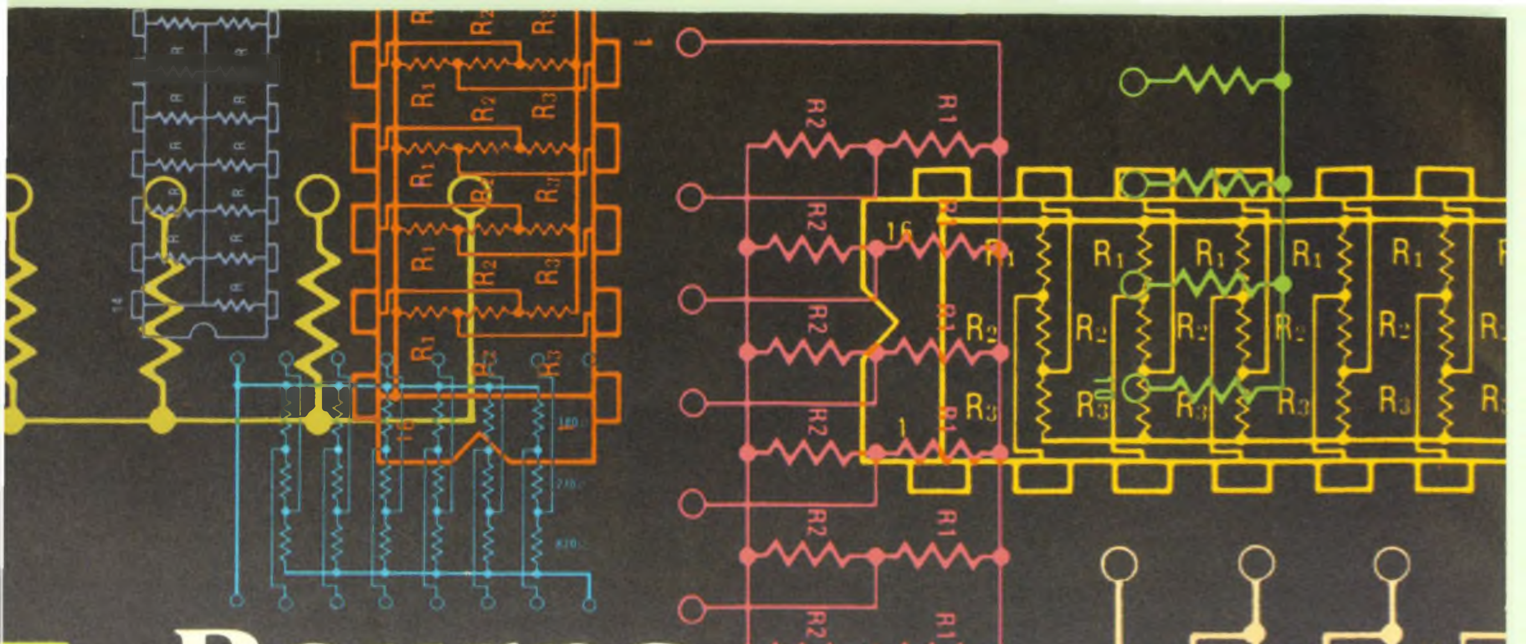
VOL. 26 NO. 5

Electronic Design®

FOR ENGINEERS AND ENGINEERING MANAGERS — WORLDWIDE

MARCH 1, 1978

Pick a calculator, any calculator. More computing power is packed into all machines. Displays are easier to read, and reliability is better. But problems persist. Poor keyboard designs still give false entries. Live NiCd batteries play dead. And complex features of programmables make selection tougher than ever. See p. 40.



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For Future Application — Circle 230

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The World's First LED Displays You Can View in Bright Sunlight.

Now available from Hewlett-Packard are displays designed for high ambient conditions. These seven-segment displays optimize the contrast between the digit segments and the background. A specially designed P-N junction and larger top contact metallization permit operation at high peak currents. This feature enhances display light output and permits strobed operation of long display strings. Combined with proper filtering these displays can be used under high ambient lighting as bright as 10,000 footcandles!!!

Available in High Efficiency Red and Yellow, the HDSP-3530/4030 series are designed for use in outdoor terminals, gas pumps, airplane cockpits, instruments, weighing scales, agricultural instrumentation and point-of-sale terminals.

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CIRCLE NUMBER 2

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Experience,
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MIL-R-28750

M28
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These SS
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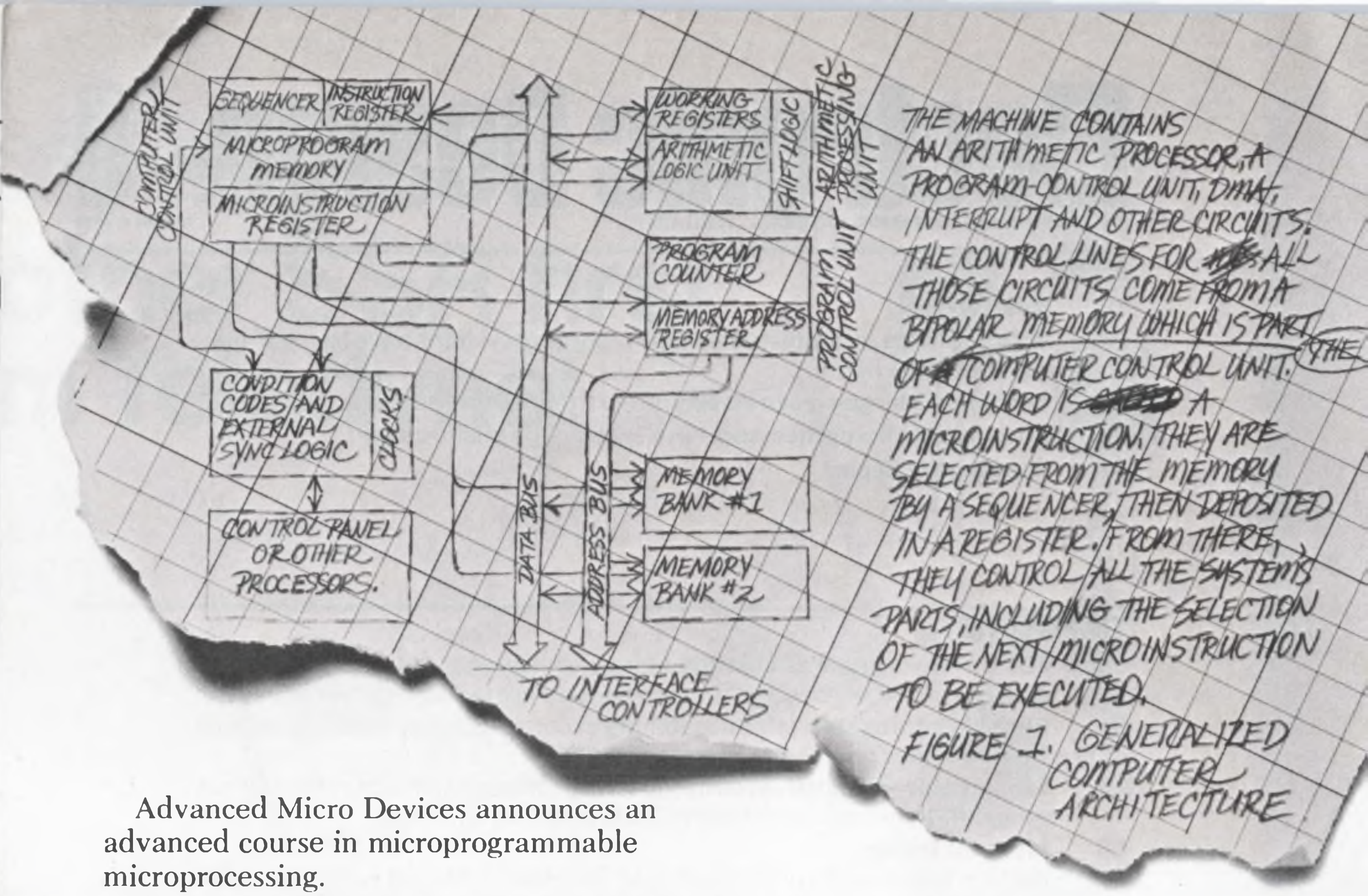

Advanced Micro Devices announces an advanced course in microprogrammable microprocessing.

Step by step, function by function, month by month, we'll build a fast, powerful, microprogrammed machine.

And on December 31, 1978, you'll know what we know. As it turns out, that's quite a lot.

BUILD A MICROCOMPUTER THIS YEAR.

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31
T

Across the desk

Putting the brakes to radar brake control

Your article on automobile radar systems in the U.S. for brake control (ED No. 23, Nov. 8, 1977, p. 30) indicates that noticeable progress has been made in the U.S., but I remember the Japanese reporting approximately this much success at a conference in Detroit around 1972. It appears from your article, though, that the most serious questions raised in 1972 haven't been solved by the approaches you describe, including:

- Inability to determine a real threat. An oak tree or a bridge abutment is a threat. An empty trash can is not, but it has a beautiful radar cross-section.
- Water splash or heavy rainfall problems. Ironically, these bad conditions can occur when braking help might be most needed.
- The braking systems don't know what you're thinking. For example, if you pull out to pass with a car coming on, the systems in your article could brake you just before you turn back into your lane, leaving you in a rather bad position.
- EMI and reliability. The danger from some stray signal is very serious. Likewise, the over-all reliability of the electronics will have to be several orders of magnitude better than anything of this general level of complexity ever built. It will be hard to prove that the units save a life, but rather obvious when it causes a serious accident.

There is nothing wrong with using radar to warn a driver, but taking control raises serious questions. I, for one, would not want the system(s) you describe to control my car.

W.T. Walton

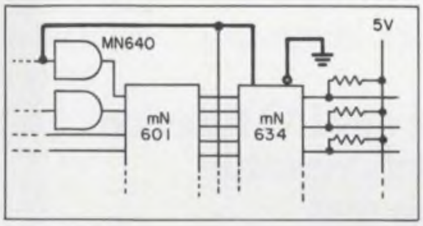
38 Windward Dr.
Severna Park, MD 21146

A few changes

The article, "Exploit Existing NOVA Software by Designing computer Systems Around the Micro NOVA" (ED No. 19, Sept., 13, 1977, p. 54), contained several inaccuracies.

