipulation operations.
- Pre-programmed for science, mathematics and statistics.
- 16 addressable memories.

The HP-21 scientific
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The HP-21 makes short work of technical calculations. If you seek a calculator that does more than simple arithmetic, this is it.
- 32 built-in functions and operations.
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- Performs rectangular/polar conversion, register arithmetic and more.
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- Two selectable display modes: fixed point and scientific.
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The HP-22 business management
$125.00*
The HP-22 easily handles the kinds of calculations most often faced in business management today. It can breeze through business math calculations and build existing statistical data into reliable forecasts. If you want a business management calculator, here it is.
- Combines financial, mathematical and statistical capabilities.
- Performs complex time-value-of-money including interest rates computations.
- Performs rates of return and discounted cash flows for investment analysis.
- Performs extended percent calculations, accumulated interest, amortization and more.
- 10 addressable memories.
- Full decimal display control.

The HP-27 scientific/plus
$175.00*
The HP-27 is for the scientist, engineer or business person responsible for budgets, cost analysis, resource allocations and more.
- It features a comprehensive set of statistical and financial functions for planning, forecasting and analysis. For the first time, they've been added to HP's complete set of scientific functions.
- 10 financial functions for investment analysis.
- NEW—internal rate of return and net present value for uneven cash flows.
- 15 statistical functions for planning and forecasting.
- NEW—normal distribution and correlation coefficients.
- 28 pre-programmed exponential, log and trig functions for scientific and engineering calculations.
- 20 memories with selective clearing options for greater flexibility, 10 of which are addressable memories.
The First Family.

The HP-97 & the HP-67 powerful fully programmable calculators - HP-97 $750.00*  HP-67 $450.00*

The HP-97 and HP-67 are the most powerful fully programmable battery-operated portable scientific calculators you can buy. In fact, both offer about 3.4 times** the programming power of our classic HP-65—the industry standard. Programs written for either the HP-67 or HP-97 can be run on the other without modifications of any kind. The HP-97's thermal printer is also remarkable—and unusually quiet.

- Handles up to 224 steps.
- All prefix functions and operations are merged.
- Directly records programs or contents of all 26 data storage registers onto magnetic cards.
- 10 user-definable keys.
- 3 types of addressing—Label, Relative and Indirect.
- 3 printing modes—Manual, Normal and Trace (HP-97 only)
- Standard Application Pac with 15 programs of broad appeal included free. Optional Pacs in engineering, finance and other disciplines available at $35.00 each.

**Complete details on request.

The HP-25C scientific programmable with continuous memory $200.00*
The HP-25C is our keystroke programmable. It can solve automatically the repetitive problems every scientist and engineer faces. What's more, its Continuous Memory capability lets you retain programs and data even when it's turned off.

- Continuous Memory capability.
- 72 built-in functions and operations.
- Keystroke programmability.
- Branching, conditional test and full editing capability.
- 8 addressable memories.
- We also offer the HP-25 (without the Continuous Memory feature) for $145.00.*

The HP-80 financial $295.00*
The HP-80 performs calculations involving the relationship between time and money: bond prices and yields, conversions, trend line analysis, interest calculations and more. A built-in 200-year calendar figures number of days in bond or loan calculations.

- Financial functions: simple interest, payment per period, number of periods, present and future values, sum-of-the-years-digits depreciation.
- Bond functions: prices and yields, 200-year calendar.
- Statistical functions: mean, standard deviation, trend line.
- Mathematical functions: percentages, \( \times^2 \), serial or chain calculations.
- Addressable memory.
- Selectable display modes: fixed point and scientific notation.

* Suggested retail price—excluding applicable state and local taxes. Contiguous U.S., Alaska and Hawaii.
New Products

Additional information on new products covered in this section is available from the manufacturers. Either circle the item's code number on the Reader Service Card inside the back cover or write to the manufacturer at the address given.

HY-GAIN REMOTE-CONTROL

MOBILE CB

The Hy-Gain 9 (Model 2679) is a 23-channel AM, PLL-circuit unit with separate transceiver and microphone/control. The microphone incorporates digital channel readout, channel selector, and volume and squelch controls. It also acts as a loudspeaker. A coiled cable links the control unit to an underdash connector, from where a cable can be run to the remotely located transceiver. Sensitivity is said to be 0.7 µV for 10-db (S+N)/N, adjacent channel rejection at -40 dB, and full legal r-f power output. The transceiver incorporates automatic noise limiter circuitry.

CIRCLE NO. 88 ON FREE INFORMATION CARD

HITACHI RECEIVER

The SR-903 is Hitachi's top AM/FM stereo receiver, rated at 75 watts per channel with less than 0.3% THD. The class-G amplifier circuit is said to increase efficiency by at least 50%, thus eliminating the need for large heat sinks and reducing the receiver's weight by almost 40 percent. Frequency response of the FM section is 30 to 15,000 Hz ±1 dB, and the AM tuner has a 1.6-microvolt sensitivity, 80-dB selectivity. A protection circuit shuts off the speakers in case of an electrical malfunction and lights an LED. Other features include a 41-clickstop volume control, simultaneous tape-dubbing and monitoring capability, high and low filters, and afc that locks on to the station when the user lets go of the tuning knob. Measures 19¼"W x 15¼"D x 5¼"H (48.9 x 40 x 12.9 cm). $499.95.

CIRCLE NO. 89 ON FREE INFORMATION CARD

40-PIN IC TEST CLIP

Continental Specialties has released the fourth in its series of IC test clips, the PC-40. Patterned after the earlier models, the PC-40 is compatible with 0.6" center IC's up to 40 pins. This mini-troubleshooter offers a narrow throat for bringing IC leads up from high-density pc boards, thus minimizing accidental shorts while testing live circuits. It can also be used to inject signals and wire unused circuits into other boards. Scope probes and test leads lock onto gripping contact teeth, freeing hands for other work. Noncorrosive nickel/silver contacts provide simultaneous wiping action and low-resistance connections to IC leads. Overall plastic construction eliminates springs and pivots. $13.75.

CIRCLE NO. 90 ON FREE INFORMATION CARD

AFS STEREO HUMP-MOUNT CONSOLE

The Kar Kriet KK-1080 is a hump-mount console from Acoustic Fiber Sound Systems that mounts a stereo radio, or an 8-track or cassette system and has storage space for four cartridges or seven cassettes. The console requires no fastening devices, but rests on the driveshaft hump. Polymer "teeth" in the base prevent movement while driving. By unplugging the power, antenna and remote-speaker leads, the entire unit can be taken out and placed in the trunk. Size is 12¾"D x 8¾"W x 7½"H (30.5 x 19.3 x 17.8 cm). $9.95.

CIRCLE NO. 91 ON FREE INFORMATION CARD

CB SPEECH PROCESSOR

"Talk Power" is an add-on speech processor from Communications Power, said to provide a substantial increase in average speech talk power for CB transceivers without spillover and with minimum distortion. This logarithmic speech compressor plugs into existing 4-conductor microphone receptacles, requires no other CB-set connections or alterations. The existing microphone is retained. A solderless internal patch panel permits easy microphone connections. The unit operates from vehicle battery or ac power line. Size is 4½"W x 3¾"D x 2¾"H (12.4 x 8.2 x 6.7 cm). $69.95.

CIRCLE NO. 92 ON FREE INFORMATION CARD

PICKERING PHONO CARTRIDGE

"Sterehedron" is the name Pickering gives to the new stylus-tip shape featured in the XSV/3000 stereo cartridge. It is said to increase the area of contact with the groove wall, and to increase record life because force is spread over this greater contact area. Specifications are: frequency range 10 to 30,000 Hz; channel separation, 35 db (reference 1000 Hz), output, 5 mV; resultant tracking force, 1 gram ±½, —¼ (add 1 gram to setting with record-cleaning brush). $96.95.

CIRCLE NO. 93 ON FREE INFORMATION CARD

PAIA POLYPHONIC KEYBOARD

The latest electronic music kit from PAIA is OZ, a polyphonic pitch source for use as a portable practice keyboard, mini-organ, or trigger/pitch source for a synthesizer. The unit is battery-powered and has a built-in one-watt audio amplifier and speaker. A five-position range switch transposes the ½-octave keyboard for over 6½ octaves of total range. The switch-selectable step or multiple-pulse trigger allows a simple synthesizer interface, and a mixing input permits playing other instruments through the OZ amplifier. A tone control rolls off the normal square-wave

CIRCLE NO. 94 ON FREE INFORMATION CARD

PHONO CARTRIDGE
If you thought a rugged, professional yet affordable computer didn't exist,

think IMSAI 8080.

Sure there are other commercial, high-quality computers that can perform like the 8080. But their prices are 5 times as high. There is a rugged, reliable, industrial computer, with high commercial-type performance. The IMSAI 8080. Fully assembled, it's $931. Unassembled, it's $599. And ours is available now.

In our case, you can tell a computer by its cabinet. The IMSAI 8080 is made for commercial users. And it looks it. Inside and out! The cabinet is attractive, heavy-gauge aluminum. The heavy-duty lucite front panel has an extra 8 program controlled LED's. It plugs directly into the Mother Board without a wire harness. And rugged commercial grade paddle switches that are backed up by reliable debouncing circuits. But higher aesthetics on the outside is only the beginning. The guts of the IMSAI 8080 is where its true beauty lies.

The 8080 is optionally expandable to a substantial system with 22 card slots in a single printed circuit board. And the durable card cage is made of commercial-grade anodized aluminum.

The IMSAI 8080 power supply produces a true 28 amp current, enough to power a full system.

You can expand to a powerful system with 64K of memory, plus a floppy disk controller, with its own on-board 8080—and a DOS. A floppy disk drive, an audio tape cassette input device, a printer, plus a video terminal and a teleprinter. These peripherals will function with an 8-level priority interrupt system. IMSAI BASIC software is available in 4K, that you can get in PROM. And a new $139 4K RAM board with software memory protect. For the ultimate in flexibility, you can design the system for low-cost multiprocessor, shared memory capability.

Find out more about the computer you thought didn't exist. Get a complete illustrated brochure describing the IMSAI 8080, options, peripherals, software, prices and specifications. Send one dollar to cover handling. Call us for the name of the IMSAI dealer nearest you.

Dealer inquiries invited.

IMSAI

IMS Associates, Inc.
14860 Wicks Boulevard
San Leandro, CA 94577
(415) 483-2093
Another Heathkit Color TV breakthrough...

There's never been a Color TV System like this before.

A Bold New Concept in TV
The new GR-2001 TV system is the most sophisticated, best performing color TV kit we've ever designed, but it is also much more. It is the heart of a total home viewing system - a Computer TV!

Complete Programming Capability
With its optional Programmer, this Computer TV system allows you to program your set for an entire evening's viewing. The top bank of 8 keys accesses the static NMOS RAM and turns the on-screen clock display into a computer CRT read-out which allows you to see your "program" as you enter it through the bank of 12 keys below the programmer panel. The selected time appears in the first four digits of the clock display, the channel number appears in the second two. First, enter the time at which you want the set to change channels. Next, enter the channel number you want. Then the memory takes over. While you sit back and relax, the Programmer automatically changes to the right channel at the right time. You can program up to 32 channel changes within two 12/24-hour periods!

Those two programming periods add extra versatility. Program the first for your daytime viewing schedule, the second for evening shows. Or, program the first for weekend shows, the second for week nights. You can even preselect the programs your young children can watch - once the programmer is engaged, the manual key-board is disconnected and can only be reactivated by the remote control or by pressing the correct button on the programming panel.

You can even program the set to return to manual operation at a preselected time, then resume automatic operation at another time. When the last program you want to see is over, the set can be programmed to switch to an empty channel. This will cause the screen to go blank and the on-screen readout to flash on and off indicating that it is time to turn the system off with the front panel pushbutton or optional remote control.

Convenient Remote Control
The optional wireless remote control lets you adjust volume, turn the set on or off, adjust tint, activate the digital readout, scan up or down through the preselected channels, and turn the optional programmer on and off - all at the touch of a button. This wireless remote control has improved circuitry for greater range and reliability and is the best we've ever offered.

Random Access Tuning
The 1 x 4 keyboard lets you instantly choose any of up to 16 preselected stations - up to 24 with the optional eight channel accessory. Switch from VHF to UHF, up or down, in any sequence, and be tuned instantly, without switching through empty channels. Up and down buttons on the keyboard also let you scan all the preselected stations.

Automatic Antenna Rotor Control
A Heathkit exclusive! With the optional antenna rotor control, you can program the GR-2001 to automatically rotate your outdoor antenna system as it changes from one channel to another, for optimum reception on every channel. No special knobs to turn, no buttons to push. You can select up to eight separate antenna headings with up to three stations per heading. It's perfect for areas where stations are in widely separated locations.

Superb Color and Sound
The TV set itself contains dozens of circuit refinements and improvements designed to give you the best picture and performance you've ever seen. The Automatic Gain Control circuit, for example, has been significantly improved to better resist airplane flutter. And since you build it yourself, you can be assured of a set that is free of mass production "glitches" that show up all too often in other sets now on the market. Other improvements are listed below.

Separate Audio IF Stage
The audio circuitry is probably the finest on any commercial set in the world. The sound signal has its own separate IF stage to dramatically reduce the "buzz" caused by the picture carrier modulating the sound. You can hear the difference - especially if you use the output jack to connect the GR-2001 to your stereo system. The built-in wide-range speaker offers excellent fidelity as well. It's one of the first sets ever to give you real hi-fi sound from a TV!

Phase-Locked-Loop Horizontal and Vertical Hold Circuits
New phase-locked-loop horizontal and vertical oscillators "lock-in" on any channel for a picture that's rock-steady and stable. There are no conventional vertical and horizontal hold controls because you never need them! There are no alignment problems either, so you get consistently excellent pictures year after year.

Black-Matrix Picture Tube
The GR-2001's 25" (diagonal) ultra-rectangular picture tube provides one of the brightest, sharpest pictures in the world. The tube is fully shielded to maintain outstanding color purity by eliminating stray magnetic fields.

Easy To Assemble
Though the GR-2001 is one of our more complex kits, the average person shouldn't have any difficulty in assembling it. A step-by-step illustrated manual will lead you through assembly right up to troubleshooting and testing. And if you do happen to need assistance, help is only a phone call away. A complete staff of Technical Consultants will answer all your questions. We won't let you down.

GR-2001 Specifications
Deflection: Magnetic 90°.
Focus: Electrostatic.
Convergence: Magnetic.
Antenna Input Impedance: VHF: 750Ω balanced or 75Ω unbalanced. UHF: 300Ω balanced.
Picture IF Carrier: 45.74 MHz.
Sound IF Carrier: 41.25 MHz.
Color IF Subcarrier: 42.17 MHz.
Sound IF Frequency: 4.5 MHz.
Video IF Bandwidth: 4.08 MHz at 6 dB down.
Hi-Fi Output: Frequency Response: ±1 dB, 50 Hz to 15 kHz.
Output Voltage: Greater than 1.0 V RMS.
Audio Output: 4Ω or 8Ω, 2 Watts.
Power Requirement: 110 to 130 Volts AC, 60 Hz, 200 Watts.
Kit Net Weight: 146 lbs.
GR-2001 TV kit alone (chassis, picture tube and one speaker): $699.95
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New NRI Memory Expansion Kit

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NRI offers you five TV/Audio Servicing Courses

NRI can train you at home to service Color TV equipment and audio systems. You can choose from 5 courses, starting with a 48-lesson basic course, up to a Master Color TV/Audio Course, complete with designed-for-learning 25” diagonal solid state color TV and a 4-speaker SQ” Quadraphonic Audio System.

NRI gives you both TV and Audio servicing for hundreds of dollars less than the two courses as offered by another home study school. All courses are available with low down payment and convenient monthly payments. All courses provide professional tools and “Power-On” equipment along with NRI kits engineered for training. With the Master Course, for instance, you build your own 5” wide-band triggered sweep solid state oscilloscope, digital color TV pattern generator, CMOS digital frequency counter, and NRI electronics Discovery Lab.

NRI’s Complete Communications Course includes your own 400-channel VHF transceiver

NRI’s Complete Communications Course will train you at home for one of the thousands of service and maintenance jobs opening in CB; AM and FM transmission and reception; TV broadcasting; microwave, teletype, radar, mobile, aircraft, and marine electronics. The complete program includes 48 lessons, 9 special reference texts, and 10 training kits. Included are: your own “designed-for-learning” 400-channel VHF transceiver; electronics Discovery Lab’; CMOS digital frequency counter; and more. You also get your all important FCC Radio-telephone License, or you get your money back.

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Ohio Scientific Instruments' completely assembled mainframe computer, the OSI Challenger, is designed to accept a number of options. However, the minimum configuration comes with a serial interface, 1024 words of RAM, and a 256-word monitor PROM, all of which make the machine immediately usable.

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The pocket-sized 302 frequency counter from the Gary McClellan Company has a frequency range of 3 Hz to 20 MHz, better than 30 mV sensitivity at 23 MHz, and ±0.005% accuracy. Three frequency-measurement ranges and a four-digit LED display combine to provide up to seven digits of display. The 302 is powered by a standard NiCd battery pack; the unit comes with a charger. $120.00. Address: Gary McClellan Co., P.O. Box 2085, 1001 West Imperial Highway, La Habra, CA 90631.

**SONY ELCASET TAPE DECK**

The EL-5 is Sony's front-loading tape deck featuring the new Elcaset system that uses a cassette shell larger than the Philips-type cassette, with 1/4-inch tape travelling at 3 3/4 ips. During automatic threading, the tape is pulled out of the cassette for transport. The EL-5 has two ferrite-and-ferrite heads, Dolby noise-reduction system, and a dc servo-controlled motor. Feather-touch operation is provided by a solenoid-operated logic-controlled system that permits changing from one mode to another without depressing the stop button. Separate EQ and bias switches accommodate three types of tape. Other features include a memory rewind tape counter, line/mic mixing, large VU meters, and MPX filter switch. Under $700.

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PHONO CARTRIDGE DATA

A colorful six-page brochure which describes the company's "transversal suspension system" has been issued by AKG Acoustics on five models of its "Phonocartridges." Using cutaway diagrams and line drawings, the brochure discusses the new system and provides specifications on the five models in the new line. Address: AKG Acoustics, 91 McKee Drive, Mahwah, NJ 07430.

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ELECTRONIC CIRCUIT-DESIGN AIDS

A 26-page catalog of electronic circuit-design aids from sockets and breadboards to complete educational systems is available from E&L Instruments. The catalog includes more than 180 products for builders of electronic circuitry. Described in the catalog are systems for teaching and experimenting with op amps, IC logic, and microprocessors. Other products covered are solderless breadboarding sockets, tools, component kits, and a selection of practical and instruction manuals. Address: E&L Instruments, Inc., 61 First St., Derby, CN 06418.

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IEEE STANDARDS CATALOG

The new 32-page catalog of IEEE Standards lists over 350 standards publications in numerical sequence and also provides a subject index to the standards. Many American National Standards published by the IEEE are also included. Standards developed within the IEEE cover test methods, practices for electrical installations, units, definitions, graphic symbols, and application methods. The catalog lists important new and newly revised publications on graphic symbols, metric practice, and instrument interfaces. Address: IEEE Standards Office, 345 E. 47th St., New York, NY 10017.

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EVALUATING FOUR-CHANNEL

I HAVE JUST spent the better part of a weekend listening to and evaluating four-channel records. Certainly it's not difficult to derive considerable satisfaction from many of these discs as musical diversions. But when you're called upon to figure out exactly what's going on, spatially and directionally, then diversion turns into work. When faced with an ambiguity in the sonic positioning of some voice or instrument, it's hard to know whether to blame the recording, the medium, the listening room, or your own ears.

I have a sneaking suspicion that getting the most out of four-channel sound, as the commercial record companies are presenting it to us, will turn out to involve a gradual learning process. I know that, over the years, I've gotten better at ferreting out the producer's intent in the "surround sound" type of recording, and I don't think superior decoders and recording techniques are entirely responsible.

For example, during my first months of quadraphonic listening I could play a surround-sound record three or four times before realizing that the acoustic guitar on band 3 was coming—or was supposed to be coming—from the right rear. With more practice, I began to find that I could make such distinctions almost instantly in many cases. In short, I had apparently developed a sensitivity to certain aural "cues," and perhaps even a certain ability to anticipate the producer's hand on the pan pot. This was certainly a far cry from my first encounters with four-channel, when I often found myself standing in the middle of a room, listening to a discrete "ambiance-type" quadraphonic tape of a symphony orchestra, and wondering which direction was front.

Matrix Anyone? Of course, it is this sort of ambiguity for which early matrix systems have been notorious, even though many discrete recordings have not been entirely free of it either. Indeed, it is easy to bad-mouth the matrix approach; a little too easy in my opinion. If a simple Dynaquad hookup can do so much to enhance the experience of recorded music, then a still-more-elaborate matrix must be good for something, right?

Well, during this past weekend I finally got around to assembling the equipment, acquiring the records, and doing the listening necessary to make or break the case for matrix in my own mind.

The Equipment. This project was precipitated by the almost simultaneous arrival of several key ingredients: CBS SQ and Sansui QS-encoded versions of Michael Oldfield's recording Ommadawn, the only strictly commercial release I know of that is available in these two systems; a freshly checked-out Sansui QSD-1 QS decoder; and a brand-new SQL-200 SQ decoder from CBS Technology Center.

Both of these decoders are logic-assisted in their own proprietary ways. The Sansui is the most elaborate of the Vario-Matrix decoders, functioning in three separate frequency bands in an effort to provide maximum aural separation. The CBS product combines the gain-riding "corner" logic with the recently developed variable-blend technique to enhance front-to-back separation.

With a left-front input, the frequency response of the Sansui measured up almost 2 dB in the mid-bass region, down about ½ dB in the upper mid-range, and down at least as much above 14 kHz or so. The CBS device was admirably flat at low frequencies but rose almost a dB in the upper mid-range, descending to about -2 dB above 9 kHz. These measurements were made with the CBS STR 130 test record by comparing a straight-through signal with the response plots obtained when each of the decoders was inserted into the chain. And they were made after the completion of listening to avoid prejudicing subjective reactions.

Ommadawn. This recording, which served as the standard for comparison of the two systems, was a reasonably happy choice in one respect and a poor one in another. Mr. Oldfield's work is nothing if not repetitious, and this permitted the same musical material to be judged at length without constantly backtracking on the record. This was good. What was not so good was that the two records—SQ and QS—were not entirely equivalent in quality. The QS version, apparently cut and pressed in England, tended to be noisy and distinctly "unclean" sounding (for lack of a better term to describe various distortions). The SQ disc, a domestic product, was head and shoulders above this mediocre level (good on you, Columbia, for once!), and the difference had to be allowed for in the comparisons.

Nor was this the only difference. Once I got going, with levels matched and channels frequency-equalized with the appropriate test records, it became clear that I could have easily been dealing with two separate mixes of the original master tape. The SQ disc, on first hearing, exhibited much more evidence of intense rear-channel activity than the QS, which seemed to sneak an instrument behind you only occasionally.

In this respect, the SQ rendition was more impressive and satisfying. But trouble occurred in subsequent playings when I tried to determine precisely what was happening, and where, in the SQ...
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<table>
<thead>
<tr>
<th>Stereo Receivers</th>
<th>Sugg. Retail Price</th>
<th>Min. RMS Power Per Channel into 8 Ohms</th>
<th>Total Harmonic Distortion at Rated Power (Max.)</th>
<th>FM Sensitivity</th>
<th>Stereo -50dB*</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA-5760</td>
<td>$799.95</td>
<td>165 watts from 20Hz-20kHz</td>
<td>0.98%</td>
<td>1.8 V</td>
<td>36.73dBF</td>
</tr>
<tr>
<td>SA-5860</td>
<td>499.95</td>
<td>85 watts from 20Hz-20kHz</td>
<td>0.1</td>
<td>1.8 V</td>
<td>36.23dBF</td>
</tr>
<tr>
<td>SA-5460</td>
<td>399.95</td>
<td>65 watts from 20Hz-20kHz</td>
<td>0.1</td>
<td>1.8 V</td>
<td>36.23dBF</td>
</tr>
<tr>
<td>SA-5360</td>
<td>299.95</td>
<td>38 watts from 20Hz-20kHz</td>
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<td>1.8 V</td>
<td>37.23dBF</td>
</tr>
<tr>
<td>SA-5'60</td>
<td>229.95</td>
<td>25 watts from 30Hz-20kHz</td>
<td>0.5</td>
<td>1.8 V</td>
<td>37.23dBF</td>
</tr>
<tr>
<td>SA-5860</td>
<td>169.95</td>
<td>12 watts from 40Hz-20kHz</td>
<td>0.9</td>
<td>1.8 V</td>
<td>38.23dBF</td>
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rear channels. Within the thick textures of Oldfield's orchestration it was next to impossible. The sound certainly surrounded one in a flattering wash of aural color; and, in the few spots where instrumentation became simple, the localization was reasonably good. However, as a whole the impression was one of vague zones of sonic identities. Frequently they seemed to shift, but I could never be sure just where.

what happens as the condition of equal busy-ness is approached? My guess is that the SQ "corner" logic is turned off first, because any attempt to keep its gain-riding action going will result in a loss of signal. The variable-blend should be able to go on working forever, if you're willing to accept the loss of left-right separation it imposes.

The QS Vario-Matrix system would seem to have an advantage in being units that are placed higher up the walls than is customary. Nevertheless, if memory serves, it was James Cunningham, an eminent name in audio for many years, who first suggested that conventional four-channel techniques can produce a feeling of height, and then proceeded to prove it with several demonstrations. He has proved it again on a record produced with his assistance on Dick Schory's Ovation label. The disc serves as a four-channel (QS) demonstration vehicle and sampler for the Ovation catalog. In my opinion, the best moments come in the demo section. It includes an all-too-brief excerpt from a fabulous thunderstorm, a rousing fireworks bombardment, and a few aptly designed synthesizer effects.

The Cunningham/Schory thesis is that a mono signal from all four speakers will produce an apparent sound source somewhere over a centrally located listener's head. The technique seems to work fine. At one point there is an electronic hailstorm of sound that appears to rise up from the front speakers, pass over the listener's head at a point somewhere about ceiling level, and dive back down into the rear speakers. Then there is a brief sea-scape excerpt, where I hear the cries of a gull hovering on a thermal about 15 or 20 feet above the surf. I may be kidding myself in some way, but I swear that's where the bird is to my ears, with very little ambiguity.

I hope this means that four-channel is making some progress. I confess to being a fan of the medium—or its potential, at least—and I certainly don't want to be the last on my block with four speakers in his listening room.

Sansui QSD-1 Synthesizer Decoder.

By contrast, in the QS rendition the localization of sound sources was relatively precise, and most of it frontal. Now and again an instrument would pop up in the rear, and usually it would stay put. What the QS cut lacked was the "spacey" impression of the SQ rendering, which was genuinely dramatic although imprecise and undefinable. (The recording also lacked adequate treble, which was a severe handicap in the comparison.)

Logic, etc. As mentioned before, the records seemed like products of two different mixes, and quite possibly they are. But if we can legitimately make the assumption that both were intended to be faithful to some prior "authoritative" mix, and if we then ask which of the two is the more faithful, I think the edge has to go to QS. It was able to exhibit the stability of localization that, in general, enabled you to confirm where instruments were, and one would expect that to have been a goal of the engineer who created the four-channel mix. On the other hand, every time I tried to focus in on the specifics of SQ's quadrephonic image I became more confused rather than less, despite the enjoyment I derived from the spacious-seeming SQ "wash" of sound.

Both manufacturers are wont to give highly impressive separation figures for their logic-assisted decoders (ranging from 20 dB to infinity), but these don't reflect the changing conditions encountered in music. Ultimately, when all four channels get equally busy, any logic manipulation has to be turned off within the decoder, and the system reverts to the separation figures of the basic matrix (3 dB between adjacent channels). But able to keep its logic going almost up to the bitter end. Its action involves no signal losses, and the logic circuits can be designed to function speedily and drastically with no obvious distortions of the aural image. As far as I can tell, neither of these systems shines with material like the steady-state drone of Ommadawn, but the QS decoder holds on to its localization deeper into the stew of sound than the SQ unit, and the principle of its logic operation is as good an explanation for this as any.

Other Recordings. On the better ambient-type four-channel recordings, I can find virtually no fault with either of the matrix systems. Evidently, one of the fronts on which real progress has been made in recent years is the mixing and mixing of credible omnience and reverberation. Even the highly touted new Columbia recording of Carmina Burana with Michael Tilson Thomas and the Cleveland Orchestra, nominally a surround-sound or at least wrap-around-sound production, has its (rather short-lived) moments in which the evocation of large spaces is powerful. On the Vox label, engineers Joanna Nickrenz and Marc Aubert have captured some remarkably rich and spacious sounding reverberation in QS-encoded form. A particular standout is Ravel's orchestral works with the Minnesota Orchestra, although the disc processing does not always do full justice to the inherent merits of the recordings.

Every once in a while, someone arises to deplore the fact that current four-channel schemes have no specific provision for a height dimension; these remarks are often accompanied by a proposal for ceiling speakers, or at least
Yamaha headphones take the headache out of holiday shopping.

Every year it's the same old story. You move heaven and earth trying to find a gift that's both personal and practical. After all, you never were one to buy just any new thing and call it a gift. It's got to be right. No matter how long it takes to find it.

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What's more, the HP-2's superb tonality, wide frequency response and low distortion are comparable to those of headphones costing much more than our suggested retail price of $45. (In other words, your gift sounds more like a million dollars than a few dollars.)
And there's comfort to match. Yamaha consulted world-famous designer Mario Bellini to help us make these headphones the most comfortable ever worn. A soft strap distributes the HP-2's featherlight 8 ounces evenly over your head. The ear cups, with supple foam pads, are specially designed to ride lightly on your ears. Instead of flattening them out. And of course, height and angle are completely adjustable.