The last two sentences of p. 56 should read: "During a Refresh operation, the CPU specifies a group *equivalent to 1/64 of all the* memory locations to be refreshed, but transfers no data. *The refresh address is* selected by a 6-bit refresh address *register* placed on the lower six address lines."

Also, Fig. 8a on p. 63 should be corrected as indicated.



Daniel Falkoff
Design Engineer

Data General
Route 9
Westboro, MA 01581

Misplaced Caption Dept.

Our engineers react positively to design reviews. Our younger engineers, in particular, look forward to these inputs.

Sorry. That's "Massacre of the Barbarians," from the Column of Marcus Aurelius located in Rome.

Electronic Design welcomes the opinions of its readers on the issues raised in the magazine's editorial columns. Address letters to Managing Editor, Electronic Design, 50 Essex St., Rochelle Park, NJ 07662. Try to keep letters under 200 words. Letters must be signed. Names will be withheld upon request.

Intel delivers the micro components designers

There's no more efficient way to solve your interface and control requirements for microcomputer-based systems than our peripheral components.

They're single-chip solutions to even the most complicated operations, integrating up to 22,000 transistors per chip to replace circuit boards full of discrete logic with a single component. Result: you cut parts cost, reduce package count and board space, and simplify both development and operating software.

"I can accomplish almost any I/O function with one chip using Intel's versatile peripheral interfaces and dedicated device controllers."

We've designed each of these peripheral chips to be an intelligent, programmable component in your system and to perform most functions with minimal cpu supervision. The resulting decrease in cpu overhead provides your system with higher performance and increased throughput.

The dedicated function components below are available now, with more on the way. Here's a brief description of their versatility.

8271 Programmable Floppy Disk Controller. Provides full control of up to four standard or minifloppy drives. (Available early 1978.)

8273 SDLC/HDLC Protocol Controller. For SDLC and HDLC communications.

8275 Programmable CRT Controller. Provides fully buffered interface and control of almost any raster scan CRT display.

8278/8279 Programmable Keyboard/Display Interfaces. Keyboard/sensor array input scan, and output scan for LED, incandescent and other displays. 128-key or 64-key input.

8251A Programmable Communications Interface. Industry standard USART for synchronous or asynchronous serial data transmission, including bisync.

8253 Programmable Interval Timer. Contains three independent 16-bit counters, programmable modes from dc to 2MHz.

8255A Programmable Peripheral Interface. General purpose I/O interface with 24 individually programmable I/O pins.

8257 Programmable DMA Controller. Provides four-channel, high speed direct memory access independent of CPU.

8259 Programmable Interrupt Controller. Handles eight levels of vectored priority interrupt. Expandable to 64 levels.

computer peripheral are talking about.

UPI-41™ is Intel's Universal Peripheral Interface, bringing distributed intelligence to microcomputer systems for the first time.

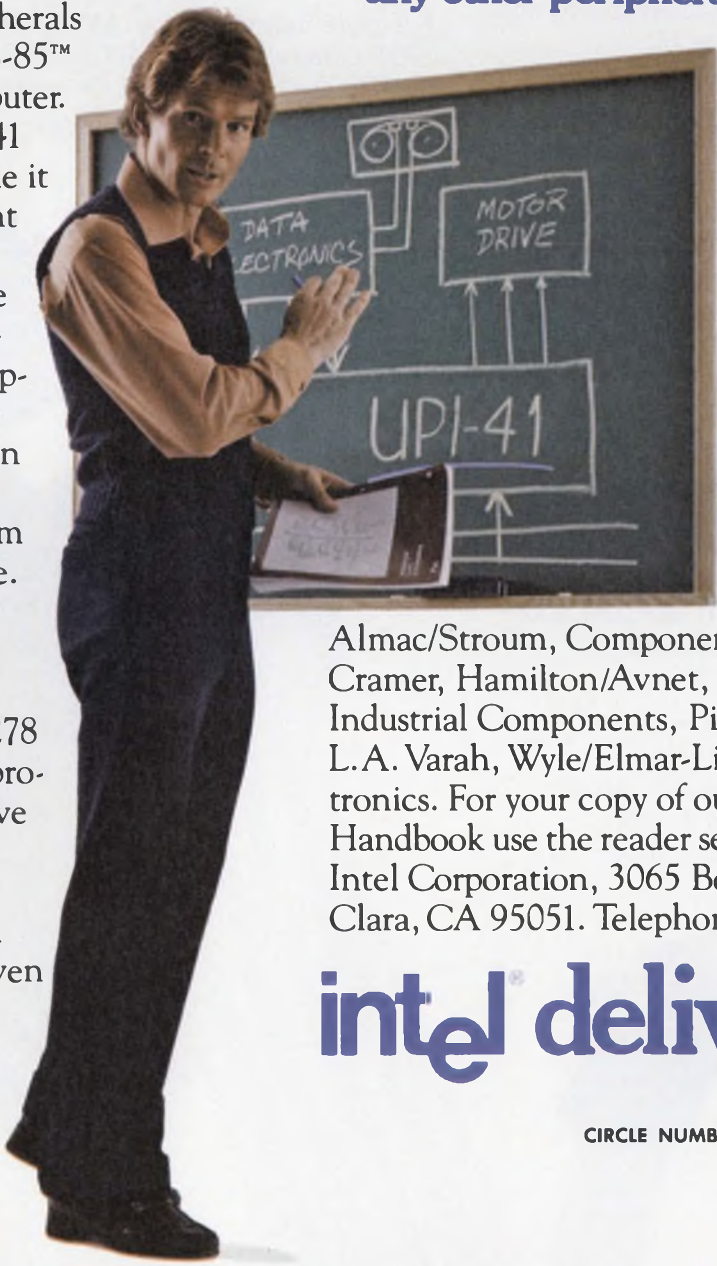
Actually a highly integrated, user-programmable microcomputer, UPI-41 is a new solution that obsoletes custom LSI and specialized discrete designs for interfacing most low and medium speed peripherals with an MCS-80,™ MCS-85™ or MCS-48™ microcomputer.

Intel delivers UPI-41 in two versions that make it easy for you to implement your own designs. The 8741 includes an erasable and reprogrammable 1K-byte EPROM, for development, testing and low volume production. Then the 8041, with masked ROM, provides maximum economy in high volume.

We've taken the UPI-41 concept a step further with the 8278, described at left. The 8278 is the first of several preprogrammed 8041's that we've adapted to specialized applications.

Because UPI-41 is a microcomputer, we've given it the same high level of support we give all our microcomputers. UPI-41 is supported by our Prompt™ 48 Design Aid, the Intellec® microcomputer development system with resident UPI-41/MCS-48 Macro Assembler. Plus applications assistance worldwide, full documentation, training classes, design seminars and a rapidly expanding users' software library.

"And, for my special I/O requirements, Intel's UPI-41 Universal Peripheral Interface is user programmable to control nearly any other peripheral device."



Intel's peripheral components, and the MCS-80, -85 and -48 microcomputers they support, are available through: Almac/Stroum, Component Specialties, Cramer, Hamilton/Avnet, Harvey Electronics, Industrial Components, Pioneer, Sheridan, L.A. Varah, Wyle/Elmar-Liberty and Zentronics. For your copy of our Peripheral Data Handbook use the reader service card or write: Intel Corporation, 3065 Bowers Ave., Santa Clara, CA 95051. Telephone: (408) 987-8080.

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CIRCLE NUMBER 6

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And there are no exceptions. AMPLIMITE High Density Flexible connectors work with all .050" centerline 28-30 AWG round conductor ribbon cable. You get an axial cable-to-connector interface second to none in strength and ruggedness.

AMPLIMITE HDF connectors provide complete packaging flexibility. They are available in 15-, 25- and 37-position sizes, and have through-cable capability for "daisy chain" applications. They intermate with other D-type connectors, including AMPLIMITE all-plastic right-angle headers. HDF connectors are at work in computer peripherals, modems, instrumentation, industrial controls, and word processing systems. They are completely compatible with transmission specification RS-232.

AMPLIMITE HDF connectors give you another plus. AMP technical assistance and support. It's thorough, complete, professional aid you can call on even during project planning. It can help make sure your design will be efficient and effective right from the start.