In short, the HP-2s add the convenience of personal listening to the enjoyment of any stereo system. They're compatible with anything that's got a headphone jack. And make most anything sound better, too.

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**Hobby Scene**

**Q.** I've heard that a "white" noise generator is very useful in checking out shortwave receivers. I'd like to experiment with one, but don't have a circuit. Do you?

—Stu Goldberg, Cambridge, MA

**A.** The circuit shown will produce wideband r-f noise. It uses a reverse-biased diode and has a low-impedance output. You can use it to align the receiver for optimum performance.

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**LINE VOLTAGE MONITOR**

**Q.** I'm not sure, but I think that the line voltage of the commercial power mains in my area varies a great deal. Do you have a simple circuit for monitoring the line? I have used my VOM to do this, but I'd like to leave something in the line continuously.

—Phil Poyner, Corpus Christi, TX

**A.** This circuit can be left in the line as a continuous monitor. It will give reliable indications over a limited range up to about 125 volts. Use an accurate ac voltmeter to calibrate the unit. An isolation transformer is included for safety reasons. However, the circuit does not draw much current, and a low-wattage transformer can be used.

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**RADIO SPECTRUM ALLOCATIONS**

**Q.** Do you know where I can find detailed information on radio frequency allocations for the various services? I realize there will be revisions at the outcome of WARC'79, but for now any information would be appreciated.

—Richard Collins

**A.** A fairly complete listing of radio allocations in tabular form is found in Volume II, Part Two of the FCC's Rules and Regulations. The listing is done by frequency from below 10kHz to above 275 GHz. Allocations are given under the following categories: Worldwide; Region II (the Americas); United States; and Federal Communications Commission. For details on getting a copy, write to the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

---

**CRYSTALS**

**Q.** I'm looking for miniature, low-frequency crystals for the 50- to 250-kHz frequency range. Do you know where I can find some?

—Sam Schwart, Nova Scotia

**A.** I would suggest that you contact the

---

**SURGE CURRENT PROTECTION**

**Q.** My solid state power supply went dead when I turned it on. There is nothing wrong with the circuit, and all components checked out okay before I assembled the project. But the rectifier went west. Any ideas?

—John Nagurney, Urbana, IL

**A.** Apparently the surge current flowing through the rectifier was more than it could handle. When you first turn on the supply, the large filter capacitors are essentially dead shorts until they start charging up. This causes a surge current of many amperes to flow through the diodes. Although you can replace the rectifiers with ones having larger surge current ratings, it's best to either insert some resistance in series with the capacitors or to use a circuit like that shown here. The power supply is turned on as slowly as the 2200-μF capacitor charges through R1. The greater the resistance of R1, the longer the turn-on time will be. Experiment with various values until the delay is suitable for your application. This circuit is especially effective in eliminating the "thump" that occurs in audio power amplifiers. The transistor specified has a maximum collector current rating of 15 Amperes and a total device dissipation of 115 watts. A smaller transistor can be used in low-power circuits.

---

Have a problem or question on circuitry, components, parts availability, etc? Send it to the Hobby Scene Editor, POPULAR ELECTRONICS, One Park Ave., New York, NY 10016. Though all letters can't be answered individually, those with wide interest will be published.
THE LOGICAL CHOICE: Third in a series

SYMmetrical and unsymmetrical pulses 0.5Hz-5MHz

Continuous, manual one-shot & external trigger operation. External triggering to 10MHz

Independent, controllable pulse width & spacing

100 nanosec-1 sec in 7 overlapping decade ranges. A single-turn vernier control provides continuous spacing overlapping decade ranges.

CONTINENTAL NO. 44 SPECIALIST CORPORATION - NEW HAVEN, CONN.

Input requirements: Sine waves, performance source, flexibility application---whether engineers in stepper, pulse stretcher, or other applications. Use it alone or in tandem with other DM-4's for gated control.

Design - Mate 4's specifications proves CSC's enormous versatility... plus compatibility with all major logic families, for research, design, development, quality control, production testing, maintenance, troubleshooting... you name it.

First, use the read the specs that follow... and check the price again. Or better yet, try DM-4 for yourself at your local CSC distributor. Once you do, we think you'll find it's as hard to do without as it is easy to own.

For more information about CSC's other fine products, and a list of distributors, please call or write.

DM-4 SPECIFICATIONS

Frequency Range: 0.5 Hz to 5 MHz
Pulse Width and Spacing Controls: 100 nanosec to 1 sec in 7 overlapping decade ranges. A single-turn vernier control provides continuous adjustment between ranges.
Duty Cycle: 10 to 1 Range: adjustable over entire pulse width/spacing range. 100 nanosec, "ON" 1 sec, "OFF" 1 sec. "ON" and 100 nanosec, "OFF".
Operating Modes: Continuous, manual one-shot, external trigger operation. External trigger to 10 MHz.

One-Shot

Pulse width

Output: 10-1 V positive rise/fall time. Impedance 400kΩ max.

TTL OUT Fan-out 40 TTL loads
Sink 160 milliamperes - 0.8 V max
Rise/fall time less than 30 nanosec
Pulse lead

Power: 117 VAC ±10%, 50/60 Hz, 5 watts (200 VAC, 50/60 Hz also available, at slightly higher cost). "OFF" max.

Size: (WxLxH) 101 x 185 x 83 mm
Weight: 2 lbs. (0.91 Kg)

CONTINENTAL SPECIALTY CORPORATION

EASY DOES IT

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West Coast office: Box 7809, San Francisco, CA 94119 • 415-421-8872 TWX: 910-372-7992

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DECEMBER 1976
CB Crossing the Border

The Canadian and Mexican governments have recently been getting tough on incoming motorists with Citizens Band radios. Unless you have a permit to use your radio in either country, your set could be confiscated at the border or sealed against use. To insure against this, send a copy of your FCC license to any office of the Canadian Dept. of Communications, at least six weeks before your trip. Travelers bound for Mexico must write to the Secretaria de Comunicaciones, Mexico City, or contact the nearest Mexican consulate.

Marine Radiotelephone Misuse

A recent nationwide survey made by the Radio Technical Commission for Marine Services has indicated a rapidly growing increase in the misuse of marine radiotelephone. Focusing primarily onvhf/FM, which is used by more than 250,000 boatmen, the Commission observed that there was unnecessary and excessive use of channel 16 (the emergency channel), over long conversations, omitted callsigns, and excessive use of procedural words. Unlike Citizens Band, which is intended for business or personal use, the Marine Band is emergency oriented. The Commission praised the well disciplined radio communication used by air traffic controllers, where every word spoken is essential, in comparison to many marine communications where exchanges are long and cumbersome.

CMOS For Garage Openers

With the introduction of a new digital radio control by Chamberlain Manufacturing, in its "Electro-Lift" garage-door openers, the possibility of outside false activation of automatic garage-door openers has been narrowed. New CMOS integrated circuits built into the radio's transmitter and receiver allow homeowners to select their own exclusive codes. The control, called "Code Command," provides up to 64 possible code combinations for added security.

Electronic Organ Tuning Advance

A new digital IC tone-generator system introduced by Schober abolishes any need for organ tuning adjustments. The new circuitry uses digital logic technology to make pitch relationships among the notes of an organ permanently correct. An oscillating circuit generating a signal about 250 times as high as the pitch of the highest organ note acts as a reference source for all the pitches. A single knob on the front of the organ alters the tuning so that pitch can be adjusted to match a recording or the tuning of another instrument. Before the development of this digital IC generator system, only organs with rotating mechanical generators did not require tuning. The new system is contained on a single pc board (7/2" x 14"), in contrast to the company's former requirement of 12 pc boards.

"10-Four, Good Buddy!"

"10-Four, Good Buddy!" is a new board game by Parker Brothers. The players act as truckers, driving their tractor trailers down game board highways, using CB radios equipped with hi and lo frequency spinners that determine the number of spaces the trucks can move. The game employs the special "trucker language:" players meet up with "Smokies" and a "Bear in the Air," and can get caught in a "Bear Trap."

Operation "Moonbounce"

Amateur radio operator Allen Katz, West Windsor, New Jersey has become the first person to complete two-way communication with all six major continents via radio signals reflected off the moon. On a frequency band similar to uhf television broadcast, and with a 28-foot-diameter dish antenna in his backyard, Katz achieved his goal. He was awarded a "Worked All Continents" certificate by the National Amateur Radio Union, headquartered with the ARRL.

Electronics for Autos

Tenna Corporation has entered into an agreement with the Lincoln-Mercury Division of Ford Motor Company to supply retractable Citizens Band antennas to be offered as optional equipment on the 1977 Lincoln and Mark V models. The rear-mount, electrically powered antenna features a thin center-loaded coil, which enables the unit to be retracted completely when not in use.

Rockwell International has agreed to supply General Motors with the "Miser" spark timing system, which will be standard on 1977 Oldsmobile Toronado cars. The new system, the first use of a microcomputer in a production automobile, contains two LSI circuits with more than 20,000 transistors and electronic elements.

AM Stereo Progresses

In response to a request by the FCC in the fall of 1975, for a committee to study AM stereo, the National AM Stereophonic Radio Committee was formed. At a recent meeting, the committee evaluated proposals for AM stereo systems, submitted by Communication Associates, Motorola, RCA and Sansui. Transmitter and antenna perimeters for testing AM stereo were examined and a list of test stations meeting criteria set by the committee was developed. After these test stations have been observed, the committee plans to submit its final report to the FCC for Rule Making. The committee also opposed a petition submitted by Kahn Communications, Inc., which is also developing an AM stereo system, asking the FCC to deny their petition, and encouraging Kahn to participate in the committee efforts to ensure a standardized test procedure.
FLUKE PROVES AN INEXPENSIVE, HANDHELD DMM CAN BE BUILT WITHOUT LEAVING EVERYTHING OUT.

Let's face it.
Before now, if you bought an inexpensive, handheld digital multimeter you didn't get much—they just left most everything out.

We knew that was no answer.
So we built the 8030A 31/2-digit DMM. It's a small, portable, inexpensive, handheld DMM, but it performs like our benchtop units.

With one basic difference. The 8030A was designed, built and tested to a size and shape proven best for field service and laboratory technicians. There's a built-in hood that can be slipped forward to shade the readout in sunshine. It has rms capability. The best overload protection. Diode test. It weighs 2.2 pounds, and will take a beating without failing. Finally, we guarantee accuracy specifications for one year.

And it only costs $235*.

<table>
<thead>
<tr>
<th>True rms.</th>
<th>Fluke</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-year accuracy spec.</td>
<td>Fluke</td>
</tr>
<tr>
<td>High voltage protection</td>
<td>Fluke</td>
</tr>
<tr>
<td>Diode test.</td>
<td>Fluke</td>
</tr>
</tbody>
</table>

A full line of accessories offering rf voltage, high current ac, high voltage dc, and temperature measurement probes. Fluke

There's only one place to go for all the performance you need in a handheld DMM.

There are measurement functions in five selectable ranges for dc volts, ac volts (true rms), dc current, ac current (true rms), and resistance. DC voltage measurement is from 100 µV to 1100V with basic accuracy of ±0.1%, ac measurement is from 100 µV to 750V rms with basic accuracy of ±0.5%. DC and ac current is from 100 nanoamps to 1.999 amps with basic dc accuracy of ±0.35% and basic ac accuracy of ±1%. Resistance measurement is from 100 milli-ohms to 2 megohms with a basic accuracy of ±0.4%.

We added true rms response for ac measurements. Specified accuracy is still attainable when the measured waveform is distorted.

A NEW ADVANCE, 8030A DMM. FLUKE®

*U.S. price only.
Video games are becoming almost as popular as pocket calculators, digital watches, and CB transceivers on the consumer electronics scene. In fact, suppliers don't believe they can produce enough TV games to keep retailers' shelves filled during this Christmas season of 1976.

Connected to the antenna terminals of any TV receiver, these new electronic marvels pit one player against another or against the machine in a variety of games ranging from tennis to tic-tac-toe. Some of the new video games illustrate the on-screen graphics in color.

Magnavox got the video game market rolling about four years ago with the introduction of its Odyssey® game. The original game was basically paddles and a white square that moved about on an empty TV screen. The playing field, a plastic laminate that physically attached to the face of the picture tube, gave the game boundaries, markers, and areas from which to maneuver your "man" on the screen.

It was not until fairly recently that video games began to catch on as improved versions were introduced to the market. Atari, makers of Pong®, is one company that deserves a lot of credit for popularizing the video game. Pong, a game of table tennis, added some significant improvements: electronically generated on-screen colored courts; sound effects for every hit, miss, and ricochet of the ball; and automatic on-screen digital scoring. Add to this the selling expertise of Sears, and you have a notable contender for the projected $750-million market by 1980.

There are currently some 35 companies making video games. At this writing, however, only 20 or so have had their games type approved by the FCC and are marketing games.

**Tennis Anyone?** Tennis (actually, table tennis) is available in all video games in one form or another. The first game of Odyssey gave player control over the ball in both horizontal and vertical positions. Pong® and the newer games give player control in only the vertical position. Competition between the new game makers has not grown out of what moves a player can make but on the games in which he can participate. The new games still include tennis, but now hockey and handball are typically available at the flip of a switch.

The new Odyssey 400 now allows you to play handball and hockey as well as tennis and includes on-screen digital scoring and sound effects. Atari's new Super Pong gives you a choice of the original Pong tennis game, two-man team tennis called Super Pong, Catch, and Solitaire. Catch is unique in that it allows you to control the position of a "hole" in the boundary on your side of the court. Solitaire is similar to a one-man handball game, but the height of the backboard wall is adjustable to make the game easy or difficult. When you play Solitaire, if you get the ball over the wall, you make a point; miss on a return bounce, however, and the machine scores.

Games designed to pit your skill against the machine are made by companies other than Atari and Magnavox. In addition to tennis and hockey, First Dimension has a clever Robot game.
that has you trying to score by getting the ball into a goal that is usually blocked by a mechanized moving paddle. Coleco’s handball game has provisions for only one player to bounce the ball off a wall at the far side of the screen; you can miss, losing a point, but the wall remains stationary, always returning the serve.

Unisonic gives you a choice of six games, two of which are Skeet and Targets. A white block, your target, randomly crosses the screen. You shoot at this target with an electronic gun supplied with the game. Your score of hits is automatically displayed on the TV screen after 15 rounds. Skeet and Targets are slightly different in concept than other games that merely use the TV screen as a graphic display; in these two games, the screen is an active part of the circuitry. A photocell inside the gun senses the presence (or absence if you miss) of light from the screen each time you pull the trigger and updates the score accordingly.

The Unisonic machine’s sound effects are different, too. Rather than having the sound come from a speaker built into the game itself, the audio is modulated with the video and sent to the TV receiver. The sound is then reproduced by the TV receiver’s speaker.

Universal Research has added a button to give hockey a realistic twist. Ordinarily, the puck can only be deflected by players on the screen as with most other games. A special “Puck Control” switch on the Universal Research game allows each player to catch and hold the puck, passing off only when desired. This is just one of the many switches now appearing on the more complex games.

In addition to the usual player position controls, many manufacturers are incorporating other controls to add to the skill level requirements of their games. Paddle size, speed, and ball angle can all be changed, either individually or collectively, depending on the switching arrangement provided in a particular video game. Odyssey 300, for example, has one switch with Amateur, Average, and Professional skill positions. In the Amateur position, the paddle is large and the speed and angle of the ball are mild. In Average, the paddles become smaller and the angle of deflection is increased, but the speed remains the same. In Professional, the paddles again become large, but only to keep up with the large deflection angles (40° versus 20°) and high speed (0.65 versus 1.3 seconds across the screen) of the ball while it is in play.

APF uses three separate switches to allow the player to tailor the game to the way he wishes it to be played. First Dimension allows just the speed of the ball to be changed, but each player is provided with a separate speed control, which is a bit more practical because each player can be separately handicapped. Other switches on some games permit
two or four players to participate in the game and provide automatic and manual serve selection.

The game selector switch sets up the playing field for the particular game you wish to play. While the graphics are generally set up in the same manner by each manufacturer, there are differences here, too. National Semiconductor's Adversary game, for example, allows you to play tennis on a green court, hockey on blue "ice," and handball on a brown "clay" court when used with a color TV receiver.

**IC Technology Base.** What has been primarily responsible for bringing video games down to practical size and price is the LSI integrated circuit technology support the industry has received. For many game manufacturers, the General Instruments dedicated n-channel MOS chip is used. (There are separate chips available for U.S. and European TV standards.) The 28-pin IC contains all the logic required for tennis, hockey, handball, and practice. With slightly more outboard logic, this chip also provides target and skette game modes that are played with a remote electronic gun. Score update and display for all games are also on-chip generated for these ICs.

Input programming pins on the General Instruments' AY-3-8500 game chip allow direct non-buffered switch connections for game selection, ball speed, paddle size, and four different ball-return angles. Other inputs provide for automatic and manual ball serving after each point is scored and separate resetting.

Separate video outputs from the GI chip allow combining for a monochrome or use with a color generator for a color picture display. An audio output pin on the IC can be used to deliver a signal that can be modulated with the video signal or buffered through a one-transistor circuit to drive a loudspeaker.

The flexibility of the GI chip makes it quite attractive to video game manufacturers. Game complexity, which determines the manufacturing cost, is basically a matter of whether or not a given pin on the IC is used. All that must be added to the primary circuit are a 2-MHz clock generator, r-f modulator for TV Channel 3 or Channel 4, paddle control potentiometers, loudspeaker, and power supply. The power supply is usually a set of six C cells, which may or may not be supplied with the game.

The game Adversary is quite naturally designed around National Semiconductor's MMS7100 video game and LM1889 video modulator chips. In addition to providing three selectable skill levels, Adversary allows an opponent to play against another opponent, against himself, or against the machine. A special "time-out" feature stops the play instantaneously, with no effect on the game. (The usual reset function returns all scores to 0 and initiates a new game.)

Texas Instruments has also gotten into the video-games market, but not with a finished product that bears its name. TI is offering six separate chips that can be combined in different arrays to create a range of video games from simple to complex. The TI chips currently being offered include: game logic with automatic random English, horizontal and vertical sync generator, game logic

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**HOME VIDEO GAMES**

<table>
<thead>
<tr>
<th>Brand</th>
<th>Model</th>
<th>Price</th>
<th>Games</th>
<th>Players</th>
<th>Color</th>
<th>Remarks</th>
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</thead>
<tbody>
<tr>
<td>APF</td>
<td>401</td>
<td>80</td>
<td>1,2,3,4</td>
<td>2,1</td>
<td>no</td>
<td>4th game, Super Pong, is ten, dbls. (4 players)</td>
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<tr>
<td>Atari</td>
<td>Pong</td>
<td>80</td>
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<td>2</td>
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<tr>
<td></td>
<td>Super</td>
<td>90</td>
<td>1,7,8</td>
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<td>First</td>
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<td>Video output. Can be used</td>
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<td>Monte Verde</td>
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<td>screen moving bar score</td>
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<td>300</td>
<td>70</td>
<td>1,2,3</td>
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<td>English control</td>
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<td>National</td>
<td>120</td>
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<td>yes</td>
<td>var. color, English</td>
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<td>Semiconductor</td>
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<td>Phoenix</td>
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<td>time-out button</td>
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<td>Quadronics</td>
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<td>Video Action III</td>
<td>120</td>
<td>1-6</td>
<td>2,1</td>
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</tr>
</tbody>
</table>

*1 - tennis, 2 - hockey, 3 - handball, 4 - practice, 5 - targets, 6 - skeet, 7 - solitaire, 8 - catch, 9 - robot.

---

**Pin configuration of General Instrument's AY-3-8500 game chip.**
With Mallory Security Products on the job, intruders get the message loud and clear. Anyplace, anytime. For the few dollars they cost, here are mighty effective ways to signal forced entry of a building, home, apartment, office, automobile.

Put the Mallory CA3 Intrusion Alarm in your living room, for instance. It’ll easily pass for a radio or stereo tuner while transmitting a 20-foot ultrasonic wavelength field. One that will detect the slightest intruder movement and activate an alarm. This compact area-and-

perimeter device comes with solid-state circuitry and big reliability. And a wide variety of indoor and outdoor warning accessories to choose from—bells, horns, sirens, rotating red lights, tape switches, many more.

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MALLORY DISTRIBUTOR PRODUCTS COMPANY

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SONALERT® is a registered trademark of P. R. Mallory & Co. Inc.
with manual English, wall and ball generator, character generator, and digital scorekeeping IC's. TI plans to supplement this lineup with other chips in the near future.

In spite of the wide acceptance of dedicated video-game IC's, Fairchild's new game (not available at this time) may set the trend for all video games for the future. Built around the F8 microprocessor and four random-access memory (RAM) chips, the Fairchild game is unique because it can be externally programmed with a special "Videocart" and a keyboard on the player console. Similar to a cassette tape, the Videocart reprograms the system for a new selection of games other than the system's resident tennis and hockey games. You simply consult the jacket of the Videocart for the particular game you would like to play and use the keyboard to punch in the game number. Skill levels and even time limits can be added at the console.

Fairchild intends to market the Videocarts for about $20 each. The first cartridge contains programming for a tic-tac-toe game, shooting gallery, and a doodle game that allows you to draw in color on your TV receiver's screen. Fairchild expects a total of 17 games to be available by Christmas.

As a point of interest, the use of a computer-based video-game system, which is the idea behind the Fairchild game, opens possibilities for using your TV receiver as a serious tool for learning and storing information. One Videocart might contain a question-and-answer quiz for students, while another might be programmed with a host of cooking recipes. The possibilities of such a system are limited only by the imagination of the user. Greg Reyes, Vice President and General Manager of Fairchild's Consumer Group, sees it as "opening up a flexible capability for future TV-based applications."

**Hooking It Up.** Since all video games contain their own modulator for the video (and sometimes the audio) signal, they simply connect to your TV receiver via its vhf antenna input terminals. Each game manufacturer supplies a small r-f switching box that accepts an input from the game console and another from an external standard TV antenna. Once the system is hooked up, you can select either the TV or the game position of the switch as desired. A second switch, which is usually buried inside the game console, allows selection of the modulator frequency for either Channel 3 or Channel 4.

Ironically, the simplest section of the video game's circuitry has been the cause of a great deal of trouble for the game manufacturers. Since video games are r-f generating devices, they must meet the requirements of Part 15 of the FCC's Rules and Regulations. There must be a minimum of 60 dB of isolation between the video game and TV antenna to keep the game signal from exceeding the 15-µV/m limit of radiation from the antenna set by the FCC. Unless the TV/GAME selector switch can provide the necessary 60-dB minimum isolation, the game will not receive FCC type acceptance.

There is an alternative to the r-f problem that eliminates the need for a modulator—direct video access to the TV receiver with which the game is to be used. Unfortunately, there are not many TV receivers around that provide this access. Magnavox, however, plans to offer a 1977 TV receiver with a built-in video game. The game will feed directly into the video amplifier section of the receiver, bypassing the r-f and i-f sections of the receiver. Once the trend gets started, TV receivers of the future are likely to have video input jacks as standard equipment. Such jacks will not only accommodate video games, but they will also accommodate video tape recorders and video discs.

**Hockey game on a TV screen. Courtesy First Dimension.**

**Fairchild's new game (not available at time of writing) is built around the F8 MPU and four RAM's.**
FOUR-CHANNEL sound can produce a new, welcome audio dimension, approaching a live performance ambience. Although it has not yet captured the consumer's fancy in the manner that stereo did (for reasons such as higher cost, multiple quadraphonic systems, and poor separation with earlier systems), it is slowly but surely moving into the marketplace.

With more and more matrix 4-channel FM broadcasts available around the country and lots of matrix-type records that use standard stereo cartridges, quadraphonic sound promises to grow in importance over the years.

The universal decoder presented here features the advanced QS vario-matrix approach used by Sansui, and will operate with SQ (producing the equivalent of "half logic" SQ) and other matrix-encoded media. Additionally, it can synthesize four channels from existing two-channel sources, yielding a choice of simulated quadraphonic sound or "Surround Sound," each with 20-dB separation. A complete kit is available for $75 plus $12 for an attractive case. As illustrated in Fig. 1, the circuit employs only four unique IC's and a handful of transistors.

Circuit Operation. Essentially, the QS vario-matrix analyzes where the reproduced sources are coming from, and adjusts the matrix parameters to cancel out the inter-channel leakages that are normally present in simple matrix decoding. This approach is in contrast with the gain-riding logic that attempts to alter the gain of the four channels to reduce the undesired inter-channel crosstalk.

As shown in Fig. 1, the two-channel audio enters the system via the LT (left) and RT (right) input jacks. After a stage of gain (Q01-Q02), the signal splits into two paths.

One pair of signals (marked A and B in Fig. 1) is used to drive the two phase discriminator IC's (HA 1327) that use the phase and level signals between the Ltotal and Rtotal encoded signals to detect the location of the predominant signal. The outputs of these two IC's then become four control signals—right, left,
Fig. 1. Schematic of decoder is shown above and on opposite page.
Parts List includes power supply shown in Fig. 3.

**PARTS LIST**

C1, C34, C35, C36, C37, C42, C46, C47, C81, C82—10-µF, 25-volt radial electrolytic capacitor
C2, C21, C45, C48, C75, C83, C91—3.3-µF, 16-volt radial electrolytic capacitor
C3, C18, C44—0.01-µF, 5% capacitor

C4, C8, C20, C22, C41, C53, C86, C96, C109, C111—1-µF, 16-volt radial electrolytic capacitor
C5, C25, C38, C54, C71, C100, C101—470-pF, 5%, styrene capacitor
C6, C19, C39, C51, C66, C113—0.01-µF capacitor
C7, C16—not used
C9, C17—1 µF, 16-volts, axial electrolytic capacitor
C10, C26, C108—0.0068 µF capacitor
C11, C12—100 µF, 10-volt radial electrolytic capacitor
C13, C24, C28, C33—47 µF, 25-volt radial electrolytic capacitor
C14, C15, C49, C50, C88, C98—0.033 µF capacitor
C23, C27—100-pF, 5% styrene capacitor
C29, C30, C31, C32—3300-pF capacitor
C40, C110, C112—0.012 µF capacitor
C43—0.0047 µF, 5% capacitor
C52, C107—0.015 µF capacitor
C55, C59—330-pF, 5% styrene capacitor
C56, C57, C58, C64, C94, C95—0.001 µF, 5% capacitor
C60, C72—0.0039 µF, 5% capacitor

C61, C62, C73, C74, C77, C78, C102, C103, C116—4.7 µF, 25-volt radial electrolytic capacitor

C63, C85—0.068 µF capacitor
C64, C65, C87, C97, C106—0.056 µF capacitor

C67, C68, C89, C90—0.0022 µF capacitor
C69, C70—0.033 µF capacitor
C76, C79, C80, C104—33 µF, 25-volt radial electrolytic capacitor

C92, C93—0.068 µF, 5% capacitor
C99, C105—0.018 µF capacitor
C114—0.01 µF, 50-volt, ceramic capacitor
C115—1000 µF, 35-volt electrolytic capacitor

C117—220-pF, ceramic capacitor
D1 through D6—IN1914
D7 through D10—IN4001

F1—½-ampere slow-blow fuse and holder
IC1—HA1328 (Sansui)
IC2, IC4—HA1327 (Sansui)
IC3—HD3103 (Sansui)
IC5—723 voltage regulator
J1 through J6—phono jack
LED1—red LED
Q1, Q2—MPSA55
Q3 through Q10—2N3391A
Q11—1-ampere npn power transistor

The following resistors are ½-watt, 5%, unless otherwise noted:
R1—5600 ohms
R2, R11—47000 ohms
R3—100 k ohms
R4—100 k ohms
R5, R6, R8, R10, R12—0.015 µF
R13, R60, R63, R73, R76, R167, R169—1000 ohms
R4—14, R20, R21, R65, R75, R78
R129, R135, R149, R152—100,000 ohms
R5, R6, R8, R10, R12, R15, R17, R19, R27, R166, R168—2200 ohms
R7, R16, R176—3300 ohms
R9, R18, R31, R38, R40, R41, R55, R57, R68, R70—157—22,000 ohms
R22, R24, R30—0.150—1500 ohms
R23, R87, R93, R96, R97, R101, R103, R109, R111, R115, R116—120,000 ohms
R29, R86, R94—390,000 ohms
R32, R89, R134, R137—33,000 ohms
R33, R175—8200 ohms
R36, R37—27,000 ohms
R42, R43, R44, R45—47 ohms
R46, R47, R48, R49, R131—15,000 ohms
R50, R51, R52, R159, R161—1200 ohms
R53—150,000 ohms
R54, R56, R58, R59, R67, R69, R71, R72, R80, R81, R83—220,000 ohms
R61, R64, R74, R77—1200 ohms
R79—3900 ohms
R82, R91, R100, R102, R108, R110, R113, R127, R141, R144—330,000 ohms
R84, R92, R122, R125—270,000 ohms
R90, R95, R112, R114—680,000 ohms
R98, R99, R117, R118, R119, R120, R164, R170, R171—56,000 ohms
R121, R126—1.5 megohms
R123, R124, R140, R145—560,000 ohms
R128, R130, R148, R153—1 megohm
R133, R136—560 ohms
R138, R147—2.2 megohms
R139, R142, R143—470,000 ohms
R151, R154, R177—2700 ohms
R155, R156—12,000 ohms
R158—10,000 ohms
R160, R163—680 ohms
R162—1200 ohms
R172—2000 ohms
R173—2.4 ohm, ½ watt
R174—1500 ohm trimmer potentiometer
S1—12-position, 4-pole rotary switch
S2—spst switch, 3-ampere rating
T1—30- volt secondary
Misc.—Suitable enclosure, line cord, shielded cable, hookup wire, hardware, etc.

Note—The following are available from Phototune Corp., 318 E. 28th St., New York, NY 10016: kit of IC1 through IC4 with etched and drilled pc board, #QSP-3 at $25; complete kit of all parts except case, #QSK-3 at $75, plus $2 for shipping (Canadian and foreign, add shipping and insurance for $4 lb); drilled and screened case at $12. New York state and city residents, include appropriate sales tax.

AmericanRadioHistory.com
back, and front—that are passed to control IC (HD3103). This IC, containing five FET’s, generates the dc voltages that are used to vary the parameters of the phase-matrix IC-HA1328.

The second signal path feeds the phase-matrix transistors Q03 and Q04, whose outputs go to the HA1328. In the matrix IC, the incoming audio signals are combined with the control signals from the HD3103 to produce four audio outputs—Lfront, Rfront, Lback, and Rback with a better than 20-dB inter-channel separation. These signals are then passed through cross-coupled emitter followers (Q07 through Q10) to form the actual output signals.

The technique involving the use of a symmetrical variable encoding/decoding matrix (vario-matrix), and controlling it with signals derived from the phase relationship of the two encoded channels, enhances the separation between any pair of the four decoded channels. The same vario-matrix can be used to enhance the reproduction of conventional 2-channel stereo signals into an excellent simulation of 4 channels because, in conventional stereo recording, the majority of the left and right signals are in phase with each other. Even when some of these signals are out of phase, the reverse-phase components are minimal compared to those components that are in phase. If the reverse-phase information could be added to the in-phase,
Theoretically, it would be possible to produce 4-channel separation from a conventional stereo recording. By the addition of some relative signals, stereo signals can produce two other synthesized stereo signals. In the "Surround" mode, the decoder can also be used for 4-channel reproduction from sources on the podium, or just about anywhere on the middle of the group that is playing. The effect is to place the listener in a "Concert Hall," and "around" the listener with very rich sound coming from all four speakers. The addition of some relatively signals, stereo signals are caused to appear. The decoder can also be used for 4-channel reproduction from sources on"
coded with the CBS SQ system (a phase-matrix technique). The four outputs (LF', RF', LB' and RB') are equivalent to the outputs from a basic SQ decoder with partial logic. This provides a corner separation of between 3 dB and infinity. Application of the vario-matrix to phase-matrix decoding provides a greater separation between CF (center front and CB (center back) than the basic SQ decoder.

Construction. Although any type of construction can be used, the complexity of the circuit can be greatly reduced by using the single-sided foil pattern shown in Fig. 2, which also shows the component installation. Because of the board density, most of the resistors are mounted vertically. Sockets should be used for the IC's. A low-power soldering iron (25 watts) with small-gauge rosin-core solder is used to mount the components. Check the polarities of semiconductors and electrolytic capacitors. After component installation, look the board over for accidental shorts between the closely spaced copper traces. Note that a well-regulated power supply (Fig. 3) using an IC regulator and series pass transistor (with slip-on heat sink) has been incorporated on the board and the \(+V_{CC}\) is connected to the main portion of the board via a small jumper (J1). Do not connect this jumper at this time.

To select the four functions—SQ, QS, Surround, and Hall—a four-position, 12-pole rotary switch is wired as shown in Fig. 4. Note that seven components are mounted on the switch, while all the other connections are made to numbered pads on the board. The switch should be pre-wired with sufficient cable length to reach the board after the switch has been mounted on the front panel. Multiconductor cable makes for the best appearance. Power-on LED1 is also mounted on the front panel with a sufficient length of insulated pair to connect it to the pc board.

The finished pc board without the IC's installed (except for the power supply regulator), should be tested before installing it in a cabinet. (The prototype used a Ten-Tec MW-8, having dimensions of 4 3/16' high, 6 5/16' deep by 7 1/2' wide.) Drill suitable holes in the front panel for the function selector switch, power on-off switch, and LED1.

The six phono connectors—two for inputs and four for outputs, can be mounted on the rear apron and suitably identified. The power line can exit via a grommeted hole on the rear apron.

The system requires only one adjustment—the power supply voltage level. Using a dc voltmeter connected between the positive output of the supply...
(jumper J1) and ground, turn on the power and note that LED1 glows, then adjust trimmer potentiometer R174 for a meter indication of 25 volts. Once this adjustment has been made, turn off the power and connect jumper J1 into place.

Install the IC's, identifying each pin 1 by its index cutout and dimple. Take a last look at the board checking for correct component installation, then turn on the power. The front-panel LED should come on. Using the dc voltmeter, check the VCC line at each of the points where the voltage is applied, according to the schematic. If the dc voltage at any point is off by more than 15%, there is an incorrect condition that must be cleared up before going further. If the power supply is functioning properly and the voltages at the IC's are incorrect, recheck the wiring and component installation. Install in the cabinet.

If all dc checks are good, connect the decoder into an operating system such as that shown in Fig. 5.

To make a final system check, the use of a QS encoded test record is suggested. One of these, the Ovation Records OVOD 4000, features musical and test-tone sequences to demonstrate that the proper channel locations and separations are being achieved.

To test the SYNTHESIZER mode, a stereo record such as Pink Floyd’s "Dark Side of the Moon" (SMAS-1163), using the cut “Money,” will show the quality of synthesized four-channel music that can be obtained from a stereo disc.

To test the CONCERT HALL mode, any good classical recording with reasonably good ambience will demonstrate the desired effect.

For SQ testing, either an SQ test record, or a musical selection such as the Bill Chase recording “Chase” (EQ-30472), using the cut “Open Up Wide,” can be used.

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Measure the sun's energy with

A SOLAR RADIOMETER

BY WARREN JOCHEM

WITH INTEREST in alternate sources of energy at an all-time high, a definite need exists for simple, reliable instruments to aid the experimenter. This project—a solar radiometer—is one such device. It will enable you to plan and set up solar energy converters with maximum efficiency.

Solar radiometers are by no means new. Many of us have seen Crookes radiometers, which are partially evacuated glass bulbs containing rotating vanes silvered on one side and darkened on the other. When exposed to bright light, temperature imbalance causes the vanes to spin. The brighter the light source, the faster the vanes will move. But such devices are really "conversation pieces." Commercial instruments which measure solar radiation accurately are very expensive. But this project, composed of a silicon solar cell, a milliammeter, and a shunt resistor, will measure the amount of sunlight falling on a given area. It will do so with reasonable accuracy (about 5% if the specified components are used).

Circuit Theory. The solar cell used as a light detector in the radiometer is really a large pn junction (like a diode) with one side exposed to light. Leads are attached to each side of the junction. In the presence of light of the proper wavelength, a voltage will be generated across the two leads. When a silicon cell is placed in bright sunlight, a high-impedance voltmeter will measure about 0.6 volt across it.

If a resistance (in this case a meter and shunt resistor) is connected to the output leads, a current will flow. Reducing this resistance to a very small value (0.3 ohm in this circuit) means that the solar cell is effectively working into a short circuit. It can be shown that the short-circuit current is directly proportional to the intensity of the light falling on the cell. Also, the short-circuit current is largely independent of temperature. This is important to the accuracy of the meter if it is exposed to a wide range of ambient temperatures. Actually, the current does increase slightly with heating. If the meter is left in the bright sun for a while, its readings might be a bit on the high side.

The radiometer is calibrated in "Langleys per minute," a unit which might be unfamiliar to some readers. This unit was chosen because it is the standard used in most solar research today. Accordingly, you will find comparisons of your experimental data with existing records a very simple process as no conversions are necessary. By definition, one Langley per minute is equivalent to one gram calorie of energy falling on a surface area of one square centimeter for one minute. In other words, one Langley per minute represents enough energy falling on one square centimeter in one minute to raise the temperature of one gram of water one degree Celsius. This statement is expressed mathematically by the equation:

\[ 1 \text{ Langley/minute} = \frac{1 \text{ gram calorie}}{\text{cm}^2 \text{ minute}} \]

For those who do not yet want to go metric, and who are more familiar with BTU's, the equation is:

\[ 1 \text{ Langley/minute} = \frac{221 \text{ BTU}}{\text{hr} \text{ minute}} \]

In words, this means that one Langley per minute represents the energy falling on one square foot in one hour required to raise the temperature of 221 pounds of water one degree Fahrenheit.

The peak insolation (incident solar radiation) measured at sea level is about 1.6 Langleys per minute. With this maximum in mind, the circuit has been designed so that the meter reads 1.7 Langleys/minute full scale in 0.1-Langley/minute increments. Over the course of one year at the author's New Jersey location, the peak insolation varies from about 0.7 to 1.2 Langleys/minute. Using the meter at your location, you can estimate how much solar energy is available for conversion.

The radiometer circuit is shown sche-
matically in Fig. 1. Current from photovoltaic (solar) cell PC1 flows through M1, a 0 to 50-mA meter, and shunt resistor R1. This resistor, consisting of a length of 30-gauge magnet wire wound on the body of a 2-watt, 1-megohm carbon resistor, bypasses some of the current around the meter, thereby expanding the range of light intensity to which the meter will respond. A new meter face calibrated in Langleys per minute is applied over the old one for direct insolation readout. Note that the prototype was calibrated only for the parts specified. Do not substitute any others or the accuracy might be adversely affected. However, you should have no problem finding the parts listed because they were chosen for their availability.

**Construction.** Begin by carefully removing the cover of meter M1. The cover should snap off. Remove the two small Phillips head screws that hold the face plate in place. Cut out the new scale shown in Fig. 2 and cement it over the old scale using a general-purpose adhesive. Then carefully reattach the plate (after the adhesive has set) to the meter body, securing it with the two small screws. Snap the meter cover back on the meter assembly, making sure to position the cover’s zero-adjust screw in the thin metal slot on the meter movement. Fashion a 1.75-inch (4.4-cm) diameter mounting hole on the center of an appropriate enclosure’s face plate and mount the meter in it.

Remove the solar cell and padding from the small plastic box it comes in and drill two small holes in the black bottom of the box. Position the holes to allow the leads from the solar cell to pass directly through the box when the cell is centered in it. Then center the box—black side down—on top of the enclosure (see photo). Drill two holes on the top of the enclosure to line up with those in the photocell box. Replace the foam padding and feed the output leads of the solar cell through the small plastic box into the project enclosure. Center the solar cell—blue side up—making sure it is level. Then close the transparent lid of the box. Glue the bottom of the box to the top of the enclosure, making sure that it is centered and that the cell leads pass freely into the case.

Mount a lug-type terminal strip on the left inside wall of the enclosure.

You now need a 0.5-ohm, 1% resistor. If you can find a commercial component, you can use it. If not, you can make one yourself. Prepare a 57-inch (144.8-cm) length of 30-gauge enamel-covered copper magnet wire, scraping the insulation from both ends so the wire can be soldered. Then solder one end to a 2-watt, 1-megohm carbon resistor. (Actually, any 2-watt, carbon resistor greater than or equal to 100,000 ohms is suitable.) Coil the wire around the body of the resistor and solder the free end to the other side of the resistor. Coat the wire with model airplane dope or glue to hold it in place.

When the dope is dry, attach the resistor leads to two lugs of the terminal strip. Connect short lengths of hookup wire from both sides of the resistor to the meter terminals. Then attach the solar cell leads to the lugs observing proper polarity. The red lead from the cell is positive and should be connected to the lug holding the wire attached to the + terminal of the meter. Secure the lug connections by soldering them. Reassemble the enclosure by attaching the front panel to the enclosure body, securing it with the hardware provided.

**Checkout and Use.** The solar radiometer is now complete and ready for testing. Position the project near an incandescent lamp. The meter needle should move upscale. If it deflects downward, the meter leads are reversed.

Using the radiometer is easier than using a light meter. To measure the peak solar radiation at a particular moment, aim the cell directly at the sun and record the maximum reading. This value represents the energy one square centimeter of a solar panel would receive if it were pointed directly at the sun. But very few solar panels are built to track the sun—most are pointed south and tilted upward at an angle approximately 10° greater than the local latitude. By positioning the radiometer in this manner, you can measure how much solar energy a panel would receive in practice.

To calculate the total energy reaching this type of installation over the course of a day, mount the radiometer on the top surface of the panel. Take meter readings frequently throughout the day. Plot the radiometer readings (L) versus time (t) on Cartesian graph paper. The L axis should be scaled with 0.1-Langley/minute increments, and the t axis should have 10-minute increments.

If these scaling factors are used, one block on the graph paper represents one calorie per square centimeter. To determine the amount of energy per square centimeter that reached the solar panel in the course of the day, you must "integrate" the curve by finding the total area under it. The simplest way to do this is to count the number of boxes and fractions of boxes lying under the curve. This total will be the energy falling on one square centimeter of the panel for that day.
day. To find out how much energy was available to the entire panel, multiply the area under the curve (in calories/cm²) by the total area of your solar panel (in cm²).

It should be stressed that the total available energy is not the total energy output of the solar energy converter. Solar heating panels are never 100% efficient, but average 70 to 80% for flat-plate water heaters. Any good physics or solar energy book will outline steps to measure actual efficiency. Remember that, due to variations in components and measurement techniques, your measurements will be accurate to about ±5% at best. This is fine, however, for "backyard experiments."

Other Uses. There are several other applications for this project. It can be used as a transmittance/reflectance meter to measure the percentage of solar energy transmitted or reflected by a particular material or surface. The radiometer can also be used as a pyranometer to measure radiation from the sky. Simply point the solar cell straight up. Readings taken over the course of the day should now correspond with standard meteorological data.

Relative efficiencies of lamps and other light sources can be determined. You can easily measure the electric power input (or use manufacturer’s data), and the radiated output power can be calculated using this relationship:

1 Langley = 0.0698 watt

From this data, efficiency (power out/power in) can be obtained.

Another interesting experiment uses the radiometer as an air pollution indicator. Record direct readings of solar energy as the sun is setting. On a pollution-free day, a plot of this data versus time should fall off smoothly as the length of the sun’s rays’ path through the atmosphere increases. However, if a large cloud of smog is hanging over a city to the west, the readings might dip sharply as the sun goes "behind" the smog cloud. This is only a relative indication, but comparisons over a period of days might point to some sort of pattern. By determining the angle above the horizon at which the readings start to dip and the distance to the city, you should be able to calculate the approximate height of the smog cloud by trigonometry. The technique will also be applicable looking east in the morning.

With a little imagination, you will surely find other applications for this useful project.

DECEMBER 1976

Our Synergistic System

We make one of the finest tone arms in the world (ask the editors of AUDIO magazine) but how well it performs is dependent—at least partly—on the cartridge.

But even the finest combination of cartridge/tone arm is influenced by how clean the records may be... and how clean the stylus is. So we have both a superb manual and automatic record cleaner, and a fine stylus cleaner.

We also make one of the finest phono cartridges in the world (ask almost anyone about the AT209SLa) but how well it can perform is governed at least in part by the tone arm.

And of course the whole system works best only if it is free from such things as acoustic or mechanical feedback (especially with a cartridge having subsonic capabilities like ours), and excessive cable capacity. We solve these problems neatly and effectively with our AT-605 Audio Insulator and AT-610 Low Capacity cable set.

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Start anywhere in our system. You’ll soon find that as you add Audio-Technica products, you multiply enjoyment.

audio-technica.
OF MAJOR concern to most CB'ers is the effective working range of their communications equipment. Here we explore a method of accurately predicting range for base-to-mobile and mobile-to-base radio links. Since CB communications are limited by FCC regulations to 150 miles, we'll focus our attention on ground wave rather than sky wave signals.

Radiation from an antenna follows two routes. One component travels parallel to the earth's surface. This is called the ground wave. The other component goes up into the sky, sometimes reflected back by the ionosphere as "skip." Although the range of skip signals can be hundreds or thousands of miles, skip is a transient phenomenon at best. Apart from legal considerations, skip is presently very rare because solar activity is low, and will remain so for at least a few years in the future.

Range Predictions. By limiting our consideration to the ground wave, we can arrive at a good estimate of the consistent range of a two-way radio system. To come up with a meaningful result, three basic quantities must be determined. They are defined as follows:

- **ERP** or effective radiated power— a function of the r-f power output of the transmitter, losses in the connectors and transmission line, and antenna gain or loss.
- **Propagation loss**—a function of the heights of the two antennas, the distance between them, and the terrain loss for a given communications reliability above the median of 50% level.
- **Receiver Environmental Loss**—a function of ambient noise in the vicinity of the receiver, the receiver antenna gain or loss, losses in connectors and the transmission line, and the receiver's signal plus noise to noise ratio (S+N/N).

A convenient way to relate these three quantities is with the graph shown in Fig. 1. It is called a "Power Level Diagram." To use the diagram, simply find the power level which is equivalent to your base or mobile receiver's sensitivity in dBm or microvolts. Then add a quantity called the "J factor" and the propagation losses (both of these will be thoroughly developed). You can now determine the required ERP for the distance covered, or the distance that can be reached for a given ERP.

The **J Factor.** This is the difference between the receiver's sensitivity and the signal level required for effective communications. Studies indicate that a signal level greater than the receiver's sensitivity rating is necessary for good results. This signal level, \( V_\text{a} \), is principally influenced by the ambient r-f noise in the vicinity of the receiver. (Note that the noise considered in an S+N/N measurement is generated by the receiver itself.) However, receiving antenna, transmission line, and connector losses will also affect the value of \( V_\text{a} \).

To determine the J factor, you must either assume a value of ambient noise in the service area of the base or mobile transceiver or measure the noise level with the unit's signal strength meter. If you are going to estimate the noise level, you can use the following generalizations: 1 µV for rural areas; 3 to 10 µV in the suburbs; and 10 to 40 µV for most urban areas.

On the other hand, the transceiver's S meter can be used. Keep the squelch wide open, and note the meter reading on a clear channel. Then check the operations manual of the transceiver, a product test report, or the manu-
facturer, requesting the actual signal strengths in microvolts that correspond to meter readings from S1 through S9.

Once the value of r-f noise has been determined, refer to the graph of Fig. 2. Note that two curves have been plotted. These correspond to receiver sensitivities of 0.3 µV and 1 µV, which are the approximate lower and upper limits for state-of-the-art transceivers. Find the proper value of noise on the horizontal axis, and then determine the value of VA. This value is then inserted in the following formula:

\[ J \text{ factor (dB)} = 20 \log_{10} \left( \frac{V_A}{\text{receiver sensitivity}} \right) \]

**Propagation Losses.** These relate the ERP of the transmitting portion of the link to the fraction of the output recoverable at the receiver. Here, propagation losses over plane (flat) earth were calculated based on a base antenna height of 60 feet (18.3 m) above average ground level and a mobile antenna height of ten feet (3.05 m). One very important assumption here is that the intervening terrain is relatively flat with no high hills, deep valleys, and a few man-made obstructions. Also, additional losses of 4 dB are added to achieve a greater margin of reliability.

In many areas, the terrain is hardly ideal or flat. Accordingly, you can expect to have range decreased or increased, depending on whether the mobile is at one point on top of a steep hill or in a valley, or near the base of a tall building.

There are other factors besides contour that can make the terrain non-ideal. One such factor is ground resistivity. Although the plane earth is described as a flat, perfectly conducting surface, real earth acts as a resistance. It has been found that at frequencies near 30 MHz, vertically polarized signals passing over "good" soil (clay, loam, marsh or swamp) are affected by the contour of the surface and soil resistivity if the antenna heights are less than 30 feet (9.13 m) above average ground level.

Mobile antennas fall into this category, and as a result a decrease in propagation loss of as much as 10 dB can occur. In addition to affecting propagation, earth ground can also influence the impedance of a mobile antenna and thus affect the efficiency figure of the antenna system.

**Range Predictions.** Having determined the J factor, you can now proceed to estimate the range for a given communications link. Referring to the Power Level Diagram in Fig. 1, the "padding" effect of the J factor is readily apparent. In Fig. 2, the influence of the J factor on VA for given noise levels and receiver sensitivities can also be seen. The J factor and propagation losses have been considered in setting up Fig. 3, which relates ERP to distance. To simplify its use, a family of curves was plotted for the two receiver sensitivities (0.3 and 1 µV for 10 dB S+N/N) and for four levels of r-f noise (0.3, 1, 3, and 10 µV).

Suppose that omnidirectional coverage from a base station with an antenna of 60 feet (18.3 m) is desired. Assume that the ERP is four watts or 36 dBm. (This condition occurs when the transceiver r-f power output is four watts—the legal limit—and when antenna gain exactly compensates for connector and transmission line losses.) Further assume that the service area is suburban with a 3-µV noise level, and that the re-
The POLY 88 Microcomputer System

The POLY 88 Microcomputer System brings to the user, in one compact package, the capability of developing programs and hardware as well as enjoying the interaction with computers.

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Fig. 3. Effective radiated power versus distance for two sensitivities and various r-f noise levels.

Receiver sensitivity is 1 μV for 10 dB S+N/N. Here's how the range is predicted.

Locate the 36-dBm line and proceed across until the 3-μV curve is reached. Then read the corresponding distance. In this case, it is five miles (8 km). Of course, you can work backwards and determine how much ERP is required for 5-mile coverage. Proceed down the 5-mile line until the 3-μV curve is reached, and then read the corresponding ERP value (36 dBm or four watts).

Further Comments. Mobile antennas are less efficient than base antennas, so it is obvious that mobile range will be more limited. It will typically be three miles (1.8 km). From Figs. 2 and 3, it can be concluded that, for ambient r-f noise levels above 1 μV (which is usually the case on the Citizens Band), an increase in receiver sensitivity of 333/4%, say, from 1 μV to 0.3 μV for 10 dB S+N/N, reduces the required ERP only 10%. Only in extremely quiet r-f environments (under 0.5 μV), which probably don't exist on the Citizens Band in even the most rural areas, will there be any significant reduction in ERP required for a given distance.

In other words, a sensitivity of 1 μV for 10 dB S+N/N appears to be adequate for most applications. However, whether an S+N/N of 10 dB is sufficient for good intelligibility is altogether a different question. If a more sensitive receiver (0.3 μV for 10 dB S+N/N) is used, providing a better ratio, say, 15 dB at 1 μV, the operator has a definite advantage in terms of audio quality or intelligibility.

Another area for consideration is the relative merit of a beam over an omnidirectional antenna. Unquestionably, a beam will allow you to reduce interference (and thereby improve intelligibility) from stations in other directions than the desired station. But let's limit this discussion to the relative merit in terms of range. The maximum permissible height for an omni is 60 feet (18.3 m) above ground, natural formation, or man-made structure. For a beam, the maximum allowable height is 20 feet (6.1 m). It can be shown that if the antenna height is halved, you will require 6 dB more power to reach the same distance.

Therefore, if you now have or are planning an omnidirectional antenna with unity gain mounted at 60 feet (18.3 m), and want to weigh the advantages of installing a high-gain beam and rotor system, consider this. You must subtract 6 dB from the beam's gain because of its lower height. In terms of the graph of Fig. 3, start at 36 dBm ERP, add the beam's gain, subtract 6 dB, and proceed across the graph until the appropriate r-f noise curve is reached. Then note the predicted range. If the gain of the beam is 6 dB, the range will be the same for the omni and the beam. If gains of 9 dB or more are not available, or if the beam will not be mounted considerably higher than 30 feet (9.15 m) above average ground level, the omnidirectional antenna at 60 feet (18.3 m) above ground level is the better choice.
Digital techniques play a leading role in electronics today. Switching, coding and logic function methods are not difficult to grasp. And equally important, they make it possible to create many interesting electronics circuit designs. In this special supplement, many of these concepts are illustrated, including projects for a digital auto fuel gauge and a shirt-pocket digital stopwatch. In addition, the first article gives many helpful hints on how the electronics hobbyist should go about choosing a microcomputer from the many available today.

How to Select a Hobbyist Microcomputer

BY STEPHEN B. GRAY
Senior Editor

DECIDING which microcomputer to buy is quite a challenge. Not only are there several dozen on the market, but they’re available in a wide range of prices, with a variety of features and peripherals, and with several different MPU’s (microprocessor units), such as the 8080, 6800, 6502, F8 and 6100, among others.

One of the easiest ways to narrow down your choice of a microcomputer is to decide which basic type is best for your own use. To do this requires a breakdown of microcomputer types, as in the following paragraphs.

1. Box With. The best-known type of microcomputer looks very much like a minicomputer: a box with a bunch of switches and lights on the front panel. Two hobby computers of this type are the MITS Altair 8800b and the lmsai 8080. This microcomputer type is the most widely used among hobbyists, with the widest choice of peripherals and memory expansion boards.

2. Box Without. The second type of computer is also a box, but with a bare
minimum of switches and lights. An example is Southwest Technical Products' 6800, which has only two switches, for power and reset. Only the power switch has a light.

There are two main differences between Type 1 and Type 2 computers. First, with a Type 1, you can load short programs and operate the computer manually, reading the results on the LED display. Obviously, you can't do this with a Type 2 machine. The second difference is in loaders. When you turn on any microcomputer, you can't put a program into memory until a bootstrap loader is inserted first. This acts as a set of signs to guide the program to the right places in memory. With most of the Type 1 computers, you have to load the bootstrap instructions by hand, using the front-panel switches. With most of the Type 2 computers, which have stored loaders, all you do is press RESET and the loader is inserted automatically.

However, just because a microcomputer has a full set of switches and lights isn't always a sign that the loader must be inserted by hand. The MITS 680b is a good example of a micro with switches, lights, and a bootstrap loader in permanent memory which doesn't "drop out" when the power is turned off.

Note too, that not all micros have the same internal expansion capability. This sometimes accounts for differences in size and, naturally, influences price too.

3. PC Board. The third main type of microcomputer consists of a printed-circuit board without input or output. These were first introduced for use in commercial products, or for engineering evaluation, and many are still sold for such purposes. Several recent ones are being sold mainly to hobbyists. The best-known of Type 3 are the Jolt and SC/MP.

All the computers described up to this point have neither separate input nor output, and unless you enjoy loading programs via front-panel switches (if your microcomputer has them) and reading out the program results from the front-panel lights, you'll need some more hardware. This means a keyboard for putting data into the computer, and a more sophisticated readout for checking that the program is correct and for reading the results. There is already a wide variety of keyboard terminals available, and the most common readout today is a TV screen.

4. All-On-One Board. For those who want a complete computer with less sophisticated inputs and outputs than teletypewriter and video monitor, there are many everything-on-one-board microcomputers. This type includes a small keyboard and some form of readout. The readout is sometimes individual LED's, but is usually segmented alphanumeric display. The KIM-1 is the best known of these, although several others are coming up fast. Two units come with a case, the Infinite UC 1800 and the Hamilton/Avnet Pacer. They have built-in power supplies, whereas most of the others don't.

Just about the least expensive Type 4 microcomputer for the hobbyist who wants to learn the basics is the Elf, featured as a construction project in the August and September 1976 issues of POPULAR ELECTRONICS. This hardware and software trainer, with RCA COSMAC MPU, toggle-switch input, hex LED display, 256 bytes of RAM, four input lines, and a latched output line, costs about $80 to build. Memory is expandable at minimum cost.

Nearly all the computers of this type are on a single pc board; two exceptions are the Mike 3 and Mike 8, from Martin Research. Each is a stack of several boards, separated by spacers, with the keyboard and display on the console board at the top, CPU on a second board, memory on a third, etc. This modular approach permits using different CPU boards, either for the 8080A MPU, Z-80, or 8088.

The keyboard almost always has 16 hex keys for entering programs into machine language plus various control keys. These boards are popular among people who want to learn what computers are all about, at minimum cost. For those who want to go further, more memory can be added, as can be peripherals such as a full keyboard and/or a printer, to start with.

5. All-In-One Box. Another type of computer that doesn't require buying a keyboard or TV set has a built-in keyboard and CRT, such as the various models of the Sphere. Although this type of computer is expensive, it does have everything you'd need for almost any type of programming. However, you are locked into the integrated input/output system much as you are for an FM tuner when it's built into an FM receiver. A printed output can be added on, as it can to almost any hobby computer. The cost of a simple printer has decreased substantially. For example, Southwest Technical offers one in kit form for $250, and Electronic Products Associates has an assembled printer for $450.
Among the computers of this type, the Intecolor 8001, with an 8-color CRT, is unique. This adds an extra dimension to graphics and to just about anything you want to put on the screen.

**Intelligent Terminals.** A step up from most hobby terminals, which can be used only as input/output devices, is the intelligent terminal. With one of these, you can write, edit and store programs for transmission to a larger computer directly, or to a time-sharing computer over a telephone line (using a modem device).

Any hobby computer with a keyboard, RS-232 or 20-mA current-loop interface, and enough memory can be used as an intelligent terminal, of course. All you need are the right programs. The SOL terminal from Processor Technology provides these programs in the form of pre-programmed PROM's, called "Personality Modules," at three levels.

One module allows simple terminal operations. A second-level module makes SOL an editing terminal. The top-level module transforms it into an intelligent terminal as well as a stand-alone computer.

**Programming.** An important factor in choosing a hobby micro is to decide at which level you want to program. How much memory your computer has will determine its price and also what kind of programming language you can use.

With only a few hundred bytes of memory, you'll usually be restricted to programming in machine language, or to short programs in assembly language. Some people enjoy working in machine language, down at the bit level, using instructions such as 00111010, which is the 8080 code for "load the accumulator with the contents of the specified memory address."

But working with machine language may be boring to all but real "computer freaks." Also, you can easily make mistakes that aren't at all quickly apparent when working with only zeroes and ones. With a little more memory, though, you can program in assembly language. In order to do this, you must load an assembler into your computer's memory. This is a program that translates the assembly-language instructions, such as LDA, into machine language; in this case, 00111010.