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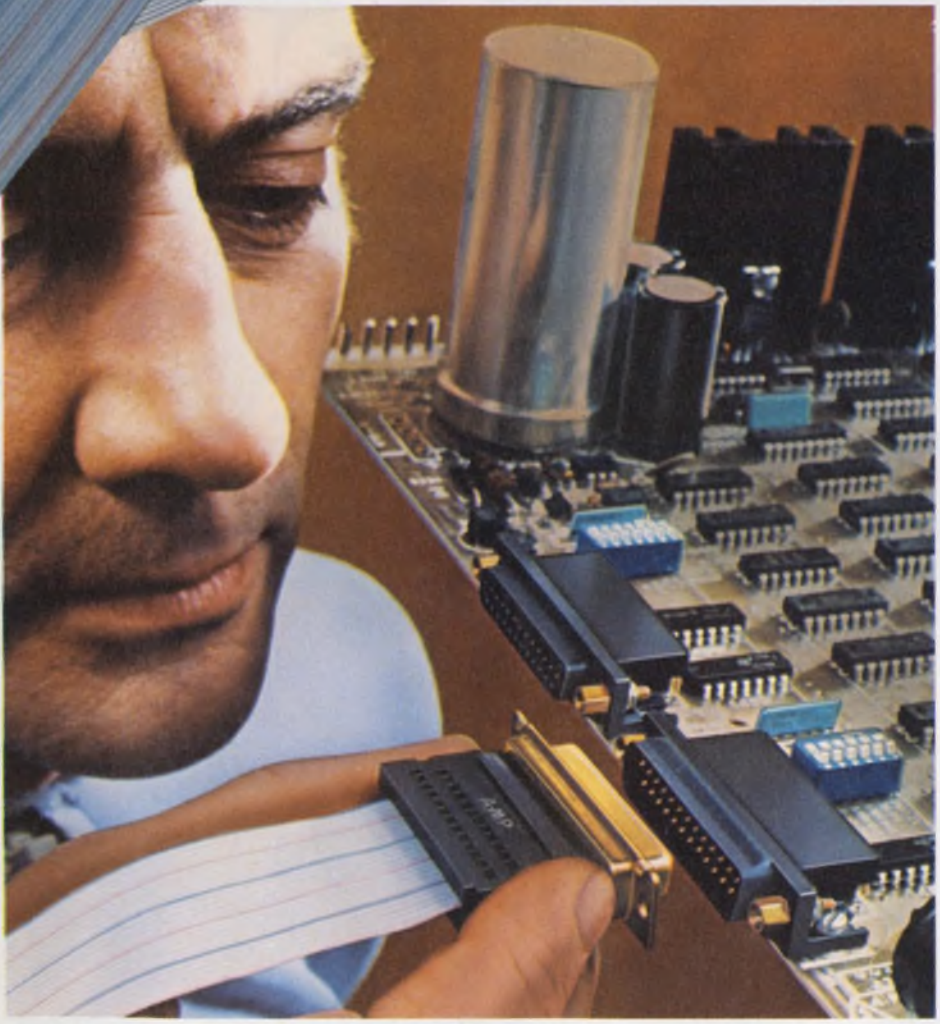
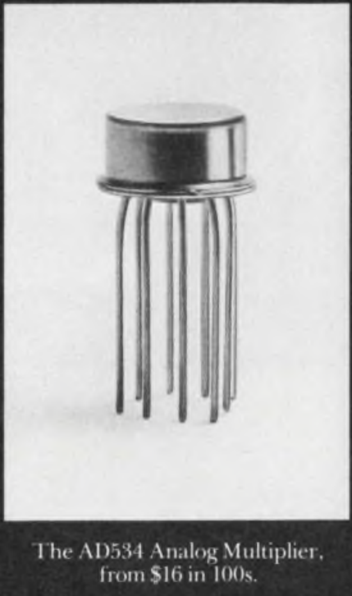
For more information on AMPLIMITE HDF connectors, just call Customer Service at (717) 564-0100. Or write AMP Incorporated, Harrisburg, PA 17105.



The single chip analog computer.

A versatile, new computational IC that's accurate and easy to use,



The AD534 Analog Multiplier,
from $16 in 100s.

The Analog Devices' AD534 Analog Multiplier. A new, monolithic, laser-trimmed, four-quadrant analog multiplier destined to smash the myth that analog multipliers are more complex than the computing function they solve.

The AD534 has a guaranteed maximum multiplication error of ±0.25% without external trims of any kind. This level of accuracy you'd normally expect to find only in expensive hybrids or bulky discrete modules. Excellent supply rejection, low temperature coefficients and long-term stability of the on-chip thin film resistors and buried zener reference preserve the AD534's accuracy even under the most adverse conditions.

The AD534 is the first general purpose, high performance analog multiplier to offer fully differential high impedance operation on all inputs. And that's what gives the AD534 its amazing flexibility and ease of use.

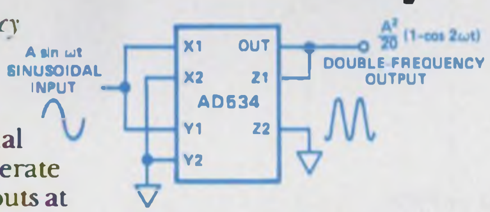
The AD534 is a completely self-contained, self-sufficient multiplier which can generate complex transfer functions very close to theoretical. Our active laser trimming of thin film resistors on the chip to adjust scale factor, feedthrough and offset allow you to plug in the AD534 and run it virtually without adjustment.

In addition to straightforward implementation of standard MDSSR functions (multiplication, division, squaring and square rooting), the AD534 simplifies analog computation (ratio determination, vector addition, RMS conversion); signal processing (amplitude modulation, frequency multiplication, voltage controlled filters); complex measurements (wattmeters, phasemeters, flowmeters) and function linearization (transducers, bridge outputs, etc.) You can set up the AD534 to perform complex calculations by using various feedback arrangements to manipulate the AD534 transfer function of

$$(X_1 - X_2)(Y_1 - Y_2) = 10(Z_1 - Z_2).$$

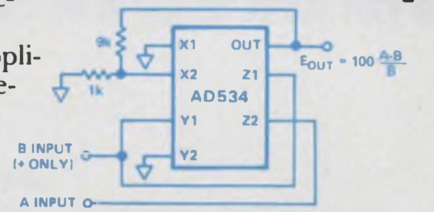
and use,

In Frequency Multiplication. Nonlinear circuits which accept sinusoidal inputs and generate sinusoidal outputs at two, three, four, five or more times the input frequency make use of trigonometric identities which can be implemented quite easily with the AD534 as shown. For this frequency doubling circuit the output should be AC-coupled to remove the DC offset resulting from the trigonometric manipulation.



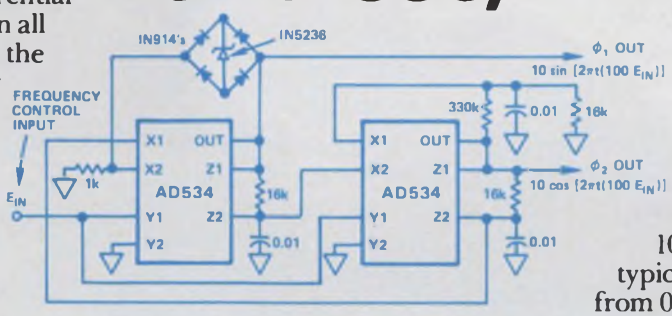
and use,

In Ratio Computing. The percentage deviation function is of practical value for many applications in measurement, testing and control. The AD534 is shown in a circuit that computes the percentage deviation between its two inputs. The scale factor in this arrangement is 1% per volt although other scale factors are obtainable by altering the resistor ratios.



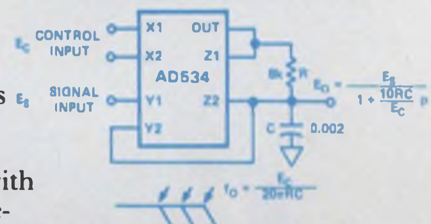
and use,

In Sine Wave Function Generation. The voltage controlled 2-phase oscillator uses two AD534's for integration with controllable time constants in a feedback loop. The frequency control input, E_{IN}, varies the integrator gains, with a sensitivity of 100Hz/V and frequency error typically less than 0.1% of full scale from 0.1V to 10V.



and use.

In a Voltage Controlled Filter. The output voltage, which should be unloaded by a follower, responds as though E_s were applied directly to the RC filter but with the filter break frequency proportional to the input control voltage $\left(\text{i.e. } f_0 = \frac{E_c}{20\pi RC}\right)$. The frequency response has a break at f_0 and a 6dB/octave rolloff.



These uses of our new Single Chip Analog Computer, the AD534, are only the beginning. For the big picture call Doug Grant at (617) 935-5565. Or write for a copy of our new Multiplier Application Guide and the data sheet on the AD534.

ANALOG DEVICES

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Meet the newest member on the board. Allen-Bradley's Type FM. It features the accuracy and stability of metal film technology. It provides you with the tight tolerance, tight temperature coefficient and stable performance you may need for precision applications. Approved to MIL-R-10509, Style RN55, Characteristic E, all tolerances. This high quality metal film resistor adds another dimension to Allen-Bradley's line of hot-molded carbon composition and cermet film fixed resistors of high reliability. We have what you need. Write for Publication EC 54.

Tolerances
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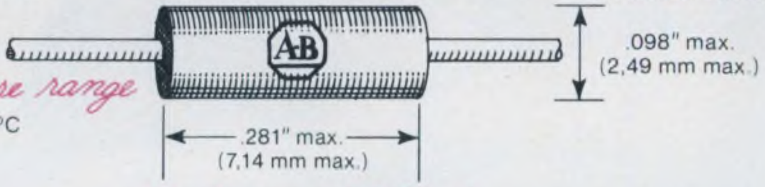
± 0.1% and ± 0.05%

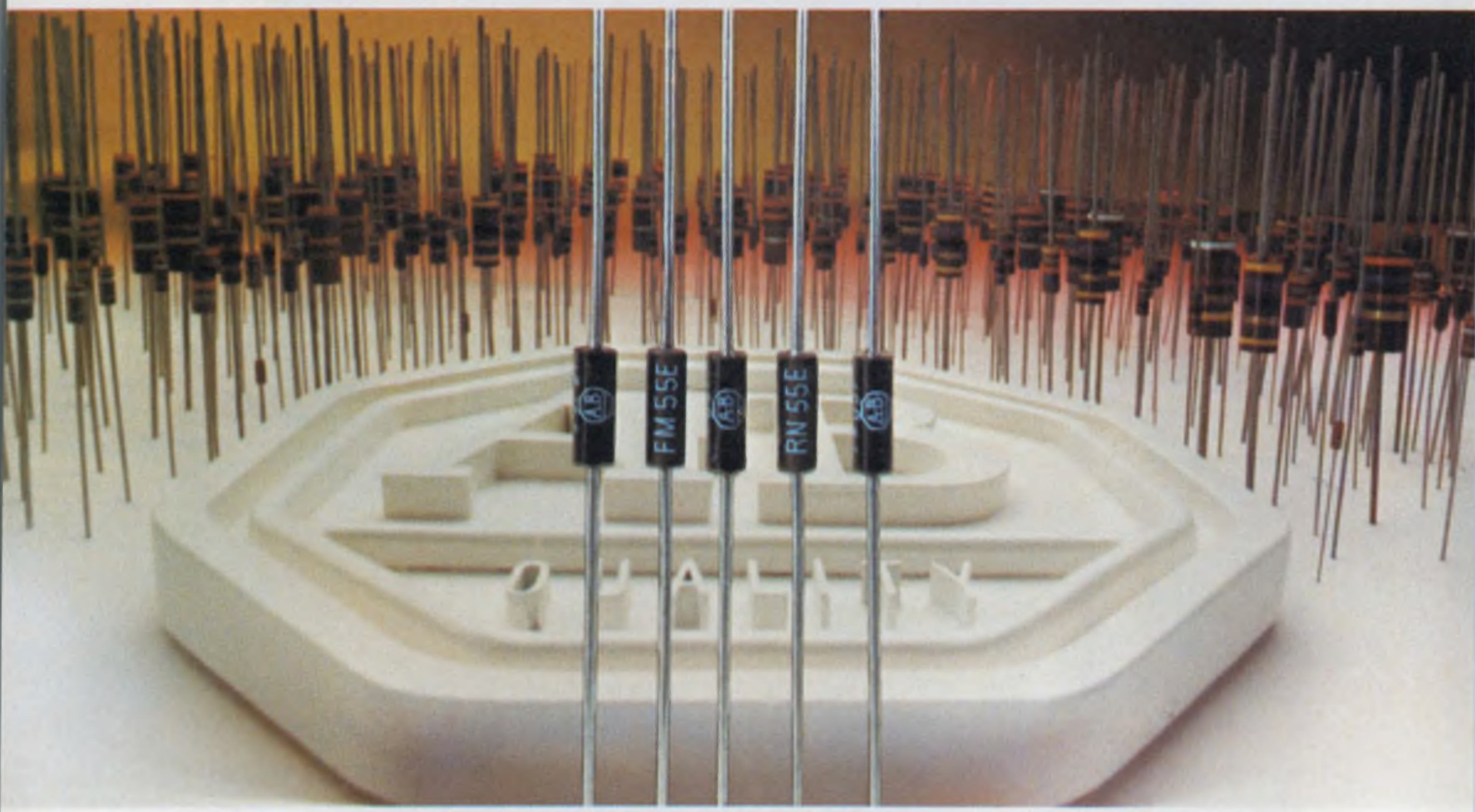
Temperature coefficient
± 25, ± 15, ± 10 PPM/°C