In assembly language, you use mnemonic names for program instructions; these are easy-to-remember abbreviations, such as LDA for "load accumulator" and MOV for "move the contents of the accumulator to register B." To add one number to another in 8080 assembly language takes eleven steps, including five mnemonics and three pairs of address codes. Address codes are in pairs because addresses take up two bytes; that is, groups of 8 bits. (An 8080 machine can address $2^{16}$ memory locations.)

The program for adding two numbers consists of these steps: load the accumulator with the number to be found at, say, memory address 128. Then take what's in the accumulator and move it to register B. Next, load the accumulator with the number to be found at address 129, and add the contents of register B to what's in the accumulator. Take the sum that's now in the accumulator, and store it at address 130. If you've previously stored numbers at addresses 128 and 129, this program will add them together and put the sum in 130. Actually, you can use any memory addresses you want, instead of 128, 129 and 130, as long as you don't select an address that's higher than the maximum address in your system.

If you'd rather write programs with mnemonics such as LDA, MOV and STA, then you need, as previously noted, an assembler program, which is also stored in memory along with your own program. For example, the MITS Altair 8800b assembler takes up 5500 bytes of memory, so if you're going to be writing programs of any real length, you'll need at least 8k bytes of memory.

But suppose you're not really interested in programming for programming's sake, but rather in what the program will do for you. If so, then you might prefer BASIC, a high-level language that will do in a single instruction, LET C = A + B, what requires eleven assembly-language instructions to do. That single BASIC instruction will store the sum of A and B in memory location C, which is determined by the BASIC interpreter all by itself, thus taking care of much housekeeping. Should you want to show the answer on your TV screen, or print it out, simply write PRINT C. Or you can combine both steps by writing a single BASIC instruction, PRINT A+B.

Just about all high-level-language programs written for hobby computers are in BASIC (there are several varieties of BASIC, each with minor differences). You can get several BASIC interpreters for some computers, requiring 4k, 8k or 12k bytes of memory. The 8k and 12k versions offer more features than the 4k BASIC. The 8k BASIC interpreter, which turns LET C = A + B into machine language, takes up 5.7k bytes of memory in...
printers, disk drives, graphics devices, memory, and for the Altair bus structure, including the Altair 8800, Processor Technology's 8080, of which many hobbyists will be satisfied with 8k or 16k of memory, many hobby computers can be expanded to 65k.

**Hobbyist Bus.** The MITS Altair 8800 microcomputer was the first to be sold in large volume, and set a bus standard that some other micro manufacturers have followed. This standard is based on the 100-pin bus, to which all the Altair 8800 boards are connected in common. Consequently, many other manufacturers of CPU boards, memory boards, and peripheral boards have tailored their designs so they will plug into the Altair 8800, and also into the busses of several other computers that use the Altair bus structure, including the Imsai 8080, the PolyMorphic Poly-88 and Processor Technology's SOL. As a result, there are more boards for CPU and memory, and for peripherals such as printers, disk drives, graphics devices, cassette memory, etc., available to owners of computers using this bus.

There are other bus lines, of course. For example, the Southwest Technical 6800 computer utilizes a different bus, with a growing number of boards for it.

**Price.** Of the five basic types of hobby computers, the cheapest is the board-only, with which you need a power supply, an input, and an output. The complete-computer-on-a-board follows, and usually requires the addition of only a power supply. Next is a box-type computer with which you'll need input and output peripherals. With a box-with-CRT type, which gives you the most equipment at a minimum cost, on a one-shot basis, you already have the peripherals, unless you also want a printed output.

Let's look at what it costs to buy a microcomputer with enough memory for the various levels of programming, taking into consideration several of the best-selling micros. The basic computer, without memory can range from $212 to $840 in kit form, $500 to $1100 assembled. These wide ranges are due to some of the computers being full-featured models, others being "barebones" types. Not many 1k memory boards are being offered any more; they were used to be about $120 kit, $160 assembled. Using just a basic 8-bit computer and 1k of memory, you could write programs containing up to about 500 instructions, if you don't mind flipping switches for hours and hours.

Stepping up to assembly language, you'll need two 4k memory boards, each of which run from $125 to $167 kit, $279 to $325 assembled. If you buy the Altair 8800b and the two 4k boards at the same time, you get a "software package" for $75, which includes the assembler and several other programs. The Southwest Technical 6800 editor/assembly package is $14.95.

You'll need some sort of input/output, of course. To connect your computer to your TV set requires an interface that can cost from $40 to $148 kit, $60 to $180 assembled. For keyboard input, you may be able to use the same interface if it can handle two serial I/O devices. You'll also need a keyboard termi-
nal, such as a Model 33 Teletype. This, however, is expensive, costing between $769 and $1500 new, depending on what features you select. With an ASR33, you can enter a program from either the keyboard or punched paper tape. Or you could get a hobby unit, such as Southwest Technical’s CT-1024 terminal. With this, the program is entered via the keyboard. The CT-1024 kit, less cabinet and power supply, is $175; there are various options available.

Programs can be entered into the computer much faster by using a cassette. To enter the 8k BASIC interpreter into the Altair 8800b takes 12 minutes from paper tape, 4 minutes from cassette. Typical cassette interfaces range from $35 to $138 kit, $65 to $195 wired. You can buy a 4k BASIC interpreter for $4 to $60 depending on manufacturer. The 8k BASIC interpreter ranges in price from $8 to $75.

**Which to Pick?** A major question to answer is: will you be satisfied with programming in assembly language, or do you want to program in BASIC? If you’re sure you’ll be happy with assembly language, you have two types of computers to choose from. The least expensive is the all-on-one-board computer, Type 4, such as the KIM-1 or 6502 Familiarizer, where the only extra to buy is a power supply except for a couple that have it built in. The other choice is Type 3, the pc board with no I/O, such as the SC/MP. To use one of these, you’ll need a power supply, keyboard, and some sort of output, either a printer or a TV receiver or video monitor.

If you’re more interested in programs than in computers, and want BASIC, you have three choices. The Type 1 computers, including the Altair 8800b and Imsai 8080, require interfaces and peripherals for input and output, as do the Type 2 machines, such as Southwest 6800 and Poly-88. You can add these at any time. You’ll need no additional hardware if you buy a Type 5 computer, which has both CRT and keyboard.

Summarizing, you must decide what you plan to do with the microcomputer now and in the future, as well as what your bankbook can tolerate.

Are you determined to be an experimenter, more interested in hardware and/or learning the fundamentals of computers? If so, a Type 3 or 4 unit might be your best bet.

If you’re more interested in “talking” to your computer and getting results easier and faster, but wish to add peripherals of your own choice at some future time, a Type 1 or 2 could be the way to go.

Should you want an all-in-one type of micro, with peripherals already incorporated, then perhaps a Type 5 should be considered.

There are other factors to weigh, of course, including language availability (do they have assembler or BASIC?), reputation of the computer manufacturer (how good are their computers and how long will they stay in business?), whether or not you plan to join a computer club for sharing ideas and trading information on software, and so on.

**More Help.** In addition to asking a manufacturer to send information on his microcomputer for performance details (see address listing), there are many...
other ways to help you decide which to buy. There are over 90 computer clubs, many with membership in the hundreds, where you can talk with people who are using various hobby computers. Dozens of computer stores around the country will show you how their products work, and answer your questions in detail. Magazines and club newsletters devoted to the computer hobbyist are also excellent sources of information. And if you get to a hobby-computer convention, such as the ones that were held in New Jersey (Trenton and Atlantic City), you can check out dozens of computers and peripherals in a single day, as well as listen to talks about hardware, software and applications.

Whatever choice you make, you'll find yourself in a new, exciting field that will add to your knowledge and fun.

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**Digit Probe**

**COMPACT, EASY-TO-USE LOGIC PROBE FITS YOUR FINGER.**

Ever see a logic probe that was so compact that it could fit over the tip of your finger? Although there is such a device (see photo), don't look for it commercially—you have to make it yourself. We call this ultra-compact logic gem the "Digit Probe," mainly because in use it's like an extension of your index finger.

Used in this manner, the Digit Probe makes it easy to trace pulses around crowded IC assemblies and PC board foil traces that all look alike.

As shown in the schematic diagrams, the circuits for the Digit Probe are basic.
Use either a LED readout or audible signal.

hi/lo indicators. Circuit A provides a visual indication of conditions existing in the circuit under test via light-emitting diode LED1. Circuit B provides an audible indication via the Mallory Sonalert®. Circuit A is convenient for tracing pulses in an operating system, while circuit B is more convenient when you have to look away from the system under test to make equipment adjustments and can't monitor a LED.

All components (except the Sonalert) in both circuits should be kept as small as possible so that the assembled circuit can be mounted on an ordinary plastic guitar/banjo pick. Use a miniature general-purpose npn transistor for Q1 and 1/4-watt resistors for R1 and R2. Any size of color discrete light emitting diode can be used for LED1.

**Construction.** The Digit Probe circuit mounts directly on the outer surface of the guitar/banjo and is held in place with quick-setting clear epoxy cement. Assembly is very easy and non-critical, but you will have to take care to keep the physical layout as compact as possible.

Start construction by trimming both leads of the two resistors to 1/4" (6.4 mm) and bending the lead stubs into hooks. Pre-tin the head of a straight pin with solder and solder the head of the pin to one lead of R1. Solder the other lead of R1 to the base lead of Q1. Solder the cathode lead of LED1 to the collector lead of Q1 and the anode lead to one end of R2. Solder separate 36" (about 1-m) lengths of small-diameter stranded hookup wire to the free end of R2 and the emitter lead of Q1, using red and black insulation, respectively. Terminate the free ends of the hookup wire with miniature alligator clips. Finally, loosely twist together the hookup wires.

If you are planning to make the audible version of the Digit Probe, eliminate R2 and LED1. Wire the circuit as described above, locating the Sonalert about 10" (25.4 cm) from the alligator clip end of the twisted-pair power cable.

Liberally coat the area of the guitar/banjo pick on which the Digit Probe circuit is to mount with epoxy cement. Press the circuit into the cement, orienting it as shown in the photo. Slip over the projecting straight pin a length of plastic sleelwing, leaving about 1/4" to 3/16" [3.2 to 4.8 mm] near the point of the pin exposed. Coat the circuit with more epoxy cement to assure a firm mechanical anchor. Then allow the cement to cure for at least 24 hours before using the probe.

**In Use.** Slip the Digit Probe over the index finger of the hand you would normally use to hold a probe during tests. Clip the alligator clips on the black and red twisted-pair hookup wire to the + and − supply lines of the circuit under test. Then, using the probe is as simple as pointing your finger.

---

**Build a Miniature Digital Stopwatch**

**Times from 1/100 s to 59 min, 59.99 s in split or Taylor modes.**

There have been many sports timer construction articles, but never one for a project as small as this. Although this six-digit LED readout timer can measure time intervals from one 1/100 of a second to 59 minutes, 59.99 seconds, it can be held easily in the palm of the hand and stored in a shirt or jacket pocket. Timing can be in either the split-cumulative mode (display frozen when START-STOP pushbutton is depressed and total elapsed time with each successive switch operation) or the Taylor-sequential mode (time interval displayed between successive switch operations).

The single IC used in this timer has a built-in crystal-controlled oscillator, a low-battery indicator (decimal points come on), and internal digit and segment drivers. The output transistors can handle up to 20 mA per segment and do...
Note that the pattern shown in the text on the top left page is not present in the image. The text continues as follows:

**PARTS LIST**

B1—Three A/AA cells in series
C1—840-pF subminiature trimmer capacitor
(optional, see text)
D1—Common-cathode six-digit calculator
readout stick on 2-in. board
IC1—7205 timer (Intersil)
S1, S2—Spdt subminiature slide switch
S3, S4—Spst miniature pushbutton switch,
normally open
XTAL—3.2768-MHz crystal

Misc.—Plastic case and cover (Ponona 2104
or similar), 24-pin IC socket (optional),
Molex pins (optional), press-on type or fine
brush and white paint, hook-up wire.

Note—The following are available from AD-
AGE, Box 1004, New Brunswick, NJ
08903: Kit K1, consisting of IC1 and
XTAL, for $21.95; kit K2, consisting of all
parts, including drilled case, except batter-
ies, for $39.95. Include $1.50 for shipping.
New Jersey residents, add 5% sales tax.

*Fig. 1. Complete timing circuit is contained in 7205 IC.*

not require external current-limiting re-
sistors. The total average current de-
mand is less than 40 mA so that three
AAA cells or 3-N rechargeables can be
used as the power source for up to 12
hours. When the battery voltage drops
below 2.6, the indicator comes on. Gen-
erally, the timer can still be used for
about 15 minutes after this occurs. The
simplicity of the circuit can be seen in
Fig. 1. A complete description of the cir-
cuit’s operation can be found in the Au-
gust, 1976, issue of POPULAR ELECT-
RONICS, p. 73.

**Construction.** Although any type of
construction can be used, to make the
sports timer as small as possible, the foil
pattern shown in Fig. 2 should be used.
Note that components are mounted on
both sides of the board as shown in Fig.
3. The IC is mounted on the blank side
of the board, preferably using a socket
or Molex pins, or it can be soldered in
place, depending on the cells used.

The LED display is a conventional 2-
inch calculator 6-to-9-digit stick with
flat red lens. In the prototype, an
NSN-66A (National Semiconductor) was
used, but a brighter readout can be ob-
tained with an NSA-1188. Other types of
readouts can be used if the appropriate
jumpers are made from the display pads
on the board. The NSN-66A can be
mounted on the foil side of the board as
shown in Figs. 2 and 3. If the bottom sur-
face of the display stick has exposed
bare copper leads, cover it with a layer
of masking tape to avoid shorting to the
PC foil pattern. Mount the display and
switches so that the tops of the switch
bodies are flush with the upper surface
of the display.

All wire connections to the board are
made through the blank side of the
board using slender flexible insulated
wire. The batteries are wired in series
and formed into a small bundle.

For the prototype a small plastic case
was used for the timer. It measured 2'/
W x 11/2"H x 11/2"D, with a fitted cover.
Drill holes for S3 and S4 on one side of
the case with sufficient spacing for the
crystal between them. With the switches
mounted on the case and connected to
the proper points, solder the power
leads to the AAA cells. Then fit the cells
into the bottom of the case and put the
PC board in the case with the display be-
tween the two switches. The edges of
the PC board (and possibly the display)
may have to be trimmed to make a pro-
per fit. Insert the PC board until the upper
surface of the display is just slightly
below the rim of the case. The operating
handles of S1 and S2 should stick above
the case rim.

Once the board has been properly po-
tioned, determine the locations of the
readouts and S1 and S2 and cut the
necessary slots in the cover. Install the
cover and identify all the switches with
a white dry-transfer lettering kit. Using
the same careful techniques, apply a
decimal point on the upper surface of
the display just to the left of the two dig-
ts on the right end. Then apply a colon
to the left of the second pair of digits.

If desired, an spst switch can be add-
between IC1 pin 19 and the negative
side of the battery. Operating this switch
will permit the display to show the run-
ning clock at any time.

*Fig. 2. Etching and drilling and component installation guides.*
Testing. Place S1 (ON-OFF) in the ON position and note that the display is .00. Depressing S3 (START-STOP) should cause the display to start counting in hundredths of a second. The IC has built-in automatic power-on reset and leading zero blanking so that the other digits will not be displayed until they are needed. Depressing S3 again should cause the display to stop and indicate some elapsed time.

Using the Timer. The START-STOP pushbutton is used as in a mechanical stopwatch. The RESET button zeros the counter.

In the SPLIT mode, operate the START-STOP button at the beginning of an event; then once more when the desired interval (half or full lap, etc.) is finished. The display will indicate the elapsed time. However, the counter is still operating, so depressing the START-STOP switch again causes the display to indicate the total elapsed time since the start of the event. If desired, operate the RESET pushbutton to stop the counter and return it to zero.

The TAYLOR mode automatically resets the counter to zero with each operation of the START-STOP switch, and the display shows the time interval between depressions. This is a useful function when you want to time each lap in a race without resetting the timer to zero.

Digital Fuel Gauge

BY GREGORY BAXES

Replace your old analog meter with a bright LED display indicating percentage of fuel remaining.

About the Circuit. The block diagram of the basic gas gauge circuit is shown in Fig. 1. Note that although the system is rigged to display three digits (to represent from empty, or 0, to full, or 100%), the units digit is a dummy seven-segment display that is always powered to show a 0; it is not driven by the circuit's logic as are the 10's and 100's digits. Since only 11 increments are actually displayed by the system, only 1½ di-

DECEMBER 1976
gifs are required. Hence, DIS1 is either blanked or displays a 1.

Integrated circuit IC2 serves as the counter generator for the system, operating at about 1 Hz. It drives a conventional decade-counting system consisting of counter IC3, latch IC4, decoder/driver IC5, and display DIS2. Under normal conditions, this counter simply cycles, with the clock pulses, from 0 to 9 and then generates an “overflow” pulse. In this system, however, the BCD outputs from IC3 are also coupled to BCD-to-decimal decoder IC7. The 0-through-9 outputs from IC7 and R19 through R29 generate a voltage that is proportional to the count at any instant. This voltage and a second voltage that is determined by the amount of fuel left in the gas tank are summed in voltage comparator IC8. The output of IC8 is either high or low, depending on the differential between the two input voltages.

The values of weighting resistors R19 through R29 are selected to provide 10% changes in the display count. If, for example, the tank is 50% full, when the IC3 through IC7 circuit “sees” a 5, IC8’s output changes state to activate the IC6 control circuit. Dual monostable multivibrator IC6 generates a strobe pulse to cause a 5 to be displayed by DIS2. Shortly after this, IC6 generates a reset pulse to allow the circuit to cycle again. In our example, the display system will indicate 50%.

The only time the system displays 100% is when the gas tank is full. At this time, IC3 counts through 9 and goes to 0, generating an overflow, or “carry,” signal. The carry signal passes to the overflow logic and is used to turn on the 1 in DIS1 when the strobe pulse appears.

The reset pulse will return the system back to 0 so that the cycle can repeat. Thus, the display is updated every second or so, depending on the rate of the clock. The display will not flicker, however, because the latch in the used 1½ digits will maintain power to the digits between strobe pulses.

Although, with slightly more logic, the gas gauge could have been designed to provide a full 100-step resolution, an 11-step resolution was selected for practical reasons. A greater than 10% resolution would have resulted in an annoying fluctuation of the numerals displayed by DIS3 as the motion of the vehicle caused the level of the gas in the tank to rise and fall.

The complete schematic diagram of the gas gauge is shown in Fig. 2.

**Construction.** You can use either a printed circuit board of your own design or perforated board to assemble the gas gauge. In either case, it is recommended that you use sockets for all IC’s to obviate the possibility of heat damage to these components during soldering. It is also suggested that you use two boards—one for the display and a second for the rest of the circuit. Use colored hookup wire for the interconnections between the boards.

There are three external connections to be made for the gas gauge: +12 volts to the vehicle’s electrical system, vehicle ground, and the “hot” side of the fuel sensor. This is most practically accomplished with the aid of a three-lug screw-type terminal strip mounted on the rear of the case in which the circuit is housed. Additionally, if you prefer, voltage regulator IC9 can also be mounted on the case, provided the case is metal, for heat-sinking purposes.

Note in Fig. 2 that the values of resistors R19 through R29 are not specified. These resistor values must be determined for the specific fuel sensor with which the gas gauge is used. To determine the values of these resistors you must first locate the “hot” lead of the fuel sensor going to the meter on the vehicle’s dashboard. Break this lead so that you can measure the sensor’s resistance between the lead and ground.

There are two ways to obtain a relatively accurate list of fuel-sensor measurements. First, you can drive your car into a gas station with your car’s meter-type fuel gauge still connected and registering empty. (Do not completely empty your tank of gas. If you assume an empty tank when the gauge reads empty, you will have a margin of safety when your tank runs low.) Have the attendant fill your tank to full and keep a record of the amount of fuel required to fill the tank. Divide the number by 10. You now know gallons at each 10% point. Then the next time you go for a refill, disconnect the “hot” sensor lead from the meter and have the attendant fill your tank in the previously noted 10% increments while measuring and logging the sensor’s resistance at each 10% point.

The second way is to estimate the 10% marks on your car’s meter-type fuel gauge, marking these points on the meter’s faceplate with a grease pencil. Fill your tank to full, install a switch in the sensor’s “hot” lead, and (with the switch closed) drive around until the meter’s pointer registers 90%. Pull over, open the switch, and measure the sensor’s resistance. Repeat this procedure until the meter registers empty, keeping a log of your measurements. Again, do not drive your car until the tank is completely empty. Remove the switch from the sensor’s hot lead.

The resistance measured for an empty tank is the value of R19 at pin 1 of IC7.
while the resistance measured for a full tank is the value of R29 at pin 11 of IC7. All other resistances are the values of R18 through R28 and fit into the circuit in consecutive order between pin 2 and pin 10 of IC7. (Note that pin 8 of IC7 goes to ground; skip this pin when installing the resistors.) You can use miniature p-type trimmer potentiometers for R19 through R29.

If your tank's fuel sensor resistance increases as the fuel decreases, connect the inputs of IC8 to pins A and A' as shown with a jumper. If the tank sensor's resistance decreases as the fuel level decreases, connect the inputs of IC8 to B and B'.

Once the digital fuel gauge project is
An A/D Temperature Converter

Use your frequency counter to measure temperature to 0.1°C resolution.

This project is a low-cost analog-to-digital converter which allows you to make accurate temperature measurements with a frequency counter. Its range is 0° to 100°C, with a resolution of 0.1°C and an accuracy of 0.5°C.

The circuit uses an inexpensive silicon signal diode as a temperature sensor, a dual operational amplifier IC, a unijunction transistor, and a handful of resistors and capacitors. Parts cost is less than $10. No warm-up period is required, and the project is easily calibrated. Several sensors can be switched into the circuit to provide temperature readings at various locations.

About the Circuit. The converter's schematic diagram is shown in Fig. 1. When power is applied to the circuit, zener diode D1 and resistor R6 set up a reference 1-mA current through temperature sensor D2, a 1N914 silicon signal diode. When D2 conducts, it exhibits a forward voltage drop of approximately 0.7 volt at room temperature (25°C). But this voltage drop is temperature dependent. For each 1°C increase in ambient temperature, the forward voltage drop decreases 2.2 millivolts. Conversely, for each 1°C decrease, the voltage drop increases 2.2 millivolts. This voltage signal is applied to the noninverting input of IC1A, an op amp integrator.

When the voltage across integrating capacitor C1 reaches a certain value, unijunction transistor Q1 turns on, discharging C1. Potentiometers R2 and R5 set the minimum and maximum charge/discharge rates, respectively. Each time C1 is discharged, an output pulse is generated. This pulse is coupled to the noninverting input of IC1B, an op amp buffer whose gain has been selected to produce a pseudo-square-wave output. The output signal, appearing at J2, is then coupled to the frequency counter, input by a short jumper of coaxial cable.

The conversion ratio of the A/D converter is 10 Hz per degree C when properly calibrated. That is, when the measured temperature is 25.4°C, the counter will indicate a frequency of 254 Hz.

A bipolar (±9-volt) power supply is required. A line-powered dc source can be used, but two 9-volt transistor batteries connected in series are also suitable.

Construction. Circuit layout is not critical, so printed circuit or perforated board can be used. Etching and drilling and component layout guides for a suitable pc board are shown in Fig. 2. Trimmer potentiometers R2 and R5 can be fashioned from vertical mounting types. Simply bend the three legs on each so the controls can be mounted flat against the circuit board. Be sure to observe proper polarity and basing on the IC, and other semiconductors. The use of an IC socket or Molex Soldercons is recommended.

Temperature sensor D2 should be connected to a length of shielded cable terminated with a phono plug. Be sure to connect the diode so that its cathode is grounded. Otherwise, false readings will be obtained. Also, it is recommended that you dip the diode in clear epoxy cement after it has been soldered. Allow the epoxy to cure for 24 hours before using the sensor. This will give a protective coating around the diode.

Connection to the frequency counter should also be made with a jumper of shielded cable terminated with proper plugs. You may want to use the same jack for J1 as is on the counter, such as a BNC jack. Alternatively, a phono jack can be used.
**PARTS LIST**

B1, B2—9-volt transistor batteries
C1—0.0047-µF silver mica or polystyrene capacitor
C2—620-pF silver mica or polystyrene capacitor
D1—6.2-volt, 1-watt zener diode (1N821 or equivalent)
D2—IN914 silicon signal diode
IC1—747A dual operational amplifier

J1, J2—phono jacks
PL1—phono plug
Q1—2N2646 or Radio Shack 276-111 uni-junction transistor

The following resistors are 10%, 1/4-watt unless otherwise specified:

- R1 = 5600 ohms
- R3 = 470 ohms
- R4 = 1000 ohms
- R6 = 6200 ohms, 5% tolerance
- R7 = 1.2 megohms
- R8 = 1000 ohms
- R9 = 10,000 ohms

R2—1000-ohm printed circuit trimmer potentiometer
R5—10,000-ohm printed circuit trimmer potentiometer
S1—Dpdt toggle switch
Misc.—Battery clips, suitable enclosure, hookup wire, shielded cable, IC socket or Molex Soldercons, machine hardware, solder, etc.

**Fig. 1.** In converter circuit, signal diode D2 acts as a linear temperature sensor.

**Fig. 2.** Actual-size etching and drilling guide at right. Parts placement guide above.

**Calibration.** Once the circuit has been built and is operating, it should be calibrated at both extremes of its range. With the converter connected to the frequency counter, insert the temperature sensor into a bath of boiling water. Adjust R5 so that the frequency counter reads 1000 Hz (100°C). Then insert the sensor in a container of crushed ice and adjust R2 for a 0-Hz (0°C) reading. Because there is a degree of interaction between the two controls, the procedure must be repeated several times until proper readings are obtained at both temperature extremes.

**Operation.** Once the project has been calibrated, it will exhibit excellent linearity over its entire temperature range. A rotary switch can be added if remote sensing at several locations is desired. The shortest possible length of shielded cable should be used with each diode. A voltage drop in the wire of even a few millivolts (that has not been compensated for in calibrating the project) will affect the converter's accuracy. If the diode sensor is damaged at temperature extremes, simply replace it with another. The cost of signal diodes is low enough for you to keep many spares on hand.

DECEMBER 1976
Propagation Delay

The Logic Gremlin

Where those "glitches" come from and what to do about them.

LOGIC circuits usually behave very logically. For example, trigger a flip-flop and its outputs change state; or drive an inverter and the signal flips over. What could be simpler?

Unfortunately, "glitches" (undesired signals) sometimes get into a circuit and cause it to misbehave. When you look into the problem, you find that all the digital logic IC's are good; the clock is fine and healthy; the power supply is clean and well-regulated; and the wired interconnections are all OK. But the circuit still produces erratic results!

If you are blessed with a high-quality oscilloscope, it is possible to spot mysterious glitches wandering around the circuit, appearing like that shown in Fig. 1.

1. If this signal is applied to a logic circuit, the circuit will trigger on the glitch as well as on the leading edge of the real signal. This produces an erratic result. In this article, we will discuss the sources of such glitches and how to eliminate them, if possible.

Basic Element. Let's begin by considering the simplest logic element—the basic inverter. Although it seems that the input and output of an inverter occur in step with each other, this is not the case. These devices require a finite amount of time to respond to a signal input. This "propagation delay" is shown in Fig. 2. Specification sheets for the logic device give the amount of delay to be expected. Interestingly, propagation delay is not related to waveform rise and fall time and is different for positive-going and negative-going waveforms. To further complicate matters, many TTL specifications sheets list both minimum and maximum delay times, with both specified for a standard resistive and capacitive load. Any extra capacitance in the load will simply produce more delay.

For example, if two TTL devices such as the 7400 quad 2-input NAND gate and the 7404 hex inverter are combined in a circuit that depends on propagation delay (sometimes we can make the glitch work for us), we can observe the effect of typical and maximum delay times. The circuit, a propagation delay one-shot, is shown in Fig. 3 with its as-

Fig. 1. Retouched photo of glitch.

Fig. 2. Inverter output delay.

Fig. 3. Making use of the glitch.
associated waveforms. The positive-going edge (A) causes the output to fall one delay time later (B). At about the same time the output at (C) falls. One more delay later, output (D) rises. Finally three delays after input (A), output (E) drives output (B) high. The solid lines show an ideal situation while the dashed lines show how propagation delay affects the width of the output pulse. Note that the output pulse width depends on the combined propagation delays of the devices used.

The question then is: which delay figures should be used? The answer is: the worst-case figures. That is simple enough, but which is the worst case? The answer to that depends on the application. The designer must decide what effect a slow or fast (responding) device will have on each part of the circuit under consideration.

Predicting Propagation Delays. Here is one method that can be used to predict whether propagation delays will cause an unwanted glitch. Two divide-by-two circuits are shown in Fig. 4A. In the circuit on the left, a NAND gate is operated by a flip-flop. In the other circuit, the gate is a NOR. Theoretically the output waveforms of the two circuits would be similar and would look like those in Fig. 4B. However, Fig. 4C shows the actual output as viewed on a scope, except that AND and OR gates were used and the top waveform was inverted from that shown in the NAND portion of Fig. 4B. Now, where did that glitch come from?

To answer this question, we will redraw Fig. 4B using a time scale of 50 nanoseconds per division and take propagation delay into account. Fig. 5A is the result. Note that the glitch is produced by the overlap between the clock and the Q output caused by the propagation delay in the flip-flop. In the case illustrated, it was assumed that the flip-flop had maximum delay and the gates were typical devices—which makes the largest glitch. Fig. 5A does not look exactly like Fig. 4B because the latter was drawn as if the waveform transitions were instantaneous, which they are not. The effects provided by rise and fall times are shown in Fig. 5B.