Power rating
0.25 watt at 70°C
0.1 watt at 125°C



Temperature range
−65°C to +175°C

Uniform molded body



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Milwaukee, Wisconsin 53204

CIRCLE NUMBER 11

PEOPLE WHO KNOW RELAYS COUNT ON STRUTHERS-DUNN FOR TIME DELAY

New Design Concept 1
The Struthers-Dunn line of standard tdrs was achieved by combining a proven hybrid solid state timing module with the entire line of standard general purpose relays. In most cases the module fits within the existing relay cover, and therefore does not affect unit size or ease of mounting.

Broad Selection 2
Imagine, more than 6000 combinations of timing, voltage, contact arrangement and mounting. New concept permits any standard general purpose relay to be equipped with built-in time delay function. Standard off-the-shelf models are U.L. recognized. Hermetically sealed models meet the requirements of MIL-R-83726. It adds up to the most complete line available anywhere.

Design Flexibility 3
The versatility of these timing modules offers a wide variety of alternatives when the control circuit must include time delay. Instead of searching for a timer to fit the circuit, simply choose the type of relay you want with the assurance that it is available with time delay capability.

Reduce Costs 4
The new tdrs will cut costs in many applications. If, for example, a system now uses a conventional electromechanical timer and a separate relay as many circuits do, the designer may substitute a single tdr and cut his component cost in half. Cost of mounting and wiring the component is also reduced.

Standard Voltages & Sockets 5
Forget previous voltage limitations. Our tdrs are available for all standard voltages from 12 VAC to 240 VAC and from 12 VDC to 125 VDC. Plug-in models available for most common sockets: Octal, square base, miniature or 12 pin rectangular plugs with quick connect, solder, printed circuit or front connect terminals.

Timing & Setting Range 6
Standard off-the-shelf models offer seven different timing ranges with adjustable setting: 0.1-1 second, 0.2-2, 1-10, 3-30, 6-60, 18-180 and 30 to 300 seconds. Settings are available three ways: Fixed (factory preset), knob adjustable or remote adjustable from a central control panel.

Reliability 7
These tdrs incorporate two time-tested components—electromechanical relays and solid state timing modules. Thus there is no weak link to cause premature failure. Repeatability of ± 3% at 20 to 25°C and ± 10% accuracy within voltage and temperature range is assured. Life expectancy is 50 million mechanical operations or 500,000 operations minimum at full load.

Transient & Polarity Protection 8
Time delay operation is protected for transient voltages as long as 5ms duration with exponential slope from 0 volts to 20 microsecond peaks of ± 2000 volts. DC models are inverse polarity protected. Tdrs will not operate with polarity reversed, but will function normally once wiring is corrected.

False Contact Protection 9
Another added operational protection. With our on-delay relays, false transfer of contacts is prevented should the voltage be interrupted during timing cycle. With off-delay relays, if control switch closes during delay period, timing resets to zero and contacts do not transfer. Full timing is assured when control switch opens again.

Total Relay Capability 10
Dependability and know-how, that's what you get from more than 50 years experience. You, too, can count on a relay line-up with unmatched diversification. We provide solutions to control problems with ten key relay functions: General Purpose, Latch Sequence, Sensitive, Reed, Solid State & Hybrid, Motor Control, Military, Special Assemblies and, of course, Time Delay.

...we're in TOTAL CONTROL

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PITMAN, NEW JERSEY 08071
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S-D

CIRCLE NUMBER 12

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See our diversified line of relays at Booth G31

Available Through 140 Stocking Distributors
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MARCH 1, 1978

Schottky-diode/FET logic bring VLSI into the real world

Gallium arsenide substrates, Schottky-barrier diodes and depletion-mode FET gates will help pave the way for the coming generation of very-large-scale integrated circuits. With these elements, entire digital systems will be manufactured on single chips.

"Mainframe central processors of present-day technology are performance-limited by the propagation-delay time that data bits encounter traveling along circuit-board paths and backplane wiring," says Dr. Richard Eden, Rockwell's principal scientist at the firm's Solid State Electronics Dept. in Thousand Oaks, CA. It takes roughly 100 picoseconds for a bit to travel a single inch in any direction.

However, in order to bring a system's logic gates any closer together, the heat generated by its logic gates must be drastically reduced—concentrating the system's volume without reducing its power consumption will only cause it to burn up.

By using GaAs, Schottky-barrier diodes for logic inputs, and (low-power) depletion-mode FETs for gain and inversion, Rockwell has reduced the gates' switching energy (speed × power) from several tens of picojoules to 1/20 of one picojoule, and cut gate-propagation delay to less than 100 ps, Dr. Eden announced at a technical session during the recent International Solid-State Circuits Conference.

At the same time, complete systems made with Schottky-diode/FET logic could be very small: Rockwell's new circuit technique "isn't even *intended* in systems with more than a single IC package, according to Eden.

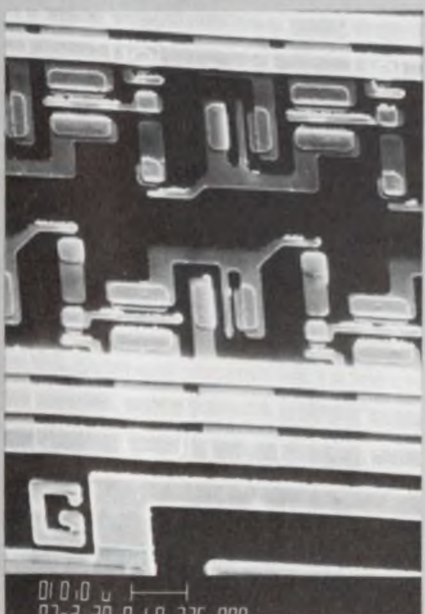
Schottky-diode/FET logic uses small (1 micron square), low-capacitance (10^{-15}F) Schottky-barrier diodes to replace active elements at the gates' inputs. This helps reduce the chip's power dissipation to 500 μW per gate. Output FETs operate in the depletion mode—normally on—so level shifting is necessary.

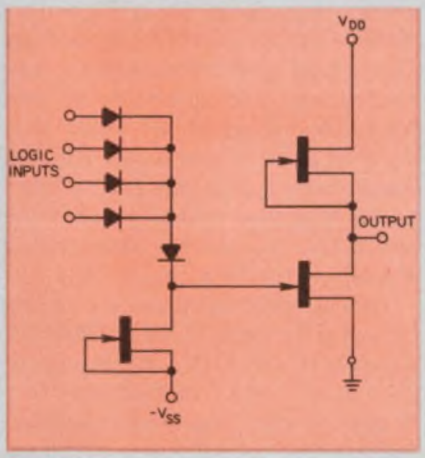
The gate's input diodes by themselves provide about 1 V of level shifting. But an additional series diode allows for less-critical output FETs, higher supply voltages, and wider signal excursions (see Fig.)

Rockwell is still several years away from a VLSI production line, but Eden already envisions broad application areas where Schottky-diode/FET logic can "overcome the speed and power shortcomings of silicon-gate technology." Computer mainframes, cache memories, and data-communications systems in particular are all likely candidates.

"As data rates need to be increased, present-day methods will become hard-pressed to keep up with the demand for performance," Eden warns. Optical fibers, for example, are capable of much higher data rates than can currently be exploited.

"Communications in the 1980s will be increasingly handled by solar-powered earth satellites," Eden predicts. "But high-speed silicon bipolar technology is hindered in space applications because of power budgeting." With GaAs Schottky-diode/FET logic requiring four orders of magnitude less power, VLSI will be well prepared to meet the challenges of outer space.





The look of very-large-scale integration. This scanning-electron microscope image (left) shows functional logic gates implemented with Schottky-diode FET logic (right).

Strapping changes modes in 16-bit microprocessor

The 16-bit 8086 microprocessor from Intel Corp. can be configured for small systems or for larger, buffered systems simply by wiring one pin the MN/MX line, to 5 V or ground. As a result, seven pins change their meanings depending on the way the MN/MX line is wired. And with pins having dual capabilities, the 8086 can be housed in a 40-pin package.

In a minimal, small-system configuration, the 8086 requires a clock-generator chip and digital latches to tie to memories and input/output lines. In the maximum mode, the 8086 ties through a bus controller that generates five of the seven signals not available from the processor after it is switched out of the minimum configuration.

The maximum mode has faster access to memory components—440 ns against 490 ns with no wait states at a 5-MHz clock rate, and 215 ns against 265 ns with no wait states at an 8-MHz clock rate.

The standard maximum clock rate is 5 MHz, with 8-MHz parts available at extra cost. Prices have not yet been set for either version.

The Intel 8086 is built with n-channel, depletion load, silicon-gate technology like that used in the Santa

Clara, CA, firm's 2147 4-k static RAM. The processor addresses memory logically as a linear sequence of 8-bit bytes, but speeds access with a 16-bit-wide physical path to memory.

Speed is also increased by internal pipelining and overlapped instruction fetch and execution.

The 8086 can use programs written for the 8080, but only after they've been recompiled or translated and reassembled. Intel's 8080-to-8086 translator, the CONV86, converts most source programs, including macros, controls, and source text. But the translator, which runs on the firm's development systems, doesn't support instruction-set dependencies such as timing, size and encoding, nor can it handle self-modifying code or interrupt sequences.

But the 8086 does offer features beyond those of the old 8-bit model. It can address up to 1 Mbyte of memory over a 20-bit bus; handle bit, byte, word, and block operations; and perform floating-point and integer arithmetic. Moreover, the 8086 provides for signed or unsigned arithmetic operations as well as 16-bit multiply and divide.

Incorporating the 8086 into multiprocessor systems is simplified by a locked-exchange or "test-and-set-lock" mechanism. A 1-byte prefix may precede any instruction and cause the processor to assert its bus-lock signal for the duration of the operation caused by that instruction. External hardware should be designed so that other bus masters are disengaged during the period of assertion.

CIRCLE NO. 319

Carter's to blame for energy crisis, says NSPE

The Carter administration is not handling the energy crisis effectively, according to 90% of the engineers surveyed by the National Society of Professional Engineers. Not only that, but almost half the respondents blame the U.S. government for causing the problem.

The responses came from a special energy survey conducted during the NSPE's Winter Meeting in New Orleans, which was attended by 500 elected delegates representing 54 state and territorial regions. The Society sponsored the survey to determine what the nation's leading engineers, representing all major disciplines, consider the critical issues in the energy crisis.

Almost everyone surveyed felt that there indeed is an energy crisis. But opinion was almost evenly divided as to the nature of the problem. Production and distribution got 51% of the vote, while resource shortage garnered 49%.

Who's to blame? The lion's share went to U.S. government policies (48%), while the country's energy consumption habits got most of the rest (38%). Interestingly, only 7% of the respondents blamed foreign energy sources, and just 6% felt the energy industry was the culprit.

As a matter of fact, more than six of every 10 respondents considered the energy industry a more reliable source of information than the U.S. government. And seven of every 10 didn't think the public had been given enough information to form a realistic judgment about the energy crisis.

The economic outlook didn't look very promising to most of the respondents. While 39% felt that by 1985 energy costs would rise by 50%, 43% predicted that by 1985 the energy they consume would cost 100% more than it does today.

Geothermal logger to read temp, pressure, flow rate

An electronic geothermal well-logging tool that simultaneously reads temperature, pressure and flow rate is being developed at Sandia Laboratories, Albuquerque, NM. An early model, which reads only temperature, has been successfully tested recently in a New Mexico geothermal well.

There is great interest in geothermal energy, says Tony Veneruso, supervisor of Sandia's Drilling Technology Div., which conducts tests of the new logging tool. He points to the new power-generating plants being constructed at the Geysers site (north of San Francisco), where geothermal electricity has been produced since the mid-1920s. This site now produces 500 MW of electricity at reasonable rates.

But conventional oil and gas logging tools aren't reliable in the unusual rock formations and high temperatures of geothermal wells, Veneruso adds. Early tests indicate that Sandia's geothermal logging tool will operate for hundreds of hours over a continuous range from room temperature to more than 300 C (575 F). It uses a combination of commercially available hybrid thick-film circuits and junction field-effect transistors, with JFETs in all active circuit devices.

A 3-in.-long platinum thermometer at the tip of the electronics package provides temperature readings. A magnetic sensor keeps track of well depth by counting the number of steel casing pipes the tool has passed. The entire package, which weighs about 5 lbs in its present form, slips into a 4-ft-long, 1-1/2-in.-diameter housing.

We won't forget how to make microwave tubes

Microwave tubes won't disappear in the 1980s and 1990s, thanks to a special program supported by the Air Force, Stanford University, and a number of microwave tube companies.

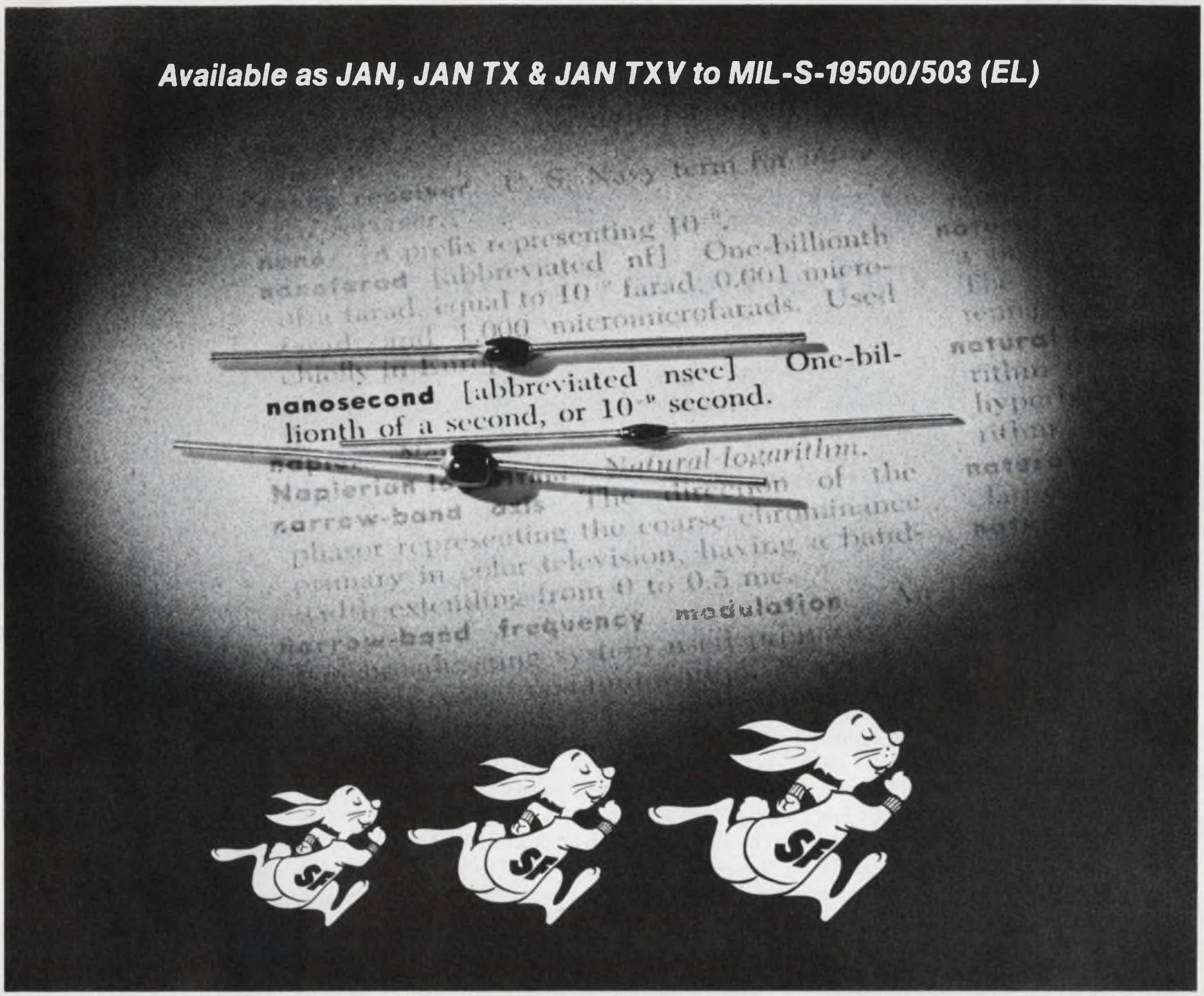
Tubes are anything but old-fashioned in the microwave field, because solid-state devices do not yet approach their high power and wide bandwidth—particularly at the higher frequencies. Yet university-level teaching and research on microwave tubes dried up in the late 1960s. Worse still, the average age of microwave-tube engineers is over 45, and many are close to retirement.

When this situation was recognized, a number of people organized the Air Force Thermionic Engineering Research Program. Stanford University was chosen to provide the teaching because it is near the greatest concentration of tube companies.

Varian, Watkins-Johnson, Litton, Teledyne Microwave, Raytheon, and Hughes are sponsoring one student apiece. Each student receives $4500 from his sponsoring company for schooling, as well as a salary of $10,000 from the Air Force.

The courses combine standard applicable graduate courses with special courses on tubes, the latter taught by Dr. Marvin Chodorow, professor of applied physics and electrical engineering. His lectures are being videotaped, and currently the tapes are air-expressed to the students on the east coast. But, that won't be necessary for much longer.

The first transcontinental satellite instructional-TV link will soon provide two-way communication between the Stanford Instructional Television Network in Palo Alto, CA and Varian's plant in Beverly, MA. Interestingly, Dr. Chodorow's lectures on microwave tubes will be carried via microwave tubes.



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Reverse Current (Max.): 5μA DC @ 25°C
Instantaneous Forward Voltage @ 3.0A: 1.0V @ 100°C
Capacitance @ 12V DC (Max.): 58 pF
Single Cycle Surge Current: 75A
Dimensions (Max.): Body .110" D x .165" L
Leads .038" D x 1.10" L

Types: 1N6079, 80 & 81 *(Trr 30ns)*
PIV: 50, 100 & 150V
Reverse Current (Max.): @ 25°C 10μA DC
Instantaneous Forward Voltage @ 5.0A: .8V @ 100°C
Capacitance @ 12V DC (Max.): 230 pF
Single Cycle Surge Current: 175A
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CIRCLE NUMBER 14

News

With cassettes, video tape recorders have found a new home—in the home

After nearly two decades of technical advancements—and false starts—video tape recorders are finally finding a place in the home. What's brought them home is a packaging technique borrowed from audio recorders—tape cassettes. Consumers are much more interested in video recorders now that they can just pop in a cassette containing 1/2 - in. wide tape instead of having to thread tape carefully by hand through a maze of guideposts.