So far we have considered only simple circuits. Clearly, by choosing the OR gate in Fig. 4A, we avoid the glitches. Now, suppose the design requires a source of timing signals derived from a counter. In the circuit in Fig. 6A, a 74197 counter drives a 74154 decoder to produce the waveforms shown in Fig. 6B. The circuit produces 16 sequential timing pulse outputs, but only five are shown in Fig. 6B. So far, so good. Unfortunately, if you look at the output on a scope, the waveform in Fig. 7A is the result. This is not a pretty picture! What went wrong?

The 74197 is a ripple counter. This means that the input clock toggles the first flip-flop, which in turn toggles the second flip-flop, etc. Eventually, the signal propagates to the output. The spec sheet for this device indicates a maximum of 60 ns delay, with a minimum of 10 ns for each stage. Next, in the 74154, the inputs are buffered by an inverter and then inverted again as necessary for the final decoding. The interlocking arrangement of inverters and gates produces differential delays and thus permits the occurrence of glitches—even if the decoder inputs are synchronized. In this case, the solution is to feed a narrow clock pulse to the enable inputs of the 74154, then invert the clock to drive the 74197 counter. This “de-glitcher” is shown by the dotted lines in Fig. 6A. If the clock pulse is wider than the counter delay, the output signals become as clean as those shown in Fig. 7B.

Solutions. We can now summarize the points covered and learn a little more about de-glitching:

1. Glitches are caused by unbalanced propagation delays in the signal path. In theory, the glitch of Fig. 5 could be eliminated by adding a delay in the circuit as shown in Fig. 8. This would require that both inverters and flip-flop have “typical” delay specifications.

2. In general, decoding with OR/NOR

![Fig. 4. Circuits in (A) should produce waveforms at (B). But (C) shows a glitch.](image)

![Fig. 5. Expansion of Fig. 4B shows propagation delay.](image)
gates, as in Fig. 4A, eliminates glitches.

3. Some logic devices incorporate enable inputs, which, if properly used, can eliminate glitches.

4. Some functions can be performed differently, such as by using synchronous counters like the 74193/74163 instead of ripple counters like the 7490/74197.

5. Though some logic families such as CMOS have slow rise times and slow operation (which should eliminate glitches), remember that any logic family will respond to glitches produced by that logic family.

6. In many cases, glitches can be eliminated by flip-flop sampling. If you have a glitched output that comes from a "black box" that can't be de-glitched by simple methods, use the circuit shown in Fig. 9A. The black-box output is fed to a D flip-flop that is clocked by the system clock. Propagation delay of the black box causes the glitches to fall between the clock pulses, but the real signal is available at the correct times. Note in the Fig. 9B that the flip-flop output is free of glitches but has been delayed one clock period plus the propagation delay of the flip-flop. If there are critical timing path considerations in the circuit, then it may be necessary to make some delay adjustment in one of the other "downstream" circuits.

7. An RC delay can be used to combat narrow glitches using the technique shown in Fig. 10A. Timing waveforms are shown in Fig. 10C. By proper selection of the RC time constant, the delay across the RC network is longer than the glitch time and the glitch disappears. For extra long glitches, it may even be necessary to use two RC networks separated by a logic gate as shown in Fig. 10B.

The RC de-glitching method is just barely acceptable for TTL logic for two reasons. The first is that since the TTL inputs require 1.6 mA drive, the resistor is limited to about 180 ohms. This requires the use of fairly large-valued capacitors—on the order of 1000 pF. Even so, the 180-ohm resistor reduces the noise immunity of the input it feeds. The second reason is that the large-valued capacitors require large drive currents from the TTL. Since CMOS logic has very high input impedance, the RC delay is very effective as a CMOS de-glitching method.

8. One particular type of TTL logic that will tolerate large values of RC time constants for de-glitching is the TTL Schmitt trigger. Figure 11 shows circuits and waveforms using the 7414 (hex Schmitt) and 74132 (quad 2-input Schmitt) for this purpose. It is still necessary to limit the resistor value to about 330 ohms using these devices. The CD4093 is a CMOS quad 2-input Schmitt trigger device that is very effective for de-glitching and delay using resistor values up to about 100,000 ohms.

9. A CMOS buffer (CD4010, CD4050) can be used for de-glitching, delay, and even switch de-bouncing with the circuit shown in Fig. 12. Feedback resistor R2 determines the hysteresis of the circuit (the Schmitt trigger action) while the time constant of R1/C sets the amount of delay.

Fig. 6. Dotted circuit in (A) is added to remove glitches.

Fig. 7. Enable gating removes glitches in (A) to give (B).

Fig. 8. Modification of Fig. 4.

Fig. 9. Flip-flop removes glitches.

Fig. 10. RC delay can be used to remove narrow glitches.

Fig. 11. Schmitt trigger solution.

Fig. 12. CMOS de-glitcher.
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Understanding Active Filters

Using op amps makes filter design easy and low-cost.

Frequency-selective filters (high-pass, low-pass, or band-pass) can be either passive or active. The former is traditionally an inductor-capacitor circuit which, particularly at audio frequencies, can be cumbersome and expensive and have a response shape that is not as selective as desired. Active filters use conventional resistors and capacitors and operational amplifiers. They are low in cost, easy to tune, not sensitive to field and hum, small and light, and are not influenced by varying load and source impedances. In addition, active filters can be easily cascaded, so that a complex filter response can be broken down into simple factored blocks that do not interact.

Where are active filters used? Electronic music is one obviously important area. Here, active filters serve as modifiers of conventional instruments, to generate new sounds by way of formant synthesis and vcf (voltage controlled filter) techniques, and to generate the transient responses involved with bell and other percussion voices.

Biofeedback circuits that monitor brainwaves use ultra-low-frequency active filters to separate the alpha, beta, delta, and theta response waves. Active filters are also used in graphic equalizers to permit modifying the audio channel response to suit individual tastes or room acoustics. Microprocessor and computer-related uses of active filters include cassette tape sine-wave generators for data recording and transmission and reception of modem (modulator-demodulator) systems that send data over the phone lines.

Laboratory applications are widespread, ranging from ultra-low-frequency seismic and geophysical signal processing, to speech and hearing studies, and Doppler tracking of moving radar targets. Elaborate, general-purpose active filters are also available for many different lab situations where certain frequencies must be emphasized and others rejected or minimized. These same circuits can be converted into high-quality signal sources with external feedback.

The biggest users of active filters are probably engineers at the phone company. They developed most of the math concepts behind active filters and have an incredible variety of uses for them, ranging from multiplexing of phone conversations onto a common carrier to equalization of telephone lines.

Psychedelic lighting systems use active filters to pick up an audio signal, break it down into various frequency channels, and modulate colored lights or lasers on a multicolor dynamic display.

Actually, today you can use active filters for just about any frequency selective task you can dream up, ranging in frequency from a few hundredths of a hertz to several hundred kHz or more. The most common types
of filter you'd be interested in are low-pass, band-pass, high-pass, universal, notch, and voltage-controlled filters. Now, let's take a detailed look at how you can build your own active filters.

**Low-Pass.** Active filters are normally broken down into building blocks that are simple and easy to tune. For fancier responses, you combine as many simple blocks as you need to get the overall desired result. One popular building block is called a second-order section. A second-order low-pass is pretty much flat in response up to a cutoff frequency. Above that, the response drops by one fourth each time you double the frequency. We say it has a cutoff slope of −12 dB per octave. A "mirror image" high-pass second-order section will have a complementary slope of +12 dB per octave, leveling off near the cutoff frequency and staying uniform for higher frequencies. Each of the second-order sections uses one or more operational amplifiers. For most lower frequency audio work, the 741 op amp is ideal. Improved 741’s, particularly the duals (4558 and 4136 are typical) are now available at low cost. Where you really need high-"Q" values or large signal swings at high frequencies, you can turn to a super 741 such as the LM318, with fifteen times the bandwidth and 150 times the slew rate of a stock 741. Or, if you're into very low-frequency work, it pays to raise the impedance levels of your circuit as high as possible to get by with smaller valued capacitors. The FET or CMOS, op amps are ideal for this, with the 3140 being a top choice for many low-cost applications.

A pair of second-order low-pass active filters, having a 1-kHz frequency are shown in Fig. 1. Each circuit is flat to near 1-kHz and then drops at −12 dB/octave well above 1-kHz. As the frequency increases, the response continues to die out.

The first circuit (Fig. 1A) is called the unity gain Sallen-Key circuit otherwise known as a VCVS or voltage controlled voltage-source filter. Since the op amp is used as a source follower (a noninverting amplifier with a gain of one, a high input impedance, and a low output impedance), an ordinary transistor emitter follower can be used just as well.

How does the circuit work? It looks at the overall mathematical transfer func-

**RESISTOR AND DAMPING VALUES FOR VARIOUS LOWPASS AND HIGHPASS RESPONSES**

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<thead>
<tr>
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tion for an inductor-capacitor-load circuit and synthesizes a similar result. So, while it does not actually replace the inductor, it's a simple matter with some fancy math to show that the circuit does everything that can be done with a passive inductor/capacitor filter and then some.

If the op amp weren't there, and if the first capacitor went to ground, we'd have an old-fashioned two-stage RC filter. This circuit has unity gain at very low frequencies (if not loaded), and a fall off at -12 dB/octave at very high frequencies. The problem is in-between where we'd like to have a sharp passband. Here the RC filter's response is very droopy and ill-defined.

Now, when the "ground" end of the first capacitor is connected to the output of the op amp, just enough energy is fed back from the power supply to simulate the energy storage in an inductor, and thus bolster the response as much as we want at the cutoff frequency. Very nicely, this feedback is localized only near the cutoff frequency. Why? Because the capacitor has too high a reactance to feed anything back at very low frequencies; and at very high frequencies, the output signal is too small to be worth feeding back. So, it's only near the cutoff frequency that the feedback has any appreciable effect.

Just how much energy do we want to feed back? This depends entirely on how much bolstering of the response we need near the cutoff frequency, and thus determines the cutoff response shape. The amount of feedback is called "d", short for damping. The larger the first capacitor is with respect to the second the lower the damping, and the more peaked the response. Values of d range from two down to zero. A damping of 2.00 is what we get with two cascaded but isolated RC sections. A d value of 1.73 will give the best possible transient and pulse response while a d of 1.41 gives the flattest possible amplitude and also a cutoff frequency that's exactly -3 dB down (0.707 voltage) from the fundamental. If we lower d further, we get a hump or peaking near the cutoff frequency. For instance, d values of 1.045, 0.895, and 0.767 correspond to humps of one, two, and three decibels respectively. If d ever hits zero, we get infinite peaking, otherwise known as an output with no input, or an oscillator.

To build the Fig. 1A circuit, we must decide what the damping is going to be, and then calculate the two capacitor values. For a flattest amplitude filter (also called a Butterworth), d will equal 1.41, and the left capacitor will be 0.02 µF and the right capacitor will be 0.01 µF, rounded off to stock values.

How do we change frequency? By changing either the capacitors or the resistors marked "R" or both. The only thing NOT allowed is to change the ratio of the two resistors (from 1:1) or the ratio of the two capacitors (from 4/d²). The product of the resistors and capacitors sets the frequency. The ratio of the capacitors sets the damping figure.

If the capacitor values are doubled, the cutoff frequency drops to 500 Hz. If the resistance values are doubled, the cutoff frequency also drops to 500 Hz. Do both and the frequency drops to 250 Hz and so on. The capacitors can be switched in steps and a dual potentiometer used to change resistance for a 10:1 frequency change.

By the way, note that the frequency varies inversely with the potentiometer settings. This will give you a dial that's very cramped at one end and nonlinear. Two ways to beat this problem are to use pots with reverse log tapers or to use pots with standard audio log tapers but put the dial on the pot shaft and the pointer on the panel, instead of vice versa. Selector switches and stepped resistor values provide another route to frequency selection and usually offer more precise control than ganged pots. Frequency steps can be in a linear or log arrangement.

Polystyrene capacitors are excellent for active filter use, but you have to keep them away from solvents and be careful not to nick them with a soldering iron. More expensive mica and Mylar capacitors can also be used. Under no circumstances should a disc or an electrolytic capacitor be used for filters.

There are one or two details that can cause trouble if you don't watch for them. With this circuit or any other low-pass filter, you have to bias the op amp's inputs in some way. This is usually done through the source, so there has to be a low-resistance dc return path through the source to ground. The source impedance, dc and otherwise, should be well below 10,000-ohms if it's not going to change the response. A second detail is to note that this is a true lowpass filter, so it also passes dc. Any bias, dc level, or offset voltage at the input goes on to the output, and if too large, can saturate the amplifier or limit the dynamic range. This effect can be eliminated by putting a blocking capacitor on the input, but you still have to bias your op amp. The 20,000-ohm resistor connected to the negative input isn't critical, and usually it is picked for minimum op amp offset.

While the Fig 1A circuit is simple and easy to build, we can do better. The capacitor values are hard to calculate and tend to spread widely for low d values, thus damping is hard to adjust. There's also no easy way to switch from high-

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Fig. 2. Multiple-feedback bandpass filter (A) is improved at (B) to have higher input impedance.

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Fig. 3. High-pass filters: unity gain (A) and equal component (B).
pass to low-pass just by rearranging components.

If you go through the Sallen-Key math in detail (a very ugly process), it turns out that there is one magic value of op amp gain that solves all these problems. This is the ultra-simple and practically unknown equal component value Sallen-Key filter shown in Fig. 1B. The magic gain value is 3−d, which means that you trim the damping by trimming the gain. The R resistors and the capacitors are identical values and are changed in pairs to change frequency. As an added feature, it can be changed to a high-pass characteristic with identical response simply by interchanging the resistors and capacitors.

One new detail to watch is that the feedback resistor must be held lower than the 78,000-ohm value that corresponds to a d = 0 oscillator. Fortunately, the d values shown here are normally well away from this danger zone, and the gain is easily set by the ratio of two resistors.

**Band-pass.** Sallen-Key techniques don’t really make good band-pass filters, so we go to the multiple feedback filters shown in Fig. 2. Usually, we are involved with such low d values in a bandpass filter that we use its inverse or Q instead. The Q is simply the ratio of the bandwidth to the center frequency. The circuit of Fig. 2A has a gain of −2Q² at resonance (the minus means a 180-degree phase shift), and a resonance frequency of 1 kHz.

The circuit is tuned by changing the values of the resistors or the capacitors, but, once again, both resistors and both capacitors are kept at fixed ratios.

The op amp gain should be at least 20Q² at the operating frequency, so this particular circuit works best with lower Q values and lower resonance frequencies. You also tend to get a wide resistor spread with high Q values so this circuit is best used for Q values of 20 or less. At resonance, the gain is very high, so be sure to limit the size of the input signals so the op amp doesn’t clip or saturate.

The extra resistor added to Fig. 2B raises the input impedance and drops the gain. However, it still has a respectable gain of −Q²/5 and ten times the input impedance of the earlier filter circuit.

**High-pass.** The Sallen-Key circuits can be used for high-pass by making them mirror images of the low-pass. These are shown in Fig. 3. Note that the unity gain version (3A) now has resistor ratios set by the damping and 1:1 capacitor ratios, so there is no way to switch the same parts around for identical low-pass and high-pass responses. The equal component value circuit of Fig. 3B doesn’t have this problem and we get from high-pass to low-pass with 4pdt switching. Since there is an internal dc bias path, we no longer have to worry about providing a dc return through the source.

High-pass filters are inherently noisier than low-pass ones because they emphasize transients, and pass harmonics of supposedly rejected wave forms. Certain circuits tend to reduce the stability margins of the internal op amp compensation. So, rarely will you get a really “clean” high-pass output from a filter, active or passive. Note also that the op amp sets an upper frequency limit and you have to save enough “daylight” between the desired cutoff frequency and the op amp’s cut-off frequency to have a passband left.

Sometimes the capacitor values of a low-frequency active filter (high-pass or

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**FOR MORE INFORMATION**

Here are some good sources of information on active filters:

- The Active Filter Cookbook, #21168, Howard W. Sams, Indianapolis, IN 46206, (1975).

The first of these has the most detail on circuits, background math, and tuning techniques (for these and other circuits), along with many response curves, rip-off circuits, and detailed band-pass design information. The second and third references are theoretical "horses mouth" source documents covering the theory behind Sallen-Key and State-Variable filters.
called state variable filters, otherwise) get too large and too expensive. This can be avoided by raising the impedance of the circuit suitably. For instance, to raise the impedance by a factor of ten multiply all resistors by ten and divide all capacitors by ten. These higher impedance circuits tend to be more offset-sensitive and should be used only when capacitor size is a serious problem.

**Universal Filters.** These are also called state variable filters, and they take three or four op amps per second-order section, often in a quad package, and use more resistors than the simpler circuits. However, they are vastly better. Universal filters have three, and sometimes more, simultaneous outputs—low-pass, band-pass, high-pass, and an optional notch output. They are easily used with Q values of 500 or more and don’t tax the frequency limits of the op amps very heavily at all. They easily realize ultra-low d values without stability problems, they are easy to voltage tune, and they are very easy to switch from high-pass to band-pass to low-pass. About their only limitation is that a lot of parts are required in systems with fancy filter responses and multiple channels.

One universal filter is shown in Fig. 4. It is tuned by changing the R resistors or the capacitors. Once again, the resistors should be identical and the capacitors identical at all times. The Q or d is set with the feedback resistor as shown, while op amp gain at the cutoff frequency should be 3G or better. Note that Q or d is easy to adjust independently. We can also design to different values of circuit gain, but this involves some non-obvious resistor calculations on the first stage. For completely independent gain, damping, and frequency another op amp can be added.

The low-pass, band-pass, and high-pass outputs are progressively phase-shifted by 90 degrees at the cutoff frequency. We can build quadrature art systems by routing the LP and BP outputs to a scope or plotter and inputting interesting audio signals to the filter. Since the circuit gain at resonance is Q, be sure to limit input signals to a suitably small size.

This circuit is really an analog computer that models a rusty pendulum. With an infinite Q resistor (d = 0), there is no damping (an oscillator). The Q resistor adds rust, or damping, to the pendulum.

The notch output shown has nothing to do with the rest of the circuit and can be left off if not desired. This output produces a zero output at resonance and a notch width proportional to the circuit Q. The notch works by summing the low-pass and high-pass outputs which cancel at the resonance frequency. If one of these input resistors is changed, the notch can be moved either side of the resonance frequency. This is a powerful class of filters called Cauer or Elliptical filters that strongly reject signals immediately outside the passband.

**Cascading.** Two second-order sections can be connected together to build a fourth, and three to get a sixth, but the damping and frequency values must be watched if a useful overall response is to be obtained. For instance, we’ve seen how a maximally flat second-order section is built with a d value of 1.41. But cascade three of these and what was a -3 decibel cutoff frequency is now a very droopy -9 decibels and no longer flat at all.

The Table shows the correct damping and frequency values for high-pass and low-pass filters of second, fourth, and sixth order. The shapes selected are for the best delay, the flattest amplitude, and a slightly peaked response. These are called the Bessel, Butterworth, and One Decibel Chebycheff responses. The cutoff frequency of all values, defined to three decibels below peak response is 1 kHz. The circuits can be tuned to any other frequency by the previous techniques we’ve looked at, but all cascaded sections must be changed by the same amount. While five-percent resistor and capacitor values are usually more than adequate for these circuits, values correct to one percent are indicated in the Table.

**Voltage Control.** To voltage control a universal filter, replace the fixed or variable frequency determining R resistors with something that looks like an electrically variable resistor. One very good choice is the CA3080 transconductance amplifier, and a voltage controlled universal filter can be built as shown in Fig. 5. This circuit provides a linear voltage versus frequency control; and frequency ranges of 100:1 and even 1000:1 are possible with careful design. One important design detail is to keep the input voltage on the 3080 positive input to 100 millivolts or less peak-to-peak for good linearity.
Product Test Reports

ABOUT THIS MONTH'S HI-FI REPORTS

Technics' new line of stereo receivers does not in general represent any radical departure from the company's past offerings. However, judging by the Model SA-5460, receiver performance has been refined still further, to the point where this $400 receiver is capable of FM and audio performance that should satisfy the needs of the critical listener. Our tests revealed that the receiver's rather impressive specifications are completely realistic.

The long-awaited CD-4 phono cartridge from Shure Brothers has finally made its appearance—the Model M24H. It is more than just a very good CD-4 cartridge, however. It is also a first-rate stereo cartridge whose "trackability" matches that of the company's Model M95ED stereo cartridge and comes close to rivaling the top-of-the-line V-15 Type III in stereo performance. Best of all is the fact that the M24H is moderately priced, costing just a few dollars more than the better stereo cartridges.

— Julian D. Hirsch

TECHNICS MODEL SA-5460 STEREO RECEIVER

Top-notch performance in medium-priced range.

The Model SA-5460 is one of a new line of stereo receivers from Technics by Panasonic. Its differential, completely direct-coupled audio amplifiers are rated at 65 watts/channel into 8-ohm loads with less than 0.1% distortion over a frequency range of 20 to 20,000 Hz. The complementary output transistors are also direct-coupled to the speaker systems driven by the amplifier section.

The phono preamplifier circuit employs integrated circuits, with precision components in the RIAA feedback equalizing network. The FM tuner section has a seven-stage i-f amplifier whose three two-element filters have uniform group delay characteristics. The i-f section, in conjunction with a phase-locked-loop multiplex demodulator, contributes to the receiver's rated channel separation of 35 to 45 dB across the audio range.

The receiver is furnished with a simulated wood-grain cabinet. It measures about 19 3/4" W x 16 1/2" D x 5 1/2" H (50.2 x 42 x 15 cm) and weighs 31 lb (14 kg). List price is $399.95.

General Description. The receiver's styling is quite similar to the Technics equipment of last year. The pale gold, satin finished aluminum front panel has a large dial window. The various controls and switches are arranged in a single row across the bottom of the panel. Half the dial area is devoted to the calibrated scales, with the FM calibration marks linearly spaced at 500-kHz intervals. The lower half of the dial cutout is finished in black, except for the illuminated signal-strength and center-channel tuning meters and a red STEREO indicator light.

At the lower left of the panel are the POWER pushbutton switch and PHONES jack, followed by pushbutton switches for two pairs of speaker systems. The BASS and TREBLE controls are lightly detented at 11 positions and the BALANCE control is center detented. The HIGH and LOW audio filters are pushbutton controlled. The VOLUME control is followed by a row of five pushbutton switches for LOUDNESS compensation, FM MUTING, stereo/mono MODE selection, and TAPE MONITOR functions for two tape decks. (A tape can be directly dubbed from one to the other tape deck.) The SELECTOR switch has positions for AM, FM AUTO, PHONO, and AUX. Finally, the large TUNING knob operates a very smooth fly-wheel tuning mechanism.

On the rear apron of the receiver is a 4 CH MPX OUT jack that provides a detected but unprocessed signal for use with a future discrete 4-channel FM decoder. Insulated binding posts are used for the 300- and 75-ohm FM and long-wire AM antenna input terminals and the speaker output terminals. Covered fuses protect the output transistors. There are two accessory AC outlets on the rear apron, one of which is switched. The ferrite-rod AM antenna is inside the receiver and is not adjustable.

Laboratory Measurements. Following the FTC preconditioning period of operating amplifiers for one hour at one-third the rated output power, the receiver's amplifiers clipped at 87 watts/channel into 8-ohm loads, 110 watts into 4 ohms, and 54 watts into 16 ohms. These tests were made with a 1000-Hz input signal. The THD measured 0.01% between 0.1 and 1 watt. It increased slowly to 0.02% at 20 watts, was 0.03% at 30 watts, and hit 0.1% at 75 watts. The intermodulation (IM) distortion was between 0.03% and 0.05% from 0.1 to 40 watts. It reached 0.1% at 60 watts.

At the rated output of 65 watts, the distortion was less than 0.08% between 20 and 20,000 Hz and was typically about 0.04%. At half and one-tenth power, the distortion was substantially less. At any normal playing level and frequency, the distortion can be expected to be between 0.15% and 0.02%.

An input of 50 mV at the AUX jacks drove the amplifier to a reference 10-watt output, with the noise level 75.5 dB
1-kHz total harmonic and 60/7000-Hz IM distortion.

The phono section lived up to the promise of the receiver's specifications. The THD was 0.82 mV, with a 70-dB S/N ratio. The phono circuits overloaded at a very safe 125 mV input signal level.

The Baxandall tone controls had a sliding turnover frequency in the bass range and a treble response hinged at about 2000 Hz. At intermediate settings, the bass control could give a substantial modification of the response below 200 Hz, with negligible effect at higher frequencies. The loudness compensation became effective only at fairly low settings of the volume control and boosted only the low frequencies. The high and low filters had gradual 6-dB/octave slopes, with the -3-dB responses at 100 and 6000 Hz. The RIAA phono equalization was accurate to within ±0.5 dB from 50 to 20,000 Hz. Unlike the case with most phono preamplifiers, the frequency response was boosted slightly at the high end of the range by the interaction with the cartridge's inductance. However, the effect was small, amounting to only 1 dB at 15,000 Hz and 3 dB at 20,000 Hz.

Harmonic distortion at three power levels.

The FM tuner section lived up to the promise of the receiver's specifications. The THD was 0.82 mV, with a 70-dB S/N ratio. The phono circuits overloaded at a very safe 125 mV input signal level.

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way. It is an excellent product whose handling and freedom from undesirable side effects are only too easy to take for granted.

The receiver's stereo FM performance is so close to ideal that a significant improvement would be difficult to imagine. There are no program sources whose frequency response, flatness, distortion, and channel separation can come even close to those of the Model SA-5460. Although not quite in the "super-power" category, the Model SA-5460 is actually a very powerful receiver, capable of doing justice to almost any home speaker system in a large listening room. Obviously, the receiver's distortion and other characteristics are consistent with the requirements of a deluxe receiver.

Our positive reaction to this receiver was enhanced by two factors that are often overlooked in receiver design but which we consider to be very important: the FM dial calibration is both legible and accurate, and the muting circuit is positive yet free of the noise bursts that sometimes accompany tuning on and off a station.

CIRCLE NO. 102 ON FREE INFORMATION CARD

SHURE MODEL M24H ALL-FORMAT PHONO CARTRIDGE

Plays stereo/matrixed and discrete 4-channel.

The Model M24H is Shure's first phono cartridge designed to provide high-quality playback of both stereo/matrixed quadraphonic and discrete 4-channel CD-4 records without compromising any format. The new cartridge is not only designed to be compatible with all modern record formats, but it tracks at lower stylus pressure and is reasonably priced.

The Model M24H physically resembles Shure's Model M95ED stereo cartridge, with a hinged stylus guard attached to its removable stylus assembly. Price is $74.95.

General Description. The extended frequency response of the Model M24H has been achieved in several ways. First, the winding inductance has been reduced (compared to stereo cartridges). Second, the moving mass of the stylus has been reduced to 0.39 mg, which is claimed to be lower than the mass of any other CD-4 cartridge on the market. Finally, a new "hyperbolic" diamond stylus with radii of 0.3 and 0.7 mil was developed, the edges of which are shaped to contact a larger portion of the groove walls on the record than is possible with a conventional elliptical stylus.

The cartridge is designed to track at stylus forces of between 1 and 1.5 grams, with 1.25 being the optimum. The typical frequency response curve published by Shure illustrates an essentially flat response up to about 10,000 Hz. The curve rises to a broad maximum of about +5 dB in the region between 20,000 and 30,000 Hz before returning to the midrange level at 50,000 Hz. Channel separation is specified at nominally 22 dB at 1000 Hz, while the output is rated at 3 mV at 5 cm/s peak velocity.

Shure's "trackability" data for the cartridge indicates that the Model M24H is essentially equivalent to the company's Model M95ED stereo and not far behind the top-of-the-line Model V-15 Type III stereo cartridges in this important parameter. The company candidly states that the stereo-only listener who has no plans for a discrete 4-channel record-playing capability might as well choose the lower-priced Model M95ED or go to the V-15 Type III cartridge if his budget permits. However, if there is any possibility of future conversion to CD-4, the Model M24H is an ideal choice of cartridges. It combines the best of both worlds at a price that is intermediate between the two top stereo cartridges.

Because of the lower inductance of the coils, the optimum stereo load capacitance of the cartridge is less than that of other Shure cartridges. Shure recommends 100 to 250 pF of capacitance in parallel with a 47,000-ohm resistance, as opposed to the 400 to 500 pF preferable for the Models M95ED and V-15 Type III cartridges. For CD-4 operation, the optimum load for the new cartridge is the 100,000-ohm input resistance that is standard for all CD-4 demodulators, in parallel with 100 pF capacitance.

Laboratory Measurements. We tested the cartridge in the tonearm of a Dual Model 701 record player, using the recommended loads for measurements in the audio and carrier ranges. The cartridge tracked the high-level, low-frequency test records nicely at only 0.9 gram, but there was considerable waveform distortion on the 1000-Hz, 30-cm/s tones of the Fairchild 101 record at 1.25 grams and still some peak clipping at 1.5 grams. The 300-Hz tones of the German High Fidelity Institute record were playable at the 60-micron level. An increase to 1.25 to 1.5 grams did not make a significant improvement. We used 1.25 grams for our subsequent tests and listening evaluation.

The output from the cartridge was 2.7 mV at 3.54 cm/s velocity. The vertical stylus angle measured 24°. IM distortion was extremely low, measuring 0.6% to 1%, at velocities from 6.7 to 18 cm/s, using the Shure TTR-102 test record. The IM rose steeply at high velocities, reaching 5% at 22 cm/s and definitely

Response and channel separation in audio range.
Results of square-wave tests with CBS STR-112 record.

mistracking at the much higher levels.