A fistful of suppliers - all of them Japanese—is now selling home VTRs under more than a dozen brand names.

Unfortunately, videocassettes developed by Sony Corp., Sanyo Electric, Victor Co. of Japan Ltd. (JVC) and Quasar Electronics (both JVC and Quasar are subsidiaries of Matsushita Electric Industrial Co. Ltd. of Osaka) are incompatible with each other. But Sanyo has now introduced a second machine that is compatible with the Sony Betamax system, and Quasar has introduced a JVC-compatible video home system (VHS) recorder. Along with Quasar and JVC, Matsushita is in the VHS camp with a recorder bearing its own Panasonic trade name, and is building VHS recorders for such marketers as GE, Magnavox, and RCA. But with firms like Zenith and Toshiba in the Betamax lineup, Betamax joins VHS in dominating the VCR field.

Playing time increases

The major battle between VHS and Betamax is finding new ways to stretch the playing time—though not the dimensions—of a tape cassette that can cost $25. Sony's original Betamax machine could record and play up to an hour on a cassette, and the first VHS recorder, introduced shortly afterwards by JVC, had a two-hour limit. Now, four-hour VHS machines and two-hour Betamax recorders are the norm, with a three-hour Betamax expected from Sony this year. In addition, Sony has an optional $100 tape changer that doubles recording time.

In both systems, recording time is increased by eliminating the Guardband spacing between tracks. According to the video recording standard developed by the Electronic Industries Association of Japan (EIAJ), the guard band is 63 μm wide and the video track 110 μm wide. So nearly a third of the tape is unused.

The guard band has been eliminated by actually taking advantage of a basic problem of magnetic tape recording: The signal that can be picked up from the tape drops off quickly if the playback head gap is even slightly off parallel with the recorded signal. Since video tape recorders paint and retrace alternate lines with two different heads, each can be slightly off perpendicular to tape travel, yet pick up its own signal properly. If the offset is in opposite directions, the difference between azimuth angles for the two heads is twice the offset. The offset in VHS is 6°, and in Betamax it is 7°, drastically reducing crosstalk and making guard bands unnecessary.

Azimuth recording, most effective at higher frequencies, is less valuable at lower frequencies. Since chrominance (color) signals are recorded at lower frequencies (688 kHz for Betamax and 629 kHz for VHS) than are luminance (black and white) signals, crosstalk attenuation on a color signal is inadequate even with azimuth recording. Color flicker and color distortion result, which explains why slanted azimuth recording was not used for years after its development.

Changing phase cuts noise

To cut crosstalk even in a lower frequency chrominance signal, both Betamax and VHS recorders use phase inversions, though in somewhat different forms. In a VHS machine, the signal fed to one recording head is advanced in-phase by 90° every horizontal picture-scanning line; the signal fed to the other head is delayed by 90° every line.

In playing back through the first head, the signal is delayed by 90° every line, so that signals from the tape that were recorded with this head come out in-phase. Signals from the second channel that appear as crosstalk in the first channel are delayed 180°. All signals are then fed through a one-line delay circuit, then the original and delayed versions of the signal are added. Since each scanning line is about the same as the last, the desired signal component is almost doubled, and the unwanted crosstalk is almost eliminated.

In the Betamax system, signals to one head don't change, while signals to the other get delayed 180° on alternate scans. Again, a delay-line filter cuts

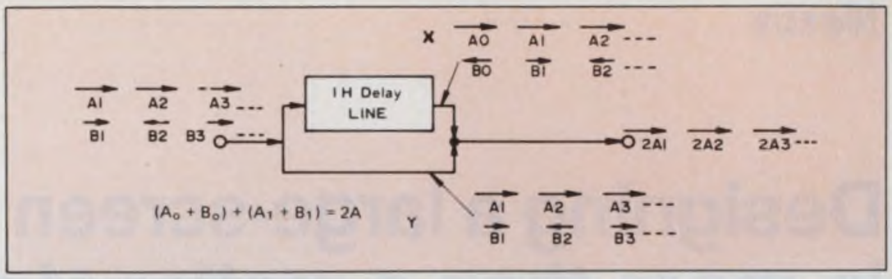
Compact, $1000 video recorders using plug-in cassettes are finding a niche in consumers' homes.

Andy Santoni
Associate Editor

crosstalk on playback.

The VHS system suppresses noise further in the black-and-white part of the video signal with a double-limiter playback circuit. The signal is separated into lower and higher frequency components, which are limited separately. If they were limited together, high-amplitude, low-frequency signals would so saturate the limiter that lower-amplitude, high-frequency signals wouldn't be amplified enough to bring them out of the noise.

The color signal on a VHS recorder comes in for further processing, too, to improve signal-to-noise ratio. The burst signal that is in every color transmission to guarantee sync between the broadcast signal and the playback signal is doubled before recording, then halved on playback. This raises the signal-to-noise ratio to 43 dB, the highest of any 1/2 - in. home VCR and about 3 dB better than other systems, says Tom Shinozaki, assistant national service manager at JVC in Maspeth, N.Y.



Phase inversions and a delay line help cut distortion in VHS tape recorders. Crosstalk components end up cancelling each other out, while desired signals are boosted, in a summing network. Betamax machines use a similar technique.

Player size cut

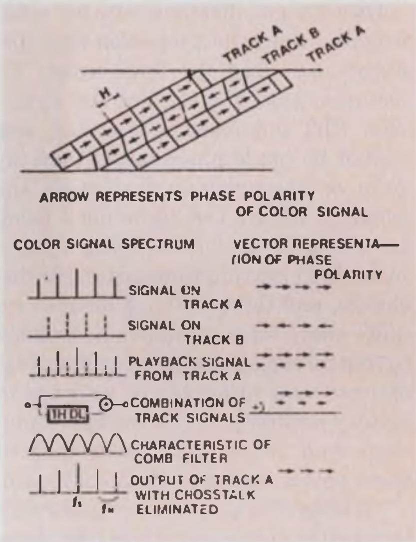
As a result of all these noise-cutting tricks, the drum that holds the heads in a Betamax machine is only 74.5 mm in diameter, and the VHS drum is only 52 mm. Without the noise reducers, a larger head drum, like the 115.8-mm drum of the EIAJ standard, would be needed to achieve acceptable s/n at the low tape speeds of these VCRs.

The smaller head drums help reduce the size of the over-all package. The JVC Vidstar unit, for example, is less than 18 x 6 x 15 in. and weighs less than 30 pounds.

This diminutive package also results from a tape-threading mechanism JVC calls "M-loading." Tape is pulled out of the cassette by two parallel arms, one on either side of the head drum, so that the final tape path is in the shape of an M.

In Betamax sets, on the other hand, tape is pulled from the cassette at one point by a rod that swings around the drum. As a result, loading takes more time and the size of the tape-transport mechanism is bigger than in a VHS set. However, this "U-loading" is more reliable than M-loading since the tape goes through fewer bends, says Yasuo Ohkura, consumer video product planner at Sony in New York.

In either case, the tape touches slightly more than 180° of the drum, which means that tape is always in contact with one or the other head—



Only one signal is phase-inverted in the Betamax system to eliminate crosstalk. As in VHS, Betamax has no guard bands between tape tracks to keep signals from spilling over.

hence the tape-path description "omega wrap."

Along with basic record and playback functions and longer playing time, all VCR manufacturers are looking to add features that will separate their machine from the rest of the pack. For those machines that don't have one built in, accessory timers permit unattended recording of broadcasts while the viewer is asleep or away. In most Betamax machines, the timer sits atop the player. VHS machines have timers that are built-in or, in the case of JVC's Vidstar, plug into the unit's front panel as an option.

But with four-hour unattended recording now possible, and six-hour capacity coming soon, a simple on/off timer won't be enough. The next generation of timers will include programmable station selectors so that the recorder can store broadcasts on different stations sequentially. Almost all timers today simply turn the machine on at a specified time and shut it off at the end of the tape.

In addition, future Videocassette recorders will feature freeze-frame and slow-motion playback. Even more interesting than that, JVC is working on a double-speed playback machine with automatic audio-frequency correction to eliminate the "Donald Duck" distortion of higher-speed playback. This will allow higher-speed scanning of programs and make a precise point on a long tape much easier to locate.

The price future is down

But even as VCR's of the future promise more and advanced performance, increasing sales volume is expected to bring prices down. Basic VCR's here today cost around $1000, better than 30% below the price for a Betamax when it was introduced two years ago. Open-reel home video tape recorders on the market a decade ago also sold for $1000, but the dollar was much more valuable then.

The price decline will be dramatic, though not as sharp as the drop for other consumer products like calculators and watches. After all, much of the cost of a videocassette recorder is in mechanical, not electronic, parts.

The future of videocassette recorders is far from clear, however. One small cloud is the video disk, which some consumers may favor over tape. After all, a fair amount of interest in VCRs is for playing back prerecorded material, not in taping new programs. And if movies and television shows become available in low-cost, stamped-out plastic discs, consumers may choose to bypass the more-expensive tape medium. That's been true of audio recordings, for example.

At any rate VCRs seem to have caught the consumer's fancy. The only question is whether their popularity will continue, or if they will turn out to be a fad like simple video games and CB radios.■■

Designing a large-screen display is more than a matter of size

Making the picture of a large-screen TV display acceptable to the average viewer may be even more difficult than you think. That's the conclusion of researchers at RCA Laboratories in Princeton, NJ. In fact, one aspect of display quality—brightness uniformity—has been analyzed thoroughly enough to determine that the kinds of large-screen TV displays now under development will have to be 200 times better than present television CRTs, says Roger W. Cohen, a group head in the display systems lab at RCA. Cohen's group is studying perception to advise other RCA lab groups that are working not only to develop the best large-screen, direct-view TV displays at the lowest cost, but also to improve aircraft and shipboard displays used by the military. Some of the research has been done for the Navy.