The repetition rate distortion of the tone bursts on the Shure TTR-103 test record was also exceptionally low, matching the Model M95ED cartridge in this test and surpassing just about every other cartridge we have tested. The distortion measured 0.6% from 15 to 22.5 cm/s and only 0.8% at 30 cm/s. The low-frequency resonance in the Dual tonearm was at about 9 Hz.

Using the CBS STR100 test record, our frequency response measurements in the audio range were flat to within ±1 dB up to about 10,000 Hz, rising to +7 dB at 20,000 Hz. Channel separation was 20 to 30 dB in the midrange. (The two channels were not identical in this respect.) One channel maintained outstanding separation all the way to 20,000 Hz, where it measured 28 dB, while the other channel was a very good 20 dB at this frequency.

We used the JVC TRS-1005 record to measure the cartridge's response in the carrier-frequency band. It was almost identical to the curve published by Shure, flat up to 10,000 Hz and rising to between +6 and +7 dB in the range between 20,000 and 30,000 Hz. At 50,000 Hz, the output was the same as at 1000 Hz. On one channel, the separation was 15 to 20 dB all the way up to 50,000 Hz, while on the other channel it was 8 dB at 40,000 Hz and 2 dB at 50,000 Hz.

In stereo, the subjective trackability was judged with the aid of Shure's Audio Obstacle Course—Era III test record. At 1.25 grams, the cartridge played every portion of this record without difficulty, except for a trace of "sandpaper" quality at the highest level of the sibilance section. Very few cartridges, stereo or CD-4, can do as well, let alone match this performance.

We connected the cartridge to a Technics Model SH-400 demodulator for playing CD-4 records. Not surprisingly, the cartridge acquitted itself admirably. Most of the records that have been prone to "shattering" distortion with other cartridges delivered clean, well-separated 4-channel sound with the Shure cartridge. In the few instances where distortion was heard, the same effect has been observed with every other cartridge. It can, therefore, be assumed that the record is at fault.

User Comment. Our tests and use of the Model M24H confirmed Shure's claim that this is a "no-compromise" cartridge for playing stereo/matrixed and CD-4 records. We could find no audible fault with the cartridge in our lab and listening tests. While it does have an accentuated response in the uppermost audible octave from 10,000 to 20,000 Hz, this does not give the cartridge an audibly bright sound. Even if the cartridge should sound a trifle crisp, most good amplifier tone controls should be able to correct the response.

As a CD-4 player, this cartridge is as good as any we have used. There are one or two CD-4 cartridges that can match the performance of the Model M24H when operated at 1 gram, but the difference between 1.25 and 1.0 gram is negligible. Not so negligible is the price.

Response and channel separation in carrier-frequency band.

DECEMBER 1976
difference between the Shure and any other cartridge of comparable quality. Based on a list-price basis, the Shure cartridge saves the user $25 to $100 on the purchase of a new CD-4 cartridge, while supplying stereo/matrixed reproduction capability. The Model M24H strikes us as being a fine value as a universal phono cartridge. It certainly passed all of our tests easily for both 4-channel and stereo use.

CIRCLE NO. 103 ON FREE INFORMATION CARD

SBE MODEL 32CB FORMULA D TOUCH/COM CB TRANSCEIVER

Mike contains LED channel display and squelch, volume, and channel controls.

THE SBE Model 32CB Formula D Touch/Com AM CB mobile transceiver employs the latest in digital frequency synthesis to provide full 23-channel coverage. What sets this transceiver apart from most others on the market is that the SQUELCH, VOLUME, and CHANNEL selector controls and a pair of red LED numeric displays are on the microphone. This puts the most-used controls right at the operator's fingertips and permits the transceiver to be located in an out-of-the-way place.

Electronically and in its performance, the transceiver is similar to the SBE Formula D reviewed in the October 1975 issue of POPULAR ELECTRONICS. It includes a switchable automatic noise limiter (NL), audio TONE control, S/RF meter, DELTA TUNE control, DISTANCE/LOCAL switch, PA operation, and a transmitter-on indicator. Operation can be from any 11.7 to 15.9-volt, negative- or positive-ground, dc power source capable of delivering up to 2.5 amperes of current. The power-supply section features reverse-polarity protection, voltage regulation, and a line filter.

The transceiver measures 9¾" x 6¾" x 2½"H (24 x 17 x 6.4 cm). It retails for $289.95.

Technical Details. The receiver section employs double conversion to i-f's at 10.695 MHz and 455 kHz. A dual-gate FET is used for the r-f amplifier, which is followed by the first and second mixers, 455-kHz ceramic filter, two bipolar transistor i-f stages, diode detector, age, squelch, series-gate anl, two audio stages, and a class-B power-output stage. The last stage is also used for PA operation and for modulating the transmitter.

The digital frequency synthesis system uses a phase-locked loop (PLL) IC. (For detailed information on how the frequency synthesizer works, see October 1975 Product Test Report for the Formula D transceiver.)

The design of the transmitter section is conventional. It uses a dual-gate FET mixer and pre-driver, driver, and r-f power output amplifiers. A double-pi output network provides matching to 50-ohm loads and spurious-response attenuation, augmented by a 54-MHz TVI trap. Automatic modulation control (amc) is designed into the circuit. Antenna transmitter is accomplished electronically with a diode switch.

Overall Performance. The performance of the transceiver was quite similar to that of its predecessor, the Formula D. Our measurements indicated a receiver sensitivity of 0.3 to 0.5 µV, depending on the setting of the TONE control, for a 10-db (S + N)/N with 30% modulation at 1000 Hz. Image and i-f signal rejection were 80 db, while unwanted spurious-signal responses were a minimum of 60 dB, except for signals near 26 MHz, where the figure was 50 dB. Adjacent-channel rejection was measured at 50 dB.

The agc held the audio output level to within 7.5 dB with an r-f input variation of 80 db at 1 to 10,000 µV. At 1 to 10 µV, the output remained within 4 db. The meter indicated S9 with a nominal input signal level of 30 µV. The squelch threshold range was 0.25 to 10,000 µV.

The maximum sine-wave audio output at the onset of clipping was 3 watts at 7% THD, using a 1000-Hz test signal and taking the measurement with an 8-ohm load. The overall 6-dB response, including that of the r-f passband, was 425 to 3500 Hz. Good sound quality was obtained from the top-side-facing speaker. The effectiveness of the amc system was fine. It permitted readability of a 0.3-µV signal in the presence of 1000-µV and more peaks of most external noise pulses.

The LOCAL/DISTANCE switch dropped the r-f gain by about 30 dB when set to the LOCAL position. However, the good signal-handling capabilities of the transceiver were seldom necessary to use the LOCAL position in the presence of strong signals.

Operating the transceiver from a 13.8-volt source, the transmitter carrier output measured slightly greater than 4 watts. Increasing the microphone input level by 10 db over that required for 50% modulation held the r-f envelope to a sine wave at 100% modulation with 4.25% THD while using a 1000-Hz test tone. A 15-dB increase introduced clipping of both positive and negative peaks with overmodulation on the latter. The THD in this case was 12.5% with adjacent-channel splatter down 50 dB. The overall signal level with voice operation allowed full modulation while holding the splatter to an excellent 55 to 60 dB down. The 6-dB audio response was 200 to 6500 Hz.

The frequency tolerance on all channels was essentially the same, holding to within 0.001%. The current drain was a little higher than usual. On receive, the drain was between 1.0 and 1.75 amperes, while on transmit—it was 1.7 to 2.25 amperes. The power supply used during these tests was rated at 13.8 volts.

User Comment. The microphone had
the customary push-to-talk switch button on the left side of its case. The VOLUME and SQUELCH controls are thumbwheel types and are located on the right side of the case. These controls have numerals on their edges, requiring the user to rotate the mike to observe the numerals.

Two square buttons located at the top of the mike’s housing are for selecting the CB channel desired. The button on the left is marked up for an upward numerical progression through the channels. The button on the right, labelled ON, is for a downward progression. Every time either button is momentarily depressed and released, the system steps one channel. By holding down a button, the channels can be continuously advanced up or down automatically until the desired channel is reached. When the transceiver is first turned on, Channel 1 always comes up first. Progression through the channels can be made in either direction at any time.

The seven-segment LED numeric displays used for indicating the channel are located at the lower center of the front of the microphone’s case.

Taken as a whole, the Touch/Com transceiver provides convenient and safe handling as well as fine performance and the latest in frequency synthesis. Its very up-to-date design is well suited for any mobile application.

SENCORE MODEL TF40 PORTABLE TRANSISTOR TESTER

Checks in- and out-of-circuit devices without setup information.

SENCORE’S new Model TF40 “Pocket Cricket” is a portable, compact in-circuit and out-of-circuit transistor and FET tester. It employs the same basic test principles used for the company’s more expensive ac-only Cricket testers and does not require set-up information to test any device.

The Pocket Cricket provides good/bad gain tests, meter-calibrated leakage, and transistor basing identification. Additionally, an audible test tone sounds if the device under test has good gain. The tester is equally convenient to use in the field on battery power and on the test bench on battery or line power, the latter with an optional power adapter. For fast in-circuit tests, there is also available an optional “Touch Test Probe” No. 39G85.

The transistor tester measures 6”L x 4”W x 1.14”D (15.2 x 10.2 x 3.2 cm) and weighs 14 oz (0.39 kg). The Model TF40 tester is priced at $98; the optional No. PA202 power adapter and No. 39G85 Touch Test Probe, $9.95 each.

General Description. The tester is designed for rapid checking of transistors and diodes even by persons with little or no technical knowledge. The control complement, therefore, has been limited to just three function switches and a rotary thumbwheel potentiometer.

The device condition display is a 2 1/2” (6.4-cm) wide meter movement whose scale is broken up into BAD and GOOD sections for gain and battery-check indications. It is calibrated from 0 to 2500 µV for leakage measurements. A built-in loudspeaker emits a tone during the tests when gain is “good.”

A large 12-position “permulator” switch occupies the major portion of the instrument’s front panel. Arranged along the bottom of the panel are the power ON/OFF and BATT CHECK SWITCH, LEAD ID control pot, and ID/GAIN/LEAK function switch. Exiting through the bottom of the instrument’s case is a cable whose three conductors are terminated in color-coded E-Z Hook® connectors. A single 9-volt battery, housed in a compartment at the top-rear of the case, provides the power necessary for testing.

Connections to the device under test are made via the E-Z Hooks. It is not necessary to know the basing or type of device being tested. You simply connect the E-Z Hooks at random to the device’s leads. Then, setting the power switch to ON and function switch to GAIN and rotating the permulator switch through its positions will give a good/bad gain indication and simultaneously identify the device as being npn (or n-channel) or pnp (or p-channel). At one or two positions of the permulator switch, the built-in speaker will emit a tone, assuming the device under test is good. Depending on whether the “good” positions of the switch are located in the N or P leads.

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belled area of the dial ring, the device is either an n type or a p type.

Once the gain/type test is performed, the function switch goes to the LEAK position and the permutator switch is rotated through only the six positions of the identified type. The meter then indicates the six possible leakage conditions for the transistor.

Finally, the permutator switch is set to either of the two "good" positions and the function switch to ID. Then the LEAD ID control is adjusted until the test tone ceases in either position, at which time the transistor is known to be bipolar and its basing is identified by matching the three-letter color code on the dial ring with the legend on the switch pointer. If the tone does not cease in either position of the permutator switch, the device is a FET, and its basing is also identified in the same manner.

Testing diodes is quite simple. Only the red and yellow E-Z Hooks are used here. The function switch is set to LEAK and the permutator switch first to the top two and then the bottom two positions. A good diode will cause the meter's pointer to deflect far up-scale in either the two upper or two lower, but not both sets of positions. A good diode will cause the test tone to sound in either the two upper or the two lower positions of the permutator switch. If the diode is open, no tone will be heard; if it is shorted, a tone will be heard in all four positions. For a good diode, the position of the permutator switch and color-code identification of the E-Z Hooks will identify the cathode and anode.

All tests can be performed in- or out-of-circuit. For in-circuit tests, the optional Touch Test Probe is a real time-saver. This probe connects to the tester via the E-Z Hooks according to a color-coding scheme. At the test end of the probe are three, also color-coded, sharp test points that contact the transistor's connection pads. The test points are pivoted to permit use of the probe on a wide variety of transistor basing and spacing configurations.

User Comment. The Pocket Cricket is a delight to use. Its proven gain-test circuit that detects a device's ability to amplify and invert a safe-level test signal, combined with a leakage test calibrated in microamperes, provides the degree of test accuracy needed by a service technician or experimenter. Combined with the in-circuit/out-of-circuit test capability and no set-up requirement, it makes testing transistors, diodes, and FET's easy and fast. In fact, we were testing and sorting loose transistors at a rate of one about every 90 seconds or so.

Small size and battery or ac line (with an adapter) power plus a ruggedized case add to the tester's worthiness. Of course, the Pocket Cricket is not the type of analyzer that an engineering technician or electronics engineer would be likely to require for complete parameter tests. Nor does it reliably test high-frequency oscillators. But for what it does, and at its price, this is an impressive instrument. It is made all the better when used with the optional Touch Test Probe and power accessory. The power accessory can serve both as a battery eliminator and recharger, the latter when the standard 9-volt battery is replaced by rechargeable nickel-cadmium cells.

Built into the tester's case is a swing-out tilt stand that raises the Pocket Cricket to a convenient viewing angle on the workbench. Another nice touch is the four rubber feet on the bottom of the instrument case. Made of non-skid plastic material, the feet prevent the instrument from sliding around on a busy electronics workbench.
A cartridge in a pear tree.

A gift of the Shure V-15 Type III stereo phono cartridge will earn you the eternal endearment of the discriminating audiophile who receives it. What makes the V-15 such a predictable Yuletide success, of course, is its ability to extract the real sound of pipers piping, drummers drumming, rings ringing, et cetera, et cetera. In test reports that express more superlatives than a Christmas dinner, the performance of the V-15 Type III has been described as "...a virtually flat frequency response...Its sound is as neutral and uncolored as can be desired." All of which means that if you're the giver, you can make a hi-fi enthusiast deliriously happy. (If you'd like to receive it yourself, keep your fingers crossed!)

Shure Brothers Inc.
222 Hartrey Ave.,
Evanston, IL 60204

In Canada:
A. C. Simmonds & Sons Limited

Manufacturers of high fidelity components, microphones, sound systems and related circuitry.

DECEMBER 1976
Should your career in electronics go beyond TV repair?

CREI prepares you at home for broader and more advanced opportunities in electronics—plus offers you special arrangements for engineering degrees.

There is no doubt television repair can be an interesting and profitable career field. TV repair, however, is only one of the many career areas in the fast growing field of electronics.

As an indication of how career areas compare, the consumer area of electronics (of which TV is a part) makes up less than one-fourth of all electronic equipment manufactured today. Nearly twice as much equipment is manufactured for the communications and industrial fields. Still another area larger than consumer electronics is the government area. That is the uses of electronics in such areas as research and development, the space program, and others.

Just as television is only one part of the consumer field, these other fields of electronics are made up of many career areas. For example, there are computer electronics, microwave and satellite communications, cable television, even the broadcast systems that bring programs to home television sets.

As you may realize, career opportunities in these other areas of electronics are mostly for advanced technical personnel. To qualify for these higher level positions, you need college-level training in electronics. Of course, while it takes extra preparation to qualify for these career areas, the rewards are greater both in the interesting nature of the work and higher pay. Furthermore, there is a growing demand for personnel in these areas.

Unlike most other home study schools, CREI programs are devoted exclusively to preparing you for careers in advanced electronics. All of CREI programs are college level. And CREI gives you both theory and practical experience in advanced electronics.

Unique Design Lab

A unique feature of CREI training is its Electronic Design Laboratory Program, which trains you to actually design circuits. It also helps you understand the theories of advanced electronics and gives you extensive practical experience in such areas as tests and measurements, breadboarding, prototype construction, circuit operation and behavior, characteristics of electronic components and how to apply integrated circuits.
Career Training at Home

Only CREI offers this unique Lab Program. It is a complete college lab and, we believe, better than you will find in most colleges. The "Lab" is one of the factors that makes CREI training interesting and effective. And the professional equipment in this program becomes yours to keep and use throughout your professional career after you complete the training.

Engineering Degree
CREI offers you special arrangements for earning credit for engineering degrees at certain colleges and universities as part of your home study training program. An important advantage in these arrangements is that you can continue your full time job while "going to college" with CREI. This also means you can apply your CREI training in your work and get practical experience to qualify for career advancement.

Wide Choice of Programs
CREI gives you a choice of specialization in 14 areas of electronics. You can select exactly the area of electronics best for your career field. You can specialize in such areas as computer electronics, communications engineering, microwave, CATV, television (broadcast) engineering and many other areas of modern electronics.

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In the brief space here, there isn't room to give you all of the facts about CREI college-level, home study programs in electronics. So we invite you to send for our free catalog (if you are qualified to take a CREI program). The catalog has over 80, fully illustrated pages describing your opportunities in advanced electronics and the details of CREI home study programs.

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CAPACITORS AND RF CIRCUIT, Part 2

As we mentioned last month, a capacitor exhibits an opposition to the flow of ac that decreases as the capacitance or frequency of the applied signal (or both) is increased. This capacitive reactance is measured in ohms, but is not a true resistance because it does not consume power and dissipate it as heat. But you might find it helpful at this point to consider the capacitor as a "phantom" resistor. The exact amount of reactance that a capacitor exhibits at a given frequency is found by using the equation $X_C = 1/(2\pi fC)$, where $X_C$ is in ohms, $f$ (frequency) in hertz, and $C$ (capacitance) in farads. For example, a 1-µF capacitor has 159.2 ohms of reactance at 1000 Hz, and 0.1592 ohms at 1 megahertz.

**Frequency Response.** One of the key terms used in discussing RC combinations is frequency response. Referring to Fig. 1, this concept is used to relate the input signal to the output signal. In descriptions of such circuits, we often come across such terms as the corner or cut-off frequency, or the break half-power or -3-dB point. They all refer to a particular frequency that is a mathematically convenient reference point.

Viewing the circuit from the input, the network looks like a series combination of resistor $R$ and capacitive reactance $X_C$. These two behave somewhat like a voltage divider—the voltage drop across each element varies with its relative amount of resistance or reactance. If $X_C$ is much greater than $R$, most of the input voltage appears across the capacitor. Thus, the output voltage is an appreciable fraction of the input. As higher frequencies, less and less voltage appears across the capacitor, while most of the input is dropped across the resistor, reducing the output voltage. (Assume these voltages are measured with a high-impedance ac voltmeter to avoid loading down the voltage divider, as discussed in a previous column.)

When $R$ is equal to $X_C$, we find that exactly $1/\sqrt{2}$ or 70.7% of the input voltage appears across the output. And because power is proportional to the square of the voltage, half of the input power is available at the output. This is why the frequency at which $X_C$ equals $R$ is called the half-power point. Also, a 50% drop in power is 3 dB below the original level, so this frequency is also called the half-power point. (Don't confuse this with a half-voltage point, where a 50% decrease in volts is -6 dB.)

You might think that 50% of the voltage appears across the capacitor, and the other 50% appears across the resistor. Such a response is correct if you are talking about a purely resistive voltage divider. But here, reactance is involved, complicating the situation. Without going into a detailed analysis, we'll simply say...
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that, where a resistance and a reactance are found, we must treat the voltage across each of them as vectors. As shown in Fig. 2, \( V_R \) and \( V_C \) are at right angles to each other. Each has a magnitude of 0.707, referenced to an input voltage of 1.0. By simple trigonometry, \( c^2 = a^2 + b^2 \) \( V_{IN} \) equals 1.0, which agrees with our basic supposition. And the phase angle—that is, the angle between the \( V_{IN} \) vector and the \( V_C \) vector—is 45°.

The relationship between cut-off frequency \( f_C \) and the values of \( R \) and \( C \) can be summarized by the simple equation

\[
I_C = \frac{1}{(2\pi RC)} \text{ or } \frac{1}{2\pi f_C},
\]

where \( T \) is the \( RC \) time constant in seconds. This frequency occupies an important point on the RC low-pass filter frequency response curve shown in Fig. 3. In this graph, the vertical axis represents the fraction of the input voltage appearing at the output of Fig. 1. Also given on the vertical axis is the decibel relationship between \( V_{IN} \) and \( V_{OUT} \). The horizontal axis is the signal frequency on a logarithmic scale. This is done so that the falling response characteristic quickly approaches a straight line with a constant slope. The slope for the simple low-pass filter shown in Fig. 1 is -6 dB per octave (from a given frequency \( f_1 \) to 2 \( f_1 \)) and -20 dB per decade (from \( f_1 \) to 10 \( f_1 \)).

This frequency response curve can be approximated by two straight lines, as the dashed region indicates. We can therefore generalize the frequency response by saying that, from dc up to \( f_C \), there is no attenuation of the input signal. At this point, the response "breaks" or "corners," then falls at a rate of -6 dB per octave.

**Low-Pass Scratch Filter.** Now let's look at a practical application of the RC low-pass filter. Many old-time music buffs treasure vintage 78 rpm records, and learn to live with the high surface noise that has developed on them over the years. Most of this noise is composed of high frequencies. So if a low-pass filter is inserted between, say, the preamplifier and the power amp, and if a proper cut-off frequency is chosen, much of this noise can be filtered out without sacrificing too much of the musical content.

A cut-off frequency of 8000 Hz is a fairly good choice. This corresponds to an RC time constant of 20 microseconds. Any reasonable combination of a resistor and capacitor that will give this result is satisfactory. For example, an \( R \) of 20,000 ohms and a \( C \) of 0.01 microfarads will yield the desired response. By using the universal curve shown in Fig. 3, with \( 1/(2\pi RC) \) equal to 8000 Hz, you can observe how the high-frequency material will be filtered out.

**High-Pass Rumble Filter.** So far, we've considered low-pass filters which pass, unhindered, signals below \( f_C \), and increasingly attenuate signals above \( f_C \) as the frequencies rise. However, we can make a high-pass filter which behaves in exactly the opposite manner by interchanging the positions of \( R \) and \( C \) as shown in Fig. 4. It has a frequency response that is a mirror image or converse of Fig. 3. Accordingly, all frequencies above the cut-off frequency—still
determined by the formula \( f_C = \frac{1}{2\pi RC} \)—are passed unattenuated. Below this frequency, the circuit's response falls off at a rate of \(-6\,\text{dB per octave}\).

Here's a practical application. Suppose your stereo system is troubled by acoustic feedback or rumble. By inserting a high-pass filter with a suitable \( f_C \) between the preamp and power amp, we can prevent these low frequencies from reaching the speaker. The cut-off frequency should be selected so that it will cause no loss in bass response, but do an effective job of attenuating the rumble. A good choice is 16 Hz, corresponding to an RC time constant of 10,000 microseconds. With an R of 20,000 ohms and a C of 0.5 \( \mu \text{F} \), the desired response will be achieved.

If we wanted to go to a higher \( f_C \), say, one octave up to 32 Hz, we need only modify the RC product so that it is halved. This could be done by using a 10,000-ohm resistor and a 0.25-\( \mu \text{F} \) capacitor, a 20,000-ohm resistor and a 0.125-\( \mu \text{F} \) capacitor, or any other reasonable RC combination.

Timers and Oscillators. Last month, we looked at two RC oscillators. One was a neon-lamp relaxation oscillator and the other used a 741 op amp as a square-wave generator. The RC time constant appears in the general formula for the oscillating frequency of these relaxation oscillators: \( f = \frac{1}{2\pi RC} \). The value of the constant \( k \) depends on whatever parallel resistance paths appear in the circuit, and also on the power supply used.

One very common application for the RC combination is as a controlling element in 555 timer and oscillator circuits. This versatile IC can function as a monostable or astable multivibrator. In the first case, it will generate a single pulse whose width is determined by the RC time constant. In the second, two resistors and a capacitor determine the amount of time the output is high, how long it is low, the rate of repetition (frequency), and the duty cycle of the output waveform. The circuits will work with any supply between 5 and 15 volts, and the pulse width or frequency is independent of the value of the supply voltage.

The astable multivibrator shown in Fig. 5 will produce square waves with a period \( T \) equal to 0.693 \((R_A + 2R_B)C\). The output frequency will be the reciprocal of the period \( (f = 1/T) \). And the duty cycle, which is the portion of the time the output is high, divided by the entire period, is given by the expression \( D = R_B / (R_A + 2R_B) \). For the values shown in Fig. 5, \( T \) is 0.525 seconds, \( f \) is 1.9 Hz, and the duty cycle is 33.3\%.

We can verify this by watching the LED's flash. When the output is low, the IC sinks current for LED1, a green light-emitting diode. When the output is high, there is no voltage drop across LED1, and it is dark; but the IC sources current for the red LED2. Component tolerances will have some effect on the nominal frequency. However, if a tantalum capacitor is used for \( C \), it should be close to 2 Hz. Of course, you can slow down the flash rate by increasing the values of the resistances or capacitance.

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<td>( )</td>
<td>EQ-10SP Two EQ module kits (stereo) plus PS-4 power supply kit</td>
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<td>( )</td>
<td>EQ-10Q Four EQ module kits (quad) plus PS-4 power supply kit</td>
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<td>( )</td>
<td>EQ-1082P Eight EQ module kits plus two PS-4 power supply kits</td>
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<td>PS-4 Power supply kit,open frame,power up to four modules</td>
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DECEMBER 1976
'TIS THE SEASON TO BE SOLID

THERE was a time—not too long ago—when choosing solid-state gifts for the holidays was a really tough task. Prices were high and selections limited. Today, the job is more of a cinch than a chore . . . so much so, in fact, that unless your shopping list is a short one restricted to such items as diamond rings, fur coats, and caviar, chances are you'll find it next to impossible not to include at least one or two solid-state items.

You can spend as much or as little as you'd like because solid-state gifts are available at prices ranging from less than five to as high as several thousand dollars.

For many, AM, FM, and combination AM/FM or multiband radio receivers are excellent gifts, as are portable tape recorders. A screw-in solid-state dimmer for table lamps is a nice, but inexpensive, gift for students, office workers and housewives. If your budget permits, you'll find that virtually everyone will be delighted with a solid-state portable TV set (even more than delighted if it's a color model).

You might even consider giving a digital calculator to everyone on your list, selecting types and models appropriate to each one's age and interests. If you have a limited budget, you'll find simple four-function (often called "four-banger") models for less than ten dollars. On the other hand, if money is the least of your problems, you can spend hundreds of dollars and thrill your friends with magnetic card programmable calculators such as Hewlett-Packard's HP-67 or Texas Instrument's SR-52. Both firms can supply pre-programmed card libraries for their instruments covering virtually every field from finance to engineering. TI also offers an optional thermal printer accessory which delivers permanent copies of calculations, including all program steps. Between these two extremes, you'll find moderately priced specialized instruments suitable for students, scientists, engineers, accountants, salespersons, mathematicians, and retailers. And there are ultra-thin models which may be carried in a purse or shirt pocket, models with non-volatile memories for retaining bank balances, folding models, and metric converters which housewives should find handy as the metric system comes into broader use. There are even special easy-to-use calculators for youngsters, such as TI's "Little Professor" and National Semiconductor's "QuizKid" models.

In one sense, the solid-state equivalent of such teaching aids as flash cards, the educational calculators add new interest and excitement to the learning experience. For family fun, there are calculator board games, such as TI's "Calculator Squares" and "Check Out."

A TV game attachment also makes a fine family gift. Electronic tennis, anyone? These are covered in a separate article in this issue.

Digital electronic watches make excellent gifts and are available at prices to suit virtually every budget. If your wallet is thin, but you have a special someone who would like a watch, TI offers several models in their TI-501 and TI-502 series which list for less than twenty dollars each. On the other hand, if you're a lavish giver and have a bank account to match, you might consider the ultra-limited-edition Pulsar Time Computer® manufactured by Time Computer, Inc. (Lancaster, PA 17604). Priced at a little under four thousand dollars (each, that is), this beauty combines a 6-digit, 5-function (with memory) calculator and a 5-function digital LED wristwatch in a single 18-kt gold case with matching 18-kt gold bracelet. It comes complete with a combination pen and key presser holder. A less expensive version is available in stainless steel for economy-minded individuals who must limit their gifts to under six hundred dollars.

CB radio is big—and growing bigger every day. Spiced with colorful language, it is considered as a hobby by many, as a cult by some, and as a necessity by others. If your gift choice is CB equipment, you can select a low-cost hand-held "walkie-talkie" (but not the 100 mw or less type that's being phased out) or spend hundreds for a complete mobile or base station. New twenty-three-channel units are available at bargain-basement prices right now because people foolishly think that they'll be obsoleted by the introduction of 40-channel types next year. (They won't!). Check the POPULAR ELECTRONICS Citizens Band Handbook 1976 for help in making your choice.

For technically oriented friends who share your hobby interests, you might select such gifts as project kits, special-purpose IC's, circuit etching, breadboard kits, solder irons, or a subscription to your favorite electronics magazine (plug). Try to choose items which parallel your friends' special areas of interest—a microprocessor or memory IC for those interested in microcomputers or control circuitry, for example. Perhaps you might choose a set of TI's new video game IC's for those with more general interests. The new TI IC's include the SN 76423 game logic with automatic random English, the SN76425 horizontal and vertical sync generator, the SN76426 character generator, the SN76427 wall and ball generator, the SN76428 game logic with manual English, and the SN76460 0 to W (Win) at 20 Digital Scoring. Supplied in standard 300-mil wide plastic packages, these new IC's may be combined to allow games with multiple balls, multiple walls, multiple players, and obstacles, and are suitable for use in tennis, hockey, racing, battle, pool, and pin ball video games.