Direct-view displays can be made brighter than the projection-type displays now used for large-screen TV pictures, says Cohen. But the direct-view CRT now used in television sets cannot be made much larger than the 25 in. now common in console sets. The problem is, all the techniques being investigated as CRT replacements—including electroluminescence, gas discharge, and light-emitting diodes—require some form of matrix addressing to control each element in the hundreds of rows and hundreds of columns of display needed to obtain enough resolution. And the brightness at each of these points must be tightly controlled.

"You have to keep the nonuniformity to something less than 1% in luminance fluctuations," says Cohen, adding that current color televisions have center-to-edge brightness variations that can approach a factor of two. The gradual drop-off in brightness from the center of the screen to the edges isn't noticeable to most observers, Cohen notes, but even small differences from one point to the next would be disturbing.

Pictures break into frequencies

High uniformity is essential because when an observer looks at a scene, the eye and brain break up the picture into spatial frequencies, much as electrical signals are broken into distinct frequencies through Fourier analysis, explains Cohen. This leads to simplified mathematical analysis of images, he notes, and makes it possible to describe display quality quantitatively.

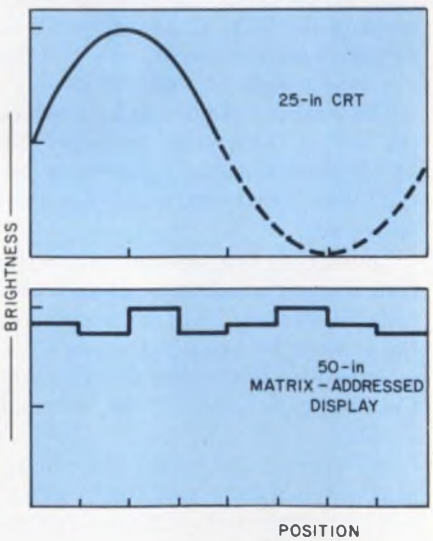
Unfortunately, such an analysis

Sometimes, measurements don't tell the whole story

The eye and brain form a complicated system for interpreting images, so simple measurements like brightness and contrast can't always determine if a picture is good.

Here, the image at the left was made by taking the average brightness of the original, analog image in each pixel, or picture element. The image at the right is made by taking the minimum brightness within each pixel.

Most observers agree that the left-hand picture looks sharper and has better contrast than the right-hand picture, yet the right-hand picture looks more "natural." There is no quantitative method for describing why most observers would choose the right-hand picture to, for example, identify a mugshot.



Matrix-addressed displays have to be better than standard CRTs for their images to be perceived just as well. With CRTs, the eye sees the gradual change in brightness as a low spatial frequency (that of the sine wave shown by a dotted line), where perception is tolerant to brightness variations. But the abrupt changes in brightness of a matrix display are seen as high frequency signals, where the eye is more sensitive.

shows that the dissection of images into separate frequencies makes today's matrix-addressed displays inadequate for large-screen viewing. A curve plotting brightness as a function of position across the screen of a matrix-addressed display is a series of straight lines, each at a slightly different level. Using Fourier analysis to break up such a step-function curve into single frequencies yields a large number of high-order terms, and the human eye and brain are very sensitive to these frequencies. Even the small brightness variations are disturbing.

In present CRTs, on the other hand, the gradual increase then drop-off in brightness from one end of the screen to the other can be plotted as a single, fairly low-frequency sinewave. The eye is relatively insensitive to brightness variations at low spatial frequencies. According to Cohen, the eye's sensitivity to brightness variations ranges from as little as 0.01% at some frequencies to nearly 100% before the difference is noticeable at other frequencies where the eye is least sensitive.

Another area that can benefit from improved displays is medical imaging: x-rays, ultrasound, and computerized tomography. Here, one unresolved question, is whether the eye can better detect differences when an image is printed in white on a black background or vice versa. Given the same contrast between black and white, the eye sometimes distinguishes shapes better when the picture is displayed in one mode and sometimes in the other, says Cohen. So, which mode is better? No one can say for sure yet. ■■

Distributed microprocessing enters the business world

The first electronic typewriter makes it easier for businesses to move toward distributed processing—decentralized computer power. And the typewriter itself uses distributed *micro*processing—a master Z-80 controller and a pair of F-8 chips—to handle drive motors.

In its basic form, the typewriter, developed by the Qyx Division of Exxon Enterprises Inc., Lionville, PA, does far more than a standard office typewriter. Yet it goes for just $1390—not much higher than the nearest comparable mechanical machine (about $900).

The Qyx typewriter has 70% fewer moving parts than electromechanical typewriters, says Dan Matthias, general manager of Qyx. Microprocessors controlling linear motors replace conventional cables, pulleys, and gears.

The Z-80 microprocessor, from Zilog Corp. (another Exxon Enterprises affiliate), Cupertino, CA, handles overall system control and memory operations. A pair of F-8 microprocessors from Fairchild Semiconductor, Mountain View, CA, controls the linear motors that position the carriage and the rotary print head.

The Qyx typewriter can be expanded beyond its basic functions by adding plug-in boards and changing keyboards—without sending the machine back to the factory and without expanding the size of the typewriter itself.

Typewriter built in blocks

The Qyx Level 1 features dual pitch (either 10 or 12 characters to an inch) and proportional spacing (each character takes up only as much space as it needs). The rotary "daisy wheel" print head is coded for type format, so changing print heads automatically resets the typewriter.

The typewriter can even center a line of type automatically and automatically type columns of decimal numbers so that the decimal points line up. Stock phrases and formats can be stored and called up to speed typing repetitive forms.

In addition, the basic typewriter has automatic erase backspace. A lift-off tape, like that used in the IBM Correcting Selectric, pulls an erroneous character off the paper so that a correction can be typed. According to Matthias, Qyx has developed the first daisy-wheel printer that can position its print head accurately enough for this function. This is accomplished by building the rotor of the linear print head-drive motor into the $25 print head itself and by feeding-back position information

The first electronic typewriter, from the Qyx Division of Exxon Enterprises, distributes computer-aided typing throughout an office while itself taking advantage of multiple processors—three μPs.

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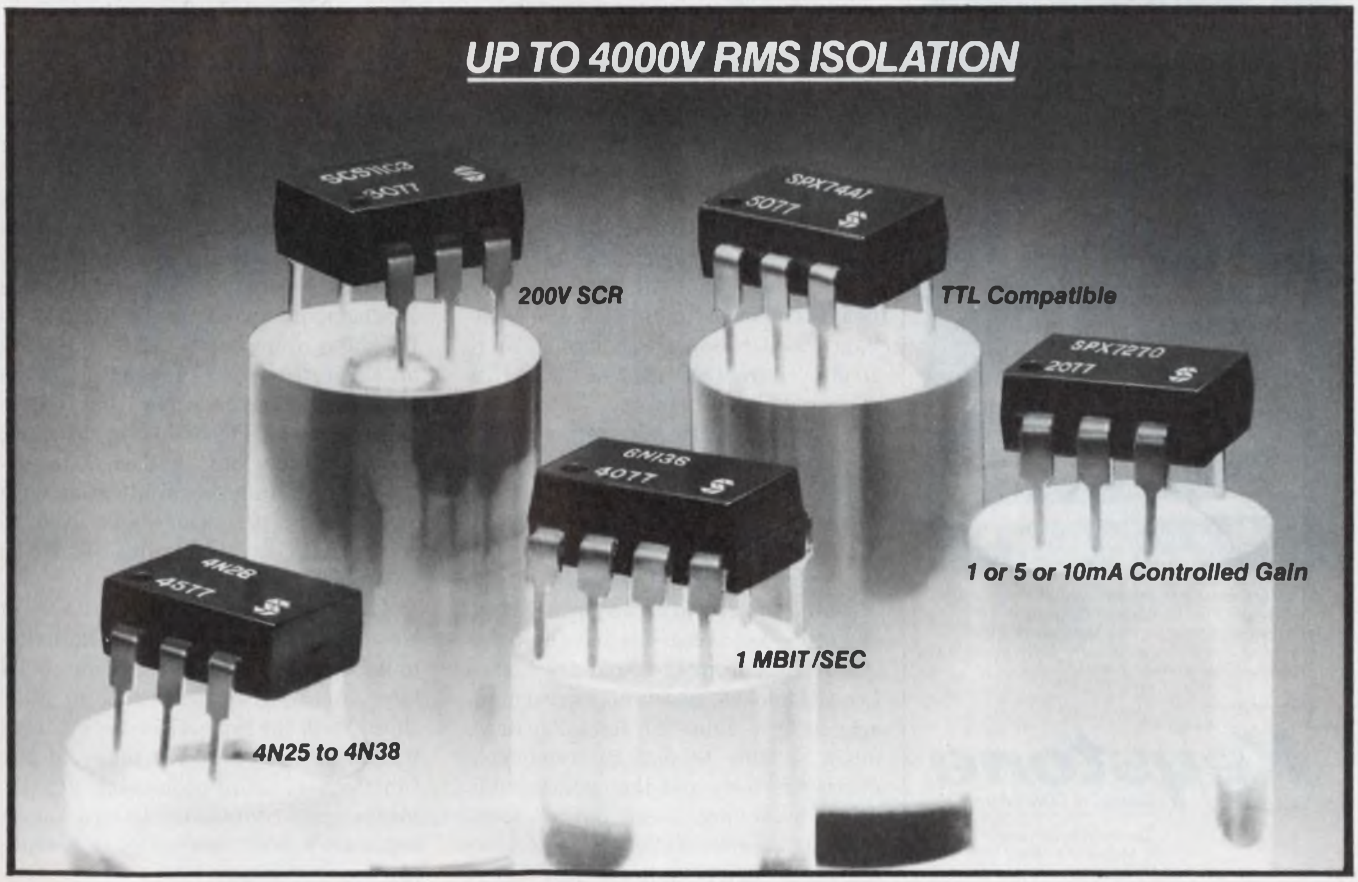

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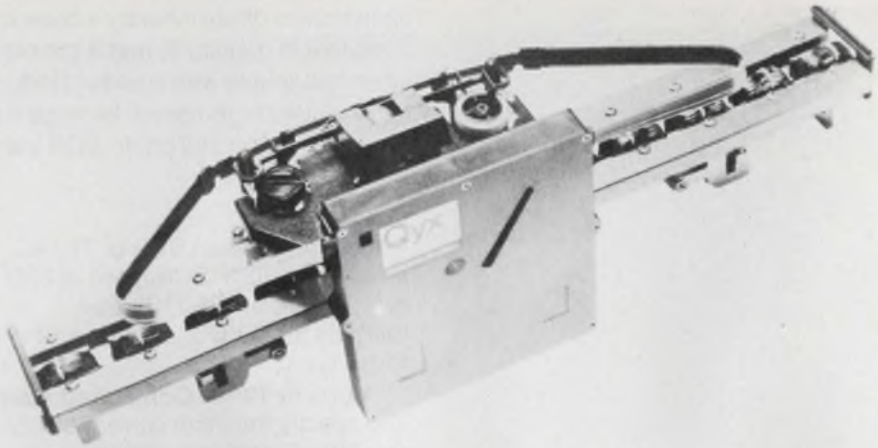

A linear stepper motor controls the position of the Qyx carriage, while a microprocessor controls the motor. The ribbon cartridge is mounted on the typewriter's case, instead of on the carriage, and flexible guides lead the ribbon to the lightweight carriage.

through a light-emitting diode and photodetector sensor.