If you prefer to choose more general technical gifts, you might check into the latest offerings from the Vector Electronics Co., Inc. (12460 Gladstone Ave., Sylmar, CA 91342). These include two new etched circuit board kits, Models 32X-1 and 32XA-1, and the Model 41X modular breadboard kit. The etched circuit kits feature positive-resist coated circuit
boards as well as bare copper clad boards, together with all the materials needed for fabricating circuits using either the direct-art-then-etch process or the positive photo-resist technique. The more complete 32XA-1 kit includes seven circuit boards and is priced at $28.00, while the smaller 32X-1 kit includes two boards and costs $11.50. Vector’s new 41X breadboard kit features the firm’s patented slit-N-wrap wiring tool, and includes ten 16-pin DIP sockets, press-in wrap posts plus an installation tool, bus strips, socket cards, and other hardware, and is priced at a little over sixty-three dollars.

**Clocking Your Circuits.** Many digital logic and microprocessor circuit designs require a fixed frequency pulse source for timing. The circuits supplying these signals, essentially simple oscillators, generally are called clocks, since their primary function is to provide a timing signal. A number of simple and inexpensive clock generator circuits are illustrated in Figs. 1 through 3. Designed specifically for use with the Signetics 2650 Microprocessor, the circuits are suitable for use with any microprocessor or logic circuit requiring single-phase, TTL-level signals. They may be used, too, as general-purpose signal sources for various other projects, such as signal generators, electronic musical instruments, function generators, or signal injectors if their operating frequencies are changed to meet the needs of the specific application. All of the circuits were abstracted from Application Memo MP52, published by the Signetics Corporation (811 East Arques Ave., Sunnyvale, CA 94086).

A pair of simple RC oscillators is shown in Fig. 1. The first, Fig 1A, uses three standard 7400 inverters. Resistor R biases the first inverter into its linear region while capacitor C provides the feedback signal from the second stage needed to start and sustain oscillation. The third inverter serves as a simple buffer/driver. The circuit’s oscillation period is approximately 3RC or, with the component values specified, about 1 µs, resulting in an output frequency of 1 MHz. In test mea-
sures with a breadboarded circuit, the output signal had a 10-ns rise time and a 7-ns fall time. While the circuit is reasonably stable, its output frequency will vary with changes in both temperature and dc source voltage (VCC).

In a typical circuit, the output frequency dropped from 1043.20 kHz at 0°C to 990.45 kHz at 70°C with VCC held constant at 5.0 volts. When the temperature was held constant at 25°C, the output frequency dropped from 1028.95 kHz with a 4.75-volt source to 1013.63 kHz with a 5.25-volt VCC. The second RC oscillator, Fig. 1B, uses a type N74123 monostable multivibrator and is somewhat more stable with respect to temperature variations than the inverter circuit. Here, the frequency of oscillation is determined by the relative pulse width of each monostable circuit and hence by the external R and C values. Again, with the values indicated, the operating frequency is approximately 1 MHz. As in the first circuit, the output frequency drops slightly with increasing temperature and/or dc supply voltage.

Having even greater stability with respect to temperature and voltage variations than the two RC oscillators, the LC clock generator circuit shown in Fig. 2 uses a pair of 7400 type inverters, an 82-ohm feedback resistor which also biases the first inverter into its linear region, and a simple LC resonant circuit made up of inductance L and capacitors C1 and C2. In operation, the LC circuit forms a basic Colpitts oscillator in conjunction with the first inverter, while the second inverter acts as a buffer amplifier to minimize oscillator loading. The operating frequency is determined by the L, C1 and C2 values, and can be calculated using the following equation:

\[
f_{osc} = \frac{1}{2\pi \sqrt{LC}}.
\]

where “C” is the effective series capacity of C1 and C2, or:

\[
C = C1C2/C1+C2.
\]

With the values specified, the fosc as in the previous circuits, is approximately 1 MHz. In experimental tests, the actual output frequency of a breadboarded circuit varied from 1017.75 kHz to 1016.30 kHz as the dc source voltage was raised from 4.75 to 5.25 volts at 25°C. When the dc voltage was held constant at 5 volts, the output frequency dropped from 1026.62 kHz to 1004.11 kHz as the ambient temperature was raised from 0°C to 70°C.

In applications where maximum frequency stability is required, crystal-controlled clock circuits should be used. A pair of suitable circuits is given in Fig. 3. The first, Fig. 3A, employs two inverters in a crystal stabilized cross-coupled multivibrator. In operation, the 820-ohm resistors bias each inverter into its linear region, while cross-coupling is provided by the crystal and by a 10-nF capacitor. A third inverter serves as a waveform squarer and output buffer. All three are type 7404 (i.e., half of a hex inverter IC). The circuit’s output frequency is determined by the crystal and a suitable type must be used to obtain a 1-MHz output signal. The second circuit, Fig. 3B, employs an inexpensive 4.433618-MHz crystal of the type used in many European color-TV sets. Again, the crystal is used with cross-coupled inverters to form an oscillator; but, in this case, the oscillator’s output frequency is divided by four by the cascaded N7474 flip-flops to develop an (approximately) 1-
MHz output signal. In both circuits, overall frequency stability with respect to temperature and source voltage is determined by the crystals' characteristics.

When duplicating the clock generator circuits for specific projects, remember that the series 7400 IC's specified require a well-filtered, reasonably well-regulated 5-volt dc source, and that the power (Vcc) and GND connections must be made to the specified pins of each device, as indicated by the appropriate terminal diagrams. All resistors are 1/4- or 1/2-watt types, while the capacitors can be either ceramic, mica, or plastic film units. Neither lead dress nor layout should be overly critical but, of course, good wiring practice should be observed, with signal-carrying leads kept short and direct.

Reader's Circuit. Submitted by a 17-year old reader, David Wang (1490 Waukazo Drive, Holland, MI 49423), the digital electronic lock circuit illustrated in Fig. 4 features inexpensive 7400 series TTL IC's in conjunction with a pair of type 555 timers. David writes that he assembled his original model for under five dollars by using an inexpensive surplus "4-banger" calculator keyboard for his basic switch array. In operation, the lock is opened (i.e., the external sensitive relay is activated) when a five-number combination is entered within a specified time limit. No number may be entered twice or out of sequence. If any number not in the combination is entered, a "penalty" delay is activated which prevents circuit operation for, during the penalty period, the lock circuit is held in reset and not even the right sequence will activate it. The combination of a limited operational time once the initial key is pressed and an unknown penalty time if a wrong key is pressed makes the lock exceedingly difficult to defeat by "guess" and manipulation.

The basic circuit consists of four interconnected J-K flip-flops, with the Q terminal of the last one providing the circuit's output signal. Operation is initiated when the 555 "enable" timer is switched to a low state by depressing key 1. Thereafter, the flip-flops are clocked in turn by depressing keys 2, 3, 4 and 5 in order. After the preset time delay, the enable timer goes to a high state, triggering the flip-flop chain and providing an output signal. If any of the penalty keys is pressed accidentally, the penalty timer is activated, applying a signal through logic gates to hold the flip-flops in a reset state for a given time.

The initial (operational) time delay is established at about 3 seconds by a 1-megohm resistor in conjunction with the 1-μF capacitor, R4 and C3, respectively, while the longer "penalty" delay is determined by R5 and C4. Capacitor C1, shunted by R1, serves to reset the final flip-flop when the circuit is first switched on. In the power supply circuit, R3 and C2 form a simple keyboard debounce filter. Series resistor R2 in the penalty timer circuit serves to stabilize the 555 against false triggering.

With neither parts placement nor wiring arrangement critical, the electronic lock circuit can be assembled on perf board using point-to-point wiring or on a suitable etched circuit board, as preferred. All the resistors are 1/2-watt types, while the capacitors can be either low-voltage ceramics or electrolytics, as appropriate to their values. The flip-flop IC's are type 7473, the logic gates 7400, and the timers, as indicated previously, type 555. The combination switches are spst momentary-contact pushbutton types (as on a calculator keyboard), while the main power switch is a spst toggle, slide, or rotary type. The lock circuit's output can be used to activate a sensitive relay or as a control signal for other logic circuitry.

Until next year ... Happy Holidays!

POPULAR ELECTRONICS
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MORE ON MOBILE ANTENNAS

MOST of us are aware that no real antenna radiates isotropically (equally well in all directions). Even if there were such an antenna, its radiation characteristics would be distorted by many external physical factors, such as height, surrounding terrain, mineral deposits, towers, buildings, etc. In a mobile installation, many of these factors are constantly changing and cannot be controlled. However, when an antenna is mounted on a vehicle which is largely composed of metal, the metal components exert the major influence on the antenna's directional characteristics.

Radiation Patterns. A convenient way to describe an antenna's performance and directionality is by studying its radiation pattern. Ideally, we would like to display the antenna system's signal strength like contour lines on a map. That is, we would like to know at what distance(s) from the antenna we could expect to see the same signal strength, just as pressure "isobars" are plotted on a weather map. Unfortunately, this type of measurement is very difficult to perform. Instead, radiation patterns are developed by observing the signal intensity at a fixed radius from the antenna. These observations are then plotted so that the distance from the center point can be interpreted in terms of decibels of signal strength. (Fig. 1).

Why should we be concerned about
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the directional characteristics of a mobile antenna? Primarily, because as we ride along the highways, we talk to those in front of and behind us (assuming the road is not curved). A directional antenna will reduce interference from the sides as it increases our range in the needed directions. The efficiency of the antenna system has a much greater influence upon your range than the power output of your rig.

There are three important factors to consider when installing a mobile antenna:
- Be certain that the radiation pattern is either circular, or favors the fore-and-aft direction.
- Be sure that it is radiating as much of the r-f power supplied to it as possible.
- Keep the primary lobe of radiated energy as low as possible, closest to the horizontal plane.

Although we normally examine the radiation pattern by looking "down" onto the horizontal plane, we should not overlook the fact that the radiation pattern is actually three-dimensional. Most antennas have a doughnut-shaped pattern (Fig. 2). It is important to keep the "doughnut" as squat as possible and thus have the major lobe (most of the signal) down on the horizon where your contacts are.

**Antenna Types.** Most radiation studies to date on CB mobile antennas have dealt primarily with classic antenna
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If the antenna is mounted on the left or right rain gutter or cowler, the pattern will be distorted, with the major lobe directed toward the opposite side of the car. A centerline location is far more desirable than either of these asymmetric locations. Similarly, an 108-inch whip mounted on the rear bumper will suffer the same deficiency. Even though it can offer a larger area for radiation and greater efficiency, its effectiveness is lost to the inadequate ground plane.

Another aspect which is important to an efficient antenna installation is the desirability of a "hard ground" directly to the antenna. These studies reveal a combination of factors that strongly favor the quarter-wave antenna for mobile use.

The half-wave dipole is far too unwieldy in size (18 feet) for use on vehicles, although physically shortened versions are available for use on wood and fiberglass boats and other vehicles without adequate ground plane surfaces. However, the metal mass of most vehicles will provide a ground plane, whether it is needed or not. Even fiberglass vehicles possess large metal parts which affect the antenna system.

On the other hand, the quarter-wave antenna requires a ground plane to reflect its mirror-image, making it "look" like a half-wave dipole. Ideally, the ground plane should extend at least a quarter wavelength in all directions from the antenna base. In practice, the ground plane is seldom as large (a circle 18 feet in diameter) as it should be. The ground plane should be a flat surface perpendicular to the axis of the antenna. A sloping ground plane will distort the radiation pattern by presenting the image of a bent dipole, and it will also modify signal polarization.

The sloping ground plane, such as might be encountered on a hatch-back, will also tilt the major lobe both skyward in the front and into the ground towards the rear. The effects of an asymmetric or incomplete ground plane will normally tend to extend the major lobe in the direction of the largest ground plane area and suppress the lobe in the shortest direction of the ground plane.

Antenna Mounts. Ideally, the antenna should be placed at the geometric center of the highest horizontal metal surface, normally the roof. However, many people do not wish to punch holes in their automobiles, and instead mount the antenna on the trunk lid, the second most favorable location.

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the ground plane at the antenna base, as well as through the coaxial antenna cable.

**Dual Antennas.** As more and more newcomers have joined the CB ranks this year, I have noticed a proliferation of dual, co-phased antennas on every type of a vehicle from 18-wheelers to Volks-wagons. Why are these twin systems being installed? I guess the major reason is that uninformed operators feel that, “If one antenna can get my signal out five miles, two antennas ought to do twice as well.” Unfortunately for those who have spent large sums to put two antennas on their vehicles, it is simply not true.

Antenna design engineers know that co-phased antennas mounted on a perfect ground plane and separated by a half wavelength (18 feet) will exhibit about 3 dB gain (or double the effective radiated power) over a single antenna. However, when the spacing between them is reduced to 10 feet, the gain is only about 1 dB (the minimum gain detectable). With smaller separations, the gain is even less and the radiated signal has about the same strength as that from a single, properly mounted antenna.

There are some circumstances in which dual antennas serve very useful purposes. But these situations are very limited and are difficult to handle in any other manner. For example, on an 18-wheeler that has a high metal box behind it, co-phased antennas mounted as far apart as possible on the side mirrors may be the only viable solution for “reaching around” behind the vehicle. Likewise, on a recreational vehicle with an upper cab entirely composed of fiberglass, side-mounted 108” whips might provide a good answer. However, they would definitely function most effectively if mounted as close as possible to the fore-n-aft center of the vehicle, rather than at one end. In this case, the reason for using co-phased antennas is to improve the radiation pattern, and power gain is not significant.

To be at all successful, dual antennas must be “co-phased” properly. That is, the coaxial feed cables must be of the correct impedance and exactly the correct length to cause the two antennas to radiate or pickup signals in such a manner that they will work together additively. It is imperative that the cables supplied by the manufacturer not be shortened, and I suggest that you do not try to make a harness unless you are well versed in antenna theory and practice.

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I was astounded the other day to hear that some of my neighbors have “found a way to double their power legally.” It seems that they have determined that there is no rule against operating two rigs from one vehicle each feeding a separate antenna but, using the same microphone.

There is only one trouble with their theory: it won’t work. Unless the two transmitters are driven from a common frequency determining device (and that is illegal), they will not operate at precisely the same frequency. The result will be a fluctuating signal as the two transmitters shift in and out of phase. This would produce unbelievably bad heterodynes. Also, doubling the output power will increase the received signal only 3 dB—about one half of an S unit. Don’t do it!

Whips. Quarter-wave mobile antennas are generally classified in one of the following types:
- full-sized ¼-wave whip (108-inch length)
- base-loaded
- center-loaded
- top-loaded
- continuously loaded

The last three of these antenna types are sufficiently similar that they will be discussed as a single type.

Undoubtedly, the most efficient type is the full-length whip because it reaches higher, presents a greater radiation length than any of its loaded (physically shortened) cousins, and wastes no power heating up a coil. Unfortunately, a nine-foot antenna cannot be mounted in a position which will provide it with a full ground plane, as can many of its counterparts. Most of its plausible mounting locations result in radiation patterns which are badly distorted. For this reason, the shorter antennas are more popular and in most cases outperform the whip.

The workhorse of compact antennas has been the base-loaded whip. It requires an adequate ground plane and does not perform well without one. It features a low radiation angle, and is usually made of a slender steel spring shaft which offers little wind resistance and stands straight at highway speeds. The most favorable locations to mount a base-loaded antenna are the center of a steel roof or on the trunk lid of a sedan. It should be mounted on the vehicle’s centerline.

The three final antenna types carry their loading coils higher on the antenna shaft. As a rule, the higher the coil is located, the more efficient the antenna. Therefore, they are more efficient than base-loaded whips. However, these antennas are more prone to damage from low obstructions than base-loaded ones. The vertical angle of radiation is generally higher for these antenna types, but they perform better in locations where the ground plane is poor and are better suited to mirror or gutter mounting. For this reason, they are usually found in cophased arrays. They also work well where there is a good ground plane, but if their loading coils are bulky they will offer more wind resistance. However, some of the newer continuously loaded fiberglass antennas are nearly as slender as a base-loaded steel whip.

Other Considerations. Antennas that sway in the wind usually produce varying signal strengths at the receiver. Antennas which bend over backwards at highway speeds radiate obliquely polarized signals which are not well received by vertically polarized antennas. Whatever the antenna type, it is strongly recommended that it be well grounded at the antenna base as well as through the coax.

Now that 40 channels have been authorized for Class D, the bandwidth is increased to 0.405 MHz. Some antennas might not give adequate performance across the entire band. There should be no trouble with antennas in excess of three feet in length; but the shorter the antenna, the more critical tuning becomes. The center frequency of the extended band will fall between channels 20 and 21, whereas the band center is now at channel 13. If you get a 40-channel rig, retune the antenna for optimum performance at the new center frequency. However, if you have a mini-whip, you might find it difficult to achieve an acceptable SWR across the entire band.

Speaking of SWR, it should be checked when the antenna is installed, and checked again periodically to insure that the antenna is still functioning properly. The SWR should be held under 3:1; and unless the rig is SWR protected, a higher SWR might severely damage your transmitter.

Following the guidelines given here, you should be able to plan an efficient mobile antenna system and select the proper antenna for your vehicle. You should buy a commercially available antenna of proven performance. If the mounting instructions are followed carefully, anyone who can handle a screwdriver should be able to install an antenna properly.
LAMP CIRCUIT QUIZ

TO TEST YOUR ABILITY TO TRACE OUT LAMP CIRCUITS, WRITE THE DIGIT 1 INSIDE EACH CIRCLE REPRESENTING A LAMP IF IT LIGHTS TO ITS MAXIMUM POSSIBLE BRIGHTNESS, A 2 IF IT HAS ANYTHING LESS THAN FULL BRIGHTNESS, AND A 3 IF IT DOESN'T LIGHT AT ALL.

ASSUME THAT ALL OF THE LAMP FILAMENTS AND RESISTORS HAVE THE SAME VALUE OF RESISTANCE.

A.

B.

C.

D.

E.

F.

G.

H.

ANSWERS:

A. 1-2-3-1
B. 3-1-3-2
C. 3-2-3-1
D. 2-3-2-1
E. 1-2-3-1
F. 2-1-3-2
G. 2-3-2-1
H. 3-1-3-2
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BOOKS ON PROGRAMMING

Perhaps the manual that came with your microcomputer kit is a little light on the software side, and doesn't tell you what you want to know about programming in assembly language. Or maybe there was no manual at all with the BASIC interpreter you bought, and you're not familiar with that language. So you start looking for a book. But first, a few words about both languages.

In talking with a number of computer hobbyists about what programming languages they use, it turns out that only a few are really into heavy assembly-language programming; most of them use BASIC. Assembly language, to quote from a Scelbi book, "is by far the most efficient method for packing a program into a small amount of memory," and for that reason is widely used in business, where there is a demand for highly efficient programs. But since the average person is more interested in what can be accomplished with a program than in the program itself, or in its efficiency, BASIC is in much greater use in schools, colleges, and among computer hobbyists. However, since there is an interest in assembly language, and because a computer with a minimum amount of memory can be programmed only in assembly language, let's look at some books on that subject.

Assembly Language. Although there are several excellent books on assembly language, there isn't one I've seen so far that's meant for the average electronics hobbyist—that is, a book that assumes the reader knows nothing at all about programming. Perhaps this is because assembly language is a rather difficult language for programming, as far as most hobbyists are concerned. I don't mean the "Computer Freaks," who enjoy working down at the machine-language level. I mean a person who knows little or nothing about computers, and who in fact may not even know what assembly-language programs are. Writing such programs requires a great amount of attention to tiny detail, as well as a great deal of time, in comparison with writing a program in BASIC (or other high-level language) to perform the same task.

The ideal (but nonexistent) book on assembly language should assume the reader is starting from zero. After a chapter or two on the elements of programming and flowcharting, it should introduce him to instructions such as LDA, MOV and STA, in small groups or one at a time, explain them thoroughly, and give a variety of short programs using them. It should fully explain how each program works and what it does.
The problem with creating such a book is that, in order to be as all-encompassing as it should be for the beginner, going into detail for each of the 78 instructions for the 8080 MPU, or the 158 for the Z-80, the book would have to be an inch or two thick. It's much easier to assume, as most of the current books do, that the reader is a programmer or an engineer, or at least has had quite a bit of exposure to computers and programming. This is similar to a manual on jet-engine repair that assumes you know all about tools and techniques.

**Osborne.** The best book I know of for learning about microcomputers won't tell you as much as you may want to know about programming, but it does an outstanding job of going into the hardware and software of seven of the top microprocessors. An *Introduction to Microprocessors*, published by Adam Osborne and Associates at $7.50, starts out with six chapters on the fundamentals, going into binary arithmetic and Boolean algebra, microcomputer organization, what's in an MPU (microprocessor unit) and how it works, CPU logic, and the elements of programming (memory addressing, stacks, and instruction sets); in meticulous detail.

The programming chapter ends by creating a "complete, but hypothetical, microcomputer instruction set," and showing why each instruction is required. This hypothetical set becomes the standard to which the seven real sets are compared, those of the F8, PACE and SC/MP, 8080, 6800, PPS-8 (Rockwell), and 2650. A meaty 138-page chapter has a "look at the way in which a variety of manufacturers have chosen to implement the basic concepts which have been described in Chapters 1 through 6."

For each MPU, the book goes into the registers, addressing modes, status flags, pins and signals, interfaces, interrupts, DMA (direct memory access), and instruction set. This is not an easy book to read because a great deal is packed into it, in rather small type, and it moves at a very fast pace. But no other book available today contains so much information about microcomputers in such a small package—only a little larger than most paperbacks. It's included with every Imsai computer as part of the support documentation. IMS calls it "an excellent 460-page book that teaches how a computer is programmed and presents an overview of microcomputer technology."

The second edition of the Osborne book has been revised and expanded to two volumes, at $7.50 each. Volume 1, "Basic Concepts," covers the first six chapters of the first edition, with new sections on chip-slice products and serial I/O. Volume 2, "Some Real Products," which expands on the original Chapter 7 to include more microprocessors, was due to be published late in October, as of this writing.

**Scelbi.** Scelbi was an early producer of a hobby computer kit. It later dropped out of the hardware business to concentrate on software. To date, Scelbi has produced half a dozen software manuals, on an assembler, editor and monitors for the 8080 MPU, and several others. They've just come out (at this writing) with a new book, a small paperback called *Scelbi 8080 Software Gourmet Guide & Cook Book*, at $9.95. The book has eight chapters, on the 8080 stack, general-purpose routines, conversions routines, decimal arithmetic routines, floating-point routines, input/output processing, and search and sort routines plus a number of helpful appen-
The book shows, better than most, the complexity of having to load a group of assembly-language programs into your computer, such as decimal-to-binary input, floating-point normalization, floating-point multiplication, binary-to-decimal output, operating program, etc. Of course, if you’re interested only in simple programs, without decimals, for games or for control applications, then you don’t need all those routines. How much simpler to work in BASIC, where all the necessary routines are included in one program!

This new Scelbi book, on the 8080, is bound to become better known than their first best-seller, *Machine Language Programming for the 8008 and Similar Microcomputers*, at $19.95 (twice the price as well as twice the size). This larger book (8½” x 11”) has been recommended to me by several computer-kit manufacturers, and can be found on the shelves of many computer stores. It has nine chapters. They cover the 8008 instruction set, initial steps for developing programs, fundamental programming skills, basic programming techniques, mathematical operations, input/output programming, real-time programming, PROM programming considerations, and creative programming concepts.

The first chapters of the two books are pretty much the same, except that the 8080 book covers 78 instructions to the 8008 book’s 48, but most of the remaining material is very different. The floating-point programs are almost identical, because the 8008 instruction set is a subset of the 8080 set. An 8008 program will run on an 8080 machine without having to be changed. For the 8080 book, the author has improved on the 8080 programs by taking advantage of some of the more powerful 8080 instructions, such as those for double-precision operations, not found in the 8008 set.

**BASIC.** Over 40 books about programming in BASIC have been written, and most of them are fairly good. The authors write with varying degrees of enthusiasm, ranging from “BASIC is great!” to “BASIC is OK, but let me tell you a little about FORTRAN.” A small handful of these books is outstanding. Here are two of them.

**Kemeny and Kurtz.** The best book on BASIC is a classic, the standard by which all other such books must be measured. It was written by the originators of the language, John Kemeny (now president of Dartmouth) and Thomas Kurtz (Dartmouth’s Director of Academic Computing). *BASIC Programming*, published by Wiley at $8.50, pays very careful attention to every detail, taking great care that the reader will have as little difficulty as possible in learning BASIC. The first chapter presents and explains a five-line program that divides one constant by another.

The second program, although 17 lines long, is quite simple, and converts meters and centimeters to feet and inches, with a page and a half of explanation. An entire chapter is devoted to loops, the heart of many programs. The concept of rounding off numbers with
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the INT statement is not simple, yet the authors, by going through each part of such a statement, have found what must be the simplest way of explaining it.

The chapter on simulation contains a baseball program that simulates the batting of one side in a nine-inning game, and one on the Knight's Tour problem. The section on harmony in music gives a long program that writes four-part harmony for a given melody.

Each chapter on applications provides a couple of projects, more complicated than the chapter exercises, that should provide the reader who has a terminal with a very thorough workout of his knowledge of BASIC. Not all the chapters are easy to understand, since several go into areas such as vectors and matrices, statistics, and calculus. Although most of the book can be understood "with a background of three years of high school mathematics," these three math areas "are normally taught at the college level." Not everybody will dig into these chapters, but they're there for those who want to, and for those who will eventually learn the requisite math.


The book is in four parts. "Getting Ready for the Journey" covers the basics and LET, PRINT and END. Six more statements are introduced in "The Economy Tour." "Techniques for the Seasoned Traveler" brings in nine more statements plus library functions. Nine applications programs are presented in "Far Away Places." The book covers 20 statements altogether, all you'll need for most applications. Although it's meant to be used with a terminal, this book doesn't have to be.

As an indication of the book's ingenuity variety, the applications programs in Part 4 include those for a hotel reservation system, generating brand names for soap, slot-machine games (cherries, lemons, oranges), monthly installment payments on a loan, and payroll.

One of the most important features is the many callouts to the programs, outlined in red, with a red line pointing to the line or lines they explain. Each of the four parts is divided into sections. At the end of each section is a review of the material covered, and there are several sets of exercises in each of the parts.

This fine book is mainly for young people, but it will be of value to anyone. It is full of detail, with many examples and much thought given to the use of graphics in teaching.

Your Favorite Book. If your favorite book on assembly language or BASIC isn't one of the five mentioned here, please don't fret. There are many other fine books, out of the 60 or more on the two languages. The ones discussed are among my favorites, given limited editorial space. However, future columns will refer to other books of interest, on both programming and applications.
ARRL ELECTRONICS DATA BOOK  
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Here is a compilation of data useful to the electronics experimenter, regardless of his level of experience. It contains ten chapters, and among the subjects treated in depth are r-f circuit data, L, C, and R networks, broad and narrow band transformer design, filter design, antennas and feed systems, and a catalog of practical solid-state circuits. All chapters include pertinent simple equations with representative solutions. Toroidal designs are emphasized in the transformer chapter. Modern filter design covers two- and three-pole Butterworth derivations for most of the frequencies of interest to amateurs, and tables of practical filter values are included.

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Applications of electricity and electronics—from the basics of alternators to digital computer automotive analysis—are examined in this book. Topics discussed are electronic charging and ignition systems, safety appliances, emission and performance devices, radios and tape players, comfort and convenience systems, automotive test equipment, computers and cars today, computer basics, and advanced automotive technology. Both theory of operation and troubleshooting information are included. Schematics, line drawings, and illustrations supplement the text. Published by Tab Books, Blue Ridge Summit, PA 17214. 266 pages. $5.95 soft cover.

RCA SOLID STATE REPLACEMENT GUIDE  
The updated RCA Solid State Replacement Guide, SPG-202R, lists more than 103,000 industry types which are replaceable by only 250 RCA SK devices, including 32 new types. Significant ratings and characteristics are given for each device to aid selection of the optimum replacement semiconductor. Dimensional outlines of device packages and terminal diagrams are given, as well as a revised hardware replacement directory.

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Bendix Radio Facio Meter, Model 847 S. Field Test Receiver/AM and FM. Schematic diagram needed. Bill Coleman, Jr., 114 Circle Drive, Rocky Mount, NC 27801.

Crosley Model 146CS all-wave and FM 200-300-MHz receiver. Also BC342. Schematics needed. Monroe Pinick, 509 S. John's Dr., Sherman, IL 62684.


Hammarlund HQ-110C receiver. Schematic, alignment, and any other information. Mark D. Koski, R.R. 2, Box 329, Camp Point, IL 62620.

CG Electronics Corp. Model TR-2 Junction Transistor Tester. Schematic and/or operations manual, or address for the company (formerly Albuquerque, NM): Paul Van Aken, 23433 Finis St., Woodland Hills, CA 91364

Any schematics or information on voice synthesizers or voice command switches. Craig Boyce, 176 E. 77 St., New York, NY 10021.


Superior Instruments Model TV-11 Tube and Condenser Tester, Lafayette Micro P 100-A police radio. Schematics, operations manuals, or any available info. Also interested in schematic for any type of electronic coin cleaner. Philip Hawkins, 124 Summer St., Central Falls, RI 02833.

EICO Model 400 oscilloscope, serial #1769. Manuals and any other info. David Allfield, 142-20 86th Drive, Jamaica, NY 11435.


Devry Tech. Inst. 5-inch scope with SJPI CRT. Model No. unknown. Need operating manual, schematic, and calibration data. A. Garvenik, Box 88, Lawton, MI 49065.


Norelco Model 2401 cassette recorder. Parts source. Wybrow Goodfery, 1022 SE Dogwood Lane, Milwaukee, WI 53222.

Halticrafters Model S-40 receiver. Need a circuit with values for an S meter. A. McGinnis, 55 Patton St., Dublin, NJ 08830.
THE NEON GLOW LAMP

I
n this day of solid-state technology, the humble neon glow lamp still has much to offer to the experimenter. Besides its luminescence, the glow bulb displays negative resistance behavior. Because of this, it is often found in voltage regulator and relaxation oscillator circuits. Best of all, glow lamps are inexpensive. You can purchase them from advertisers in the Electronics Marketplace for as little as a nickel each in quantities of several dozen.

Before we look at some interesting glow lamp circuits, let's review some of the basic operating principles of this versatile component. Knowledge of its operating characteristics will enable you to design your own circuits.

An outline view of a typical glow lamp is shown in Fig. 1. Few electronic components are as structurally simple—a glow lamp consists merely of a gas-filled bulb and a pair of electrodes to which wire leads have been attached.

Normally, the resistance of the gas between the two electrodes is so high that the lamp can be considered an open circuit. But when the voltage across the lamp is raised to the critical initial breakdown voltage, the gas ionizes and becomes highly conductive. The ionized gas glows with a characteristic color. Neon, the most common filler gas, glows orange. Argon, which is sometimes used, has a blue glow.

Figure 2 shows the I-V characteristics of a typical neon bulb. Until the breakdown voltage $V_b$ is reached, current through the lamp is very small. (This voltage will vary between 55 and 150 volts for commercially available bulbs.) When the bulb fires, it enters the normal glow region of its I-V curve. In this region, the soft, luminous glow is confined to the negative electrode, and the glow area increases directly with lamp current. The voltage-regulating properties of the neon lamp are self-evident in Fig. 2. A nearly constant voltage drop $V_b$ exists across the lamp even though the current varies over a wide range.

When current is so high that the entire surface of the electrode is covered by the glow, the voltage across the lamp rises. The neon lamp has then entered the abnormal glow region. If lamp current further increases, the lamp is operating in the arc region. Here, the voltage across the lamp drops and the orange-colored discharge becomes a bright point of bluish-white light centered on the cathode (negative) electrode. Prolonged operation in the abnormal glow region, and even a brief incursion into the arc region will destroy the lamp.

Although neon lamps operate at fairly high voltages, they consume small amounts of power, and most commercial devices are rated at a continuous current of 0.1 to 10 mA.

Fig. 1. Sketch of neon lamp's construction.

Fig. 2. Neon lamp's I-V characteristic.

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Some Precautions. Neon glow lamps are simple to use, but you should be aware of a few special restrictions. First, these lamps are subject to what is called the dark effect. That is, ionization of the gas is much more easily accomplished in the presence of ambient light. In total darkness, the glow lamp operates erratically, and its breakdown voltage increases significantly. To overcome this problem, many neon lamps contain a minute amount of radioactive gas, which stimulates ionization.

A second operating restriction is the necessity to avoid excessive operating voltages. Too much voltage will cause the lamp to operate in the abnormal glow or arc region. The third consideration is current limiting. It is necessary to place a resistor in series with a continuously operated glow lamp. This ballast resistor limits the current through the lamp to a safe value. If we assume that an ionized glow lamp has practically no resistance but a voltage drop of 80 volts, Ohm's and Kirchoff's laws dictate that a 100,000-ohm ballast resistor will allow a safe 200 μA to flow through a glow lamp connected to a 100-volt dc source.

Glow Lamp Circuits. Now that we've covered some of the basics of glow lamp operation, let's examine several practical circuits. You can use the miniature dc-dc converter described in last month's column or a pair of 67½-volt batteries connected in series as a power supply.

![Fig. 3. Relaxation oscillator.](image)

The simplest circuit is the glow-lamp relaxation oscillator shown in Fig. 3. In operation, C1 charges through R1 until the breakdown voltage of the neon lamp is reached. At that point, C1 discharges through the lamp and produces an orange flash. When the voltage across

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C1 drops below the voltage necessary to keep the lamp conducting, the lamp goes dark. Then C1 begins to charge and the cycle repeats.

To see the glow-lamp flash you will have to use at least a 1-megohm resistor. Otherwise the flash rate will be faster than the 18 pulses per second discernible by the human eye and the lamp will appear continuously on. Also, use 200-volt capacitors in this and the following circuits because of the high voltages present.

You can connect an oscilloscope across C1 to verify that the circuit is oscillating if you choose to operate it at audio frequencies. Alternatively, you can connect an 8-ohm speaker between the glow lamp and ground or place the circuit near a radio to actually hear the oscillation frequency or its harmonics.

If you're familiar with neon-lamp relaxation oscillators, you probably know that several circuits like the one shown in Fig. 3 can be cascaded to produce a pseudo-random flashing effect. These circuits are often seen flashing away in electronics labs and are called "do-nothing boxes" or "idiot lights."

An astable multivibrator made from two glow lamps is shown in Fig. 4. If we assume I1 has a lower turn-on voltage than I2, I1 will turn on first after power has been applied. This permits C1 to charge through R2 and I1. When the voltage across C1 exceeds the turn-on voltage of I2, I2 turns on and I1 turns off. Now C1 charges through R1 and I2 until its charge fires I1. Lamp I2 then turns off, C1 begins charging through R2, and the cycle repeats.

The circuits described here incorporate a relaxation oscillator, and you can easily vary the repetition rates of the oscillators by altering the values for the resistor and capacitor which, together with the lamp, form the oscillator (R1 and C1 in Fig. 3, etc.). Higher values of resistance or capacitance will slow the repetition rate. But try to keep R1 above 100,000 ohms, and C1 below 1uF.

If you do experiment with any of these circuits, be sure to observe standard safety precautions. Even a 67½-volt battery can deliver a sharp shock, and if the shock itself doesn't affect you, the resulting reflex action may dash your wrist or elbow into your work bench or chair.

For best results and optimum safety, stick to batteries or miniature high-voltage power supplies like the one described in last month's column. If you must use line power, never operate a glow-lamp circuit from the ac line without using a 1:1 isolation transformer.
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<th>Type</th>
<th>Power Supply</th>
<th>Display LEDs</th>
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<tr>
<td>Common Cathode</td>
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<tr>
<td>DIP-14</td>
<td>14</td>
<td>793137</td>
</tr>
<tr>
<td>SO-14</td>
<td>14</td>
<td>793138</td>
</tr>
</tbody>
</table>

#### DIP Switch

- **Features:**
  - Two 4-bit switches
  - Dual memory storage
  - Power-off memory retention

**Price:** $1.95

---

#### ClipLite 4/4/$1.00

**New LED Mounting System**

- **ClipLite** features a unique 30° angled bend that folds the leads.

**Price:** $1.00

---

#### Zero Diodes - Recifiers

<table>
<thead>
<tr>
<th>Type</th>
<th>Value</th>
<th>DC Current</th>
<th>Peak Inverse Voltage</th>
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<tbody>
<tr>
<td>1N4001</td>
<td>1N4002</td>
<td>1N4003</td>
<td>1N4004</td>
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#### SCR and FW Bridge Recifiers

<table>
<thead>
<tr>
<th>Type</th>
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<th>DC Current</th>
<th>Peak Inverse Voltage</th>
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<tbody>
<tr>
<td>2N7000</td>
<td>2N7001</td>
<td>2N7002</td>
<td>2N7003</td>
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#### Transistors

<table>
<thead>
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<th>Type</th>
<th>Value</th>
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</tr>
</thead>
<tbody>
<tr>
<td>2N3904</td>
<td>2N3905</td>
<td>2N3906</td>
<td>2N3907</td>
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</tbody>
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#### Capacitors

<table>
<thead>
<tr>
<th>Type</th>
<th>Value</th>
<th>DC Current</th>
<th>Peak Inverse Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>22pF</td>
<td>22nF</td>
<td>22uF</td>
<td>22mF</td>
</tr>
</tbody>
</table>

#### Sales

**50 Pcs. Resistor Assortments** $1.75

<table>
<thead>
<tr>
<th>Assortment</th>
<th>Value</th>
<th>DC Current</th>
<th>Peak Inverse Voltage</th>
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</thead>
<tbody>
<tr>
<td>0010</td>
<td>0011</td>
<td>0012</td>
<td>0013</td>
</tr>
</tbody>
</table>

**XR-2200K Kit** $17.95

**XR-2200KB Kit** $27.95

---

**Data Handbooks**

- **1240** Pin 2400 Description of 1240 ICS 35k.
- **CMOS** Pin 4400 Description of 4400 ICS 25k.
- **LSI** Pin 8400 Description of 8400 ICS 25k.

**All Three Handbooks** $6.95

---

**100 Per Strip**

**Molex Pins**

**NEW **

**Data Handbooks**

**All Three Handbooks** $6.95

---

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**CRystals**

<table>
<thead>
<tr>
<th>Part #</th>
<th>Frequency</th>
<th>Case Style</th>
<th>Case Size</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>CY1A</td>
<td>1,024 MHz</td>
<td>HC256U</td>
<td>20 x 17 mm</td>
<td>$0.95</td>
</tr>
<tr>
<td>CY2A</td>
<td>2,048 MHz</td>
<td>HC256U</td>
<td>20 x 17 mm</td>
<td>$0.95</td>
</tr>
<tr>
<td>CY3A</td>
<td>4,096 MHz</td>
<td>HC256U</td>
<td>20 x 17 mm</td>
<td>$0.95</td>
</tr>
<tr>
<td>CY4A</td>
<td>8,192 MHz</td>
<td>HC256U</td>
<td>20 x 17 mm</td>
<td>$0.95</td>
</tr>
<tr>
<td>CY5A</td>
<td>16,384 MHz</td>
<td>HC256U</td>
<td>20 x 17 mm</td>
<td>$0.95</td>
</tr>
<tr>
<td>CY6A</td>
<td>32,768 MHz</td>
<td>HC256U</td>
<td>20 x 17 mm</td>
<td>$0.95</td>
</tr>
<tr>
<td>CY7A</td>
<td>65,536 MHz</td>
<td>HC256U</td>
<td>20 x 17 mm</td>
<td>$0.95</td>
</tr>
<tr>
<td>CY8A</td>
<td>131,072 MHz</td>
<td>HC256U</td>
<td>20 x 17 mm</td>
<td>$0.95</td>
</tr>
<tr>
<td>CY9A</td>
<td>262,144 MHz</td>
<td>HC256U</td>
<td>20 x 17 mm</td>
<td>$0.95</td>
</tr>
<tr>
<td>CY10A</td>
<td>524,288 MHz</td>
<td>HC256U</td>
<td>20 x 17 mm</td>
<td>$0.95</td>
</tr>
</tbody>
</table>

**MICROPROCESSOR COMPONENTS**

| 8080A  | $5.95 |
| 8081A  | $6.95 |
| 8082A  | $7.95 |
| 8083A  | $8.95 |
| 8084A  | $9.95 |
| 8085A  | $10.95|
| 8086A  | $11.95|
| 8087A  | $12.95|
| 8088A  | $13.95|
| 8089A  | $14.95|

**8080 SUPPORT DEVICES**

| 8224  | $24.95 |

**Clock Chips - Calculator Chips**

- MN3002: 2 Digit 2.5 Digit 3-4 Digit 5-6 Digit
- MN3042: 2 Digit 2.5 Digit 3-4 Digit 5-6 Digit
- MN3044: 2 Digit 2.5 Digit 3-4 Digit 5-6 Digit

**25-Pin Connectors - D-Subminiature**

- DB25P: $3.25 each
- DB25S: $4.95 each

**3/4 DIGIT DVM KIT**

- This 0.2 VDC, 30 microvolt digital voltmeter features the Marmon 3/4 digit DVM chip set. It has a 4" LED display and operates from a single 5 VDC power supply. The unit provides complete circuitry for a rejection resistor based panel meter system complete with case. An optional power supply is available which will drive the DVM along with 111TAC components.

**Continentals Specialties**

- A-02V DVM with Case: $49.95
- B-05V Power Supply: $49.95

**VECTOR WIRING PENCIL**

- **heat sink**
- **nibbling tool & diagonal cutter**
- **63 KEYBOARD**

**DIGITAL WATCHES**

- Ladies Watch
- Quartz Clock
- 1 Year Guarantee
- Model "9000"
-Specify Gold or Chrome

**EKELAR Mens Watch**

**DIGITAL QUARTZ CAR CLOCK**

**DIGITAL CLOCK KIT - 3 1/2 INCH DIGITS**

**DIGITAL WATCHES**

**MOBILE CB ANTENNA**

**AMTEX 8 TRACK AM/FM STEREO**

**KRACO CAR SPEAKERS**

**NOVUS**

**DECEMBER 1976**

**JAMES**

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PHONE ORDERS WELCOME — (415) 592-8097

**Circle No. 48 on Free Information Card**
**MOBILE LED CLOCK**

12 VOLT AC or DC POWERED FOR FIXED OR MOBILE OPERATION.

**SIX JUMBO .4" DIGITS!**

**KIT OR ASSEMBLED**

---

**DECEMBER -**

**ORDER ASSEMBLED UNITS WIRED COMPLETE KIT**

<table>
<thead>
<tr>
<th>KIT INCLUDES</th>
<th>LARGE .4&quot; DIGITS!</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-LED Readouts (FND-395 Red, com. cathode)</td>
<td>ORDER KIT #850-4</td>
</tr>
<tr>
<td>13 Transistors</td>
<td>AN INCREDIBLE VALUE!</td>
</tr>
<tr>
<td>3 Switches</td>
<td>24-25 Molex pins for IC socket</td>
</tr>
<tr>
<td>8 Resistors</td>
<td></td>
</tr>
<tr>
<td>5 Diodes</td>
<td></td>
</tr>
</tbody>
</table>

Printed Circuit Board for kit #850-4 (etched & drilled fiberglass) $2.95

Mini-Brite LED’s for color in clock display pkg. of 5 $1.00

Modular Plug Transformer 115/10VAC (with cord) $2.50

NOTE: Entire clock may be assembled on one PC Board or Board may be cut to remote display.

Kit #850-4 will fit Plexiglass Cabinet II.

---

**6 Digit LED Clock Calendar-Alarm Kit**

This is a complete, top of the line, kit for the person that wants the best. Some of the many features and options are: 12/24 time, 28-30-31 day calendar, alternates time (8 sec.) and date (2 sec.) or can display time only and date on demand, 24 hr alarm - 10 minute snooze, alarm set indicator, 50/60 Hz. line operation or use with Xtal time base (#TB-1), built in OSC for battery back-up / AC failure, Aux. timer. Large digits.

Kit #7001B  6-4" Digits Man-64  $39.95

Kit #7001C  4-6" Digits & 2-3" (seconds)  $42.95

Kits are complete (less cabinet) including PC boards, power supply, IC socket, 9 switches, 16 transistors, and all parts required for above features and options (ideal fit in Cabinet I above).
CB Monitor Converter
• Covers Channels 1 Thru 23
Converts AM auto radio to CB monitor. 12 VDC reg. 
Ground. Styles may vary. Shpg. wt. 2 lbs.

8-TRACK 
40-Minute 
Recording 
Cassette
TA-907
Reg. $39.99
Blank tapes. Erased, not 
used. Shpg. 
E.A. wt. 1 lb.

Three 
60-Minute 
Blank 
Cassette
TA-879
Reg. $14.99
180 minutes of recording time. Shpg. 
wt. 1 lb.

Parts & Components
<table>
<thead>
<tr>
<th>Item</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4 RPM Timing Motor, 117 V. AC</td>
<td>.30</td>
</tr>
<tr>
<td>1 RPM Timing Motor, 117 V. AC</td>
<td>.30</td>
</tr>
<tr>
<td>5 RPM Reversible Motor, 117 V. AC</td>
<td>.30</td>
</tr>
<tr>
<td>100 RPM Reversible Motor, 117 V. AC</td>
<td>.30</td>
</tr>
<tr>
<td>Tubular Capacitor Kit, 100 Pcs.</td>
<td>.20</td>
</tr>
<tr>
<td>Ceramic Capacitor Kit, 100 Pcs.</td>
<td>.20</td>
</tr>
<tr>
<td>100 Ceramic Capacitors, values clearly marked</td>
<td>.20</td>
</tr>
<tr>
<td>50 Kst. Electronic Capacitors, Axial/Radial</td>
<td>.20</td>
</tr>
<tr>
<td>100 Kst. Carbon Resistors, 1/4-1/2-Watt Sizes</td>
<td>.20</td>
</tr>
<tr>
<td>5 Astd. SCR’s, 15 V. and Up, 100 MA to 1.6 AMP</td>
<td>.20</td>
</tr>
<tr>
<td>500 MA Zener Diodes, 4.3-6.9-11.2 &amp; 15 Volts</td>
<td>.20</td>
</tr>
<tr>
<td>3 Injunction Transistors, 400 V, 375 mA 4 OMS</td>
<td>.20</td>
</tr>
<tr>
<td>L.E.D. Pkg of 5 Red, 2 Volt - 5 MA</td>
<td>.50</td>
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<tr>
<td>Ultra-Mini L.E.D. Pkg. of 5 Red, 5 V. 5 MA</td>
<td>.50</td>
</tr>
<tr>
<td>TI Calculator Key Board, 20 Keys</td>
<td>.50</td>
</tr>
<tr>
<td>31/2 Digit Liquid Crystal Display</td>
<td>.50</td>
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<tr>
<td>Carlingtron Amp. Transistor Kit. 6 Transistors</td>
<td>.50</td>
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<tr>
<td>Photo Transistor, 5 Pieces - Epoxy Type</td>
<td>.50</td>
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<tr>
<td>6 Amp. Full Wave Bridge Rectifier 50 PIV</td>
<td>.50</td>
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<tr>
<td>6 Amp. Full Wave Bridge Rectifier 400 PIV</td>
<td>.50</td>
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<tr>
<td>PNP Transistor Assmpt. pkg of 10</td>
<td>.50</td>
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<tr>
<td>NPN Transistor Assmpt. pkg of 10</td>
<td>.50</td>
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<tr>
<td>7-Segment L.E.D. Display 3 in. Green</td>
<td>.50</td>
</tr>
<tr>
<td>7-Segment L.E.D. Display 3 in. Yellow</td>
<td>.50</td>
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<tr>
<td>Micro Switch Kit, 7 Assorted</td>
<td>.50</td>
</tr>
<tr>
<td>Knob Kit, 25 Pcs. Assorted</td>
<td>.50</td>
</tr>
<tr>
<td>Hobby Motor Kit, 3-6 V. DC, Pkg. 5</td>
<td>.50</td>
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Tools — Special and Practical
<table>
<thead>
<tr>
<th>Tool</th>
<th>Price</th>
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</thead>
<tbody>
<tr>
<td>Wire Wrap Tool. 30 Ga Wire on .025 Post</td>
<td>.30</td>
</tr>
<tr>
<td>IC Insertion/Extraction Tool</td>
<td>.30</td>
</tr>
<tr>
<td>IC Plug-in Test Adapter</td>
<td>.30</td>
</tr>
<tr>
<td>12 Volt DC Soldering Iron. Pencil Tip</td>
<td>.50</td>
</tr>
<tr>
<td>Turnler/Contact Cleaner, 6 Oz. Can</td>
<td>.50</td>
</tr>
<tr>
<td>Dmy Label Maker. Uses 1/4 in. Tape</td>
<td>.50</td>
</tr>
<tr>
<td>Double Face Foam Tape 1/4 x 52 In.</td>
<td>.50</td>
</tr>
</tbody>
</table>

Total
<table>
<thead>
<tr>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>.99</td>
</tr>
</tbody>
</table>

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Stick It!
HUGE SPECIAL PURCHASE!
NOT FACTORY SECONDS
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IN YOUR DVM, etc.

4 JUMBO .50 INCH DIGITS
ON ONE "STICK!"
(with colons and AM/PM Indicator)
BUY 3 FOR $10.00

BOWMAR
4 DIGIT LED READOUT ARRAY
The Bowmar Opto-Stick. The best readout bargain we have ever offered. Has four common cathode jumbo digits with all segments and cathodes brought out. Increased versatility since any of the digits may be used independently to fit your applications. Perfect for any clock chip, especially direct drive units like 50380 or 7010. Also use in freq. counters, DVM's, etc. For 12 or 24 hour format.

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8080A By AMD, Outperforms INTEL $24.00
8008-1 High Speed 8008 6.95
8212 I/O PORT 3.50
8224 Clock Generator LOW COST 4.95
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7400 - 19c 7430 - 39c 7476 - 35c 74153 - 75c
7402 - 19c 7432 - 36c 7480 - 49c 74154 - 1.00
7404 - 29c 7437 - 39c 7483 - 95c 74157 - 95c
7404 - 44c 7438 - 39c 7485 - 95c 74161 - 95c
7404 - 19c 7440 - 19c 7586 - 45c 74164 - 1.10
7408 - 29c 7447 - 85c 7587 - 1.10
7408 - 19c 7448 - 85c 7492 - 75c 74174 - 95c
7410 - 19c 7451 - 19c 7495 - 75c 74181 - 2.50
7411 - 29c 7453 - 39c 7496 - 89c 74191 - 1.25
7413 - 19c 7454 - 39c 74121 - 38c 74192 - 1.25
7420 - 19c 7474 - 35c 74213 - 65c 74193 - 1.00
60HZ CRYSTAL TIME BASE
FOR DIGITAL CLOCKS
$5.95

S. D. SALES EXCLUSIVE!

KIT FEATURES:
A. 60Hz output with accuracy comparable to a digital watch
B. Directly interfaces with all MOS Clock Chips
C. Super low power consumption (1.5 Ma typ.)
D. Uses latest MOS 17 stage divider IC
E. Eliminates forever the problem of AC line glitches
F. Perfect for cars, boats, campers, or even for portable clocks at ham field days.
G. Small size, can be used in existing enclosures.

FAIRCHILD BIG LED READOUTS
A big .50 inch easy to read character. Now available in either common anode or common cathode. Take your pick. Super low current drain, only 5mA per segment typical. PND-510 Common Anode PND-503 Common Cathode PRICE SLASHED! 95c each

39c

TERMS:
Money Back. Guarantee. No COD. Texas Residents add 5% tax. Add $5 of order for postage and handling. Orders under $10, add 75c. Foreign orders: US Funds ONLY!

50 HZ CRYSTAL TIME BASE KIT - $6.95

All the features of our 60Hz kit but has 50Hz output. For use with clock chips like the 50252 to give 24 hour time format.

UP YOUR COMPUTER!
21L02-1 1K LOW POWER 500 NS STATIC RAM
TIME IS OF THE ESSENCE

And so is power. Not only are our RAM's faster than a speeding bullet but they are now very low power. We are pleased to offer prime new 21L02 - 1 low power and super fast RAM's. Allows you to STRETCH your power supply farther and at the same time keep the wait tight off.

FAIRCHILD BIG LED READOUTS
$6.95

FOR XFRM OR AC OPERATION ADD $1.50

WESTERN DIGITAL UART
NO. TR1602B. 40 pin DIP
THIS IS A VERY POWERFUL AND
NEW-$6.95 with data
LIMITED QUANTITY

IC & K MINI TOGGLE SWITCH
No. 7103 SUB MINI SPDT CENTER OFF
SPECIAL - 99c

MOTOROLA POWER
DARLINGTON
BACK IN STOCK!
Like MJ3001, NPN 60V, 10A, HFE 6000 TYP, TO-3 case.
We include a free 723 C volt reg. with schematic for power
supply. SPECIAL - $1.99

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SEMICONDUCTORS
Leads were cut for PCB insertion. Still very useable.
All new, unused, Some House no.
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FREE KIT Catalog contains Test and Experiment’s Equipment, Data Scientific Instruments, 1054P, Livermore, CA 94550.

10% OFF WITH $50 ORDER

25% OFF WITH $250 ORDER

THOSE DISCOUNTS APPLY TO TOTAL ORDER—SUPPLIES INCLUDED

POCKET CALCULATOR KIT

LM358 or LM348 pair; 1N4148, 1N4149 diodes; additional memory components, rectangular diode plus memory; a complete memory package; all parts in kit are N.O.S. or N.O.M.; plus free Catalog.

Cable Kit only $ 1.95

New Supplies (Also kit, disp.)

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25% OFF WITH $250 ORDER

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LM358 or LM348 pair; 1N4148, 1N4149 diodes; additional memory components, rectangular diode plus memory; a complete memory package; all parts in kit are N.O.S. or N.O.M.; plus free Catalog.

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Cable Kit only $ 1.95

New Supplies (Also kit, disp.)
**FAIRCHILD ANNOUNCES THE SOLID STATE TECHNOLOGY KIT**

• FOR THE EXPERIMENTER WITH TASTE FOR "STATE OF THE ART" PRODUCTS
• COMPLETE SPECIFICATIONS ARE PRINTED ON THE BACK OF EACH TECHNOLOGY KIT

---

**CARD FRONT**

<table>
<thead>
<tr>
<th>DIGITS</th>
<th>CARD BACK</th>
<th>PHOTO ARRAYS</th>
<th>LED LAMPS</th>
<th>KITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>FTK0001 0.5&quot; High Common Cathode Digit</td>
<td></td>
<td>FTK0040 9-Element Tape Reader Array 16.00</td>
<td>FTK0020 10 Red LED Lamps</td>
<td>FTK0106 Automobile Clock Kit 40.00</td>
</tr>
<tr>
<td>FTK0002 0.5&quot; High Common Anode Digit</td>
<td></td>
<td>FTK0041 12-Element Card Reader Array 24.00</td>
<td>FTK0021 5 Mixed Colored LED Lamps</td>
<td></td>
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<tr>
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<td></td>
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<td>FTK0023 5 Three Piece LED Mounting Adapters 1.00</td>
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<tr>
<td>FTK0005 0.8&quot; High Common Anode Digit</td>
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<tr>
<td>0.8&quot; HIGH DISPLAY ARRAYS</td>
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</tr>
<tr>
<td>FTK0010 12 Hour, 3½ Digit Clock Display</td>
<td></td>
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<td></td>
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<tr>
<td>FTK0011 24 Hour, 4 Digit Clock Display</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>PHOTO TRANSISTORS</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>FTK0030 5 Flat Lens Photo Transistors</td>
<td></td>
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</tr>
<tr>
<td>FTK0031 5 Round Lens Photo Transistors</td>
<td></td>
<td></td>
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<tr>
<td>FTK0032 3 Flat Lens Photo Darlington</td>
<td></td>
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</tr>
<tr>
<td>FTK0033 3 Round Lens Photo Darlington</td>
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</tr>
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DAVIA ADVERTISERS INDEX

READER SERVICE NO. ADVERTISER PAGE NO.
1 A P Products, Inc. 96
2 AVR Electronics 112
3 Adva Electronics 135
4 Advanced Microcomputer Products 138
5 Altai Electronics 139
6 Altai Electronics 123
7 Altai Electronics 133
8 American Surplus Trading 133
9 Ancrrora Corp. 133
10 Aries Inc. 133
11 Audio-Technica U.S.A. Inc. 47
12 B-K Product of Dynascan 22
13 B-K Product of Dynascan 22
14 Byte 97
15 Byte 97
16 CREI Capital Radio Engineering Institute 82, 83, 84, 85
17 C & S Marketing 108
18 Circuit Design Inc. 118
19 Cleveland Institute of Electronics 100, 101, 102, 103
20 Cobra, Product of Dynascan 100, 101, 102, 103
21 Continental Specialties Corporation 102
22 Continuum Specialties Corporation 110
23 Delta Electronics Co. 122
24 Delta Electronics, Inc. 122
25 Digi-Key Corporation 111
26 Dynaco, Inc. 111
27 Edile Electronics 111
28 Edmund Scientific Co. 136
29 Edyn, Inc. 128
30 Edmund Scientific Co. 136
31 Empire Scientific 79
32 Fluke 81
33 Fluke 81
34 Grantham School of Engineering 111
35 Handicac U.S.A. Inc. 100
36 Hewlett-Packard 100
37 IMS Associates, Inc. 13
38 iass, Inc. 112
39 Illinois Audio 12
40 Johnson Co., E.T. 21
41 Johnson Co., E.T. 21
42 Jewelry Instruments Corp. 113
43 McIntosh Laboratory Inc. 100
44 MITS 90
45 MITS 90
46 MITS 107
47 MITS 107
48 Malny Distributor Products Co. 113
49 National Technical Schools 87
50 New-Tone Electronics 113
51 Ok Machines & Tool Corporation 113
52 Olson Electronics 20
53 Optoelectronis 52
54 PAIA 52
55 Phase Linear Corporation 111
56 Polar Paks 117
57 Polaroid Systems 50
58 Processor Technology Co. 73
59 Quest Electronics 54
60 RCA Electronics Instruments 104, 105
61 Radio Shack 23
62 SBE Inc. 56
63 S.B. Sales Co. 129
64 Sancor 94, 95
65 Shure Brothers Inc. 93
66 Solid State Sales 134
67 Sound Guard 68
68 Sound and Signal Products Corporation 58
69 Speaker Labs 97
70 Stargate Electronics Inc. 113
71 Stereo Corporation of America 97
72 Stereo Discounters 102
73 Texas Instruments 132
74 Texas Instruments 132
75 Technics by Panasonic 25
76 Tec 44
77 Teletron Corporation 88
78 View Clipper Corporation .113
79 Wawasee Electronics 91
80 Weller-Kickele Inc. 88
81 Yamaha 27
CLASSIFIED ADVERTISING 116, 118, 122, 126, 130, 132, 134, 135

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