With an optional $850 display module, a typist can read a line of copy as it is entered, then have it printed after it has been typed correctly. The red LEDs read out upper and lower-case characters in a 5 × 7 dot matrix format.

The carriage itself rides on a linear motor that is controlled by one of the F-8 microprocessors. Instead of a rotary motor and a series of pulleys and gears, the linear motor can move and position the carriage correctly for character spacing.

Expand to word processor

By adding plug-in boards and modules for data storage, the Qyx typewriter can expand to perform most of the functions of a word-processing system, yet retain its physical dimensions.

An advanced model, the Qyx Level 2, adds store and edit features; add, delete, and move commands; and right-hand justification, when needed. Up to 10,000 characters can be stored in random-access memory.

The Qyx Level 3 typewriter adds a buried-media diskette drive to the Level 2 machine. This drive can store up to 60,000 characters.

In the Qyx Level 4, the diskette drive is accessible from the front of the machine and accepts standard 5-1/4-in. diskettes. The accessible drive is slightly different from the fixed drive, says Leon Staciokas, assistant general manager at Qyx, since the accessible drive must be able to position removable media precisely and the nonaccessible drive must not wear out a semi-permanent disc. Yet both use linear-induction drive motors and linear stepper motors to position the read/write head.

The diskette drives are about half as thick as commercially available diskette drives so that they can fit within the typewriter case. Qyx has no plans to offer the drive as a separate OEM product, according to Matthias.

Change a phrase everywhere

The top-of-the-line Qyx Level 5, priced at $7750, includes two diskette 120,000 characters of storage, and features "global change." A word or phrase that appears throughout a manuscript can, with but one correction, be changed throughout the typescript each time it appears.

Any Qyx typewriter can communicate with another Qyx typewriter over standard telephone lines with the addition of a $500 communications module. The module incorporates the features of a modem and a data-access arrangement, so it can be tied to a telephone line directly. The numbers on the typewriter's keyboard can be used to dial the call, and communications moves at 1200 baud. The interface is proprietary, but "will soon be expanded to include communication with Vydec word processors and even to computers," says Matthias. Vydec is another Exxon affiliate.

All typewriters will be available in New York, Washington, and Philadelphia first, and other cities will be added later in the year, according to Matthias. With the typewriters, companies will be able to perform many of the functions of word-processing departments—like duplicate letters—at a secretary's desk, instead of in a separate operation. ■■

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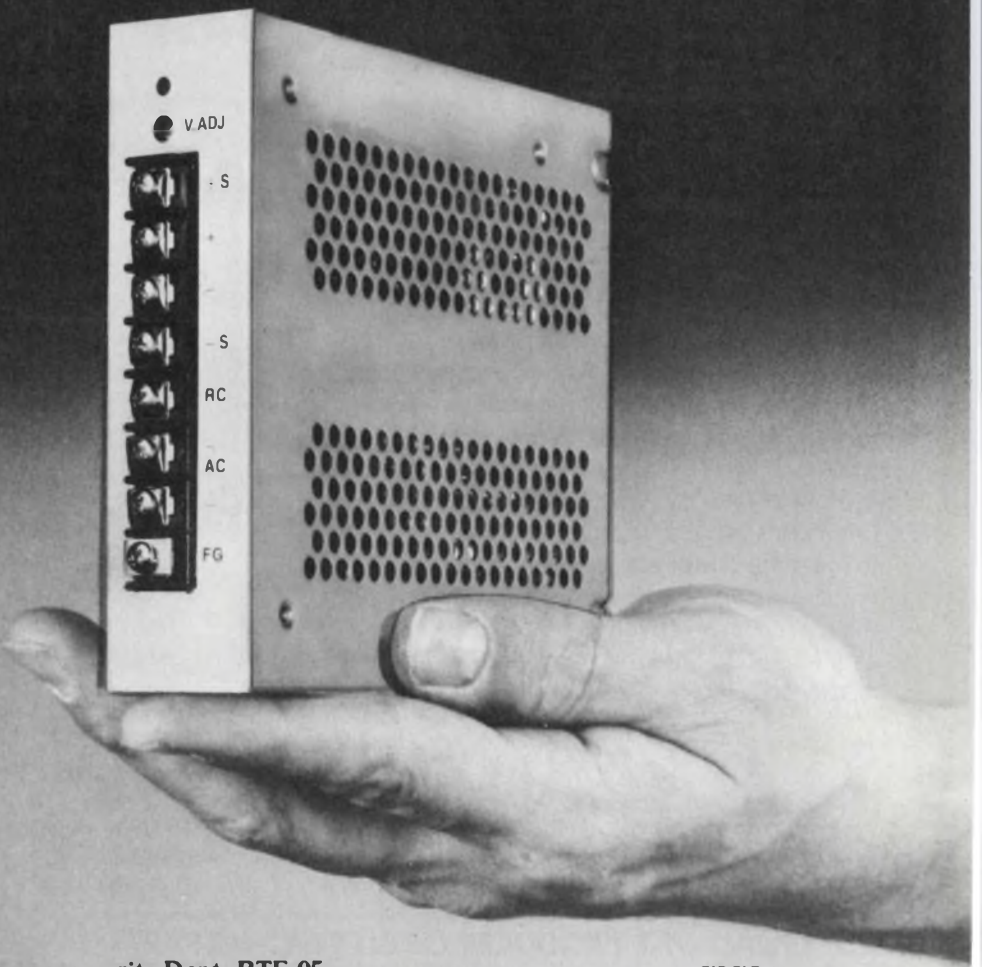

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Washington report

John Rhea, Washington Bureau

NASA seeks fifth Shuttle, warns of costly delays

Further delays in deciding on a fifth Space Shuttle orbiting spacecraft will increase its cost to $600-million, a top space agency official told the House Science subcommittee.

President Carter approved four Shuttle spacecraft when he reviewed the fiscal 1979 budget for the National Aeronautics and Space Administration, but deferred a decision on the fifth for another two years. Now, NASA Associate Administrator John F. Yardley says the fifth spacecraft is needed and would cost $365-million if procurement were to begin in fiscal 1979.

The other $235-million will stem from a more inefficient production rate and the higher cost of purchasing smaller quantities of parts from subcontractors, according to Yardley. In the past NASA has estimated the additional cost of waiting for another two years at $100-million to $200-million.

Yardley bases his case on the belief that the Space Shuttle will be used extensively during the 1980s and that five of the reusable spacecraft will be needed in case of unforeseen delays in ground operations or in case one of the craft is lost in an accident. NASA has predicted 560 Shuttle flights during the 1980 to 1991 period, but critics have doubted that the Shuttle will be that popular.

Both the Air Force and NASA plan to launch almost all their satellites from the Shuttle during that period. Under the present plan NASA will get two, the Air Force one, and the two organizations will have to share the fourth orbiter. But if the fifth spacecraft is approved, NASA will be assured of three and the Air Force of two.

U-2 spy plane slated to return

Next year the Air Force plans to reopen production of the U-2, the famous spy plane of the 1950s. A new version of the aircraft, designated the TR-1, will be produced at Lockheed Aircraft Corp.'s "Skunk Works" in Burbank, CA.

Unlike its predecessor, which conducted strategic reconnaissance from high altitudes and thus became obsolete with the development of spy satellites, the new aircraft is intended to support Army and Air Force tactical units under battlefield conditions.

The Pentagon has attempted to keep the program under wraps, but Defense Secretary Harold Brown told the House Armed Services Committee that the aircraft would be able to provide continuous standoff surveillance of a battle area, including such activity as nighttime operations, and even during bad weather. The TR-1's complement of electronic sensors will include long-range, side-looking radar for covering ground targets from outside enemy airspace.

Since Lockheed halted U-2 production more than a decade ago, the company has been experimenting with what has been called a "stealth aircraft" under the sponsorship of the Defense Advanced Research Projects Agency. Techniques developed for that aircraft, such as new types of paint and new electronic countermeasures to make the aircraft less visible to optical and radar detection, are expected to be adapted for the TR-1.

The Air Force is requesting $10.2-million to begin procurement of the TR-1 next year, but defense officials won't say how many they plan to buy or what they expect the planes to cost.

Laser weapons eyed to protect air bases

The Air Force has become interested in high-energy laser weapons to protect its European bases against enemy cruise missiles.

Studies will be sponsored by the Air Force's Armament Development and Test Center at Eglin Air Force Base, FL, which has asked interested companies to submit proposals. These are expected to be strictly paper studies aimed at figuring out the best ways to protect the bases from 1985 to 1995.

In addition to laser weapons, the studies may also cover guns, surface-to-air missiles and missiles launched by aircraft. The European bases are considered particularly vulnerable to a variety of weapons, including cruise missiles, standoff missiles launched by aircraft, and TV-guided glide bombs.

Computer data entered via voice system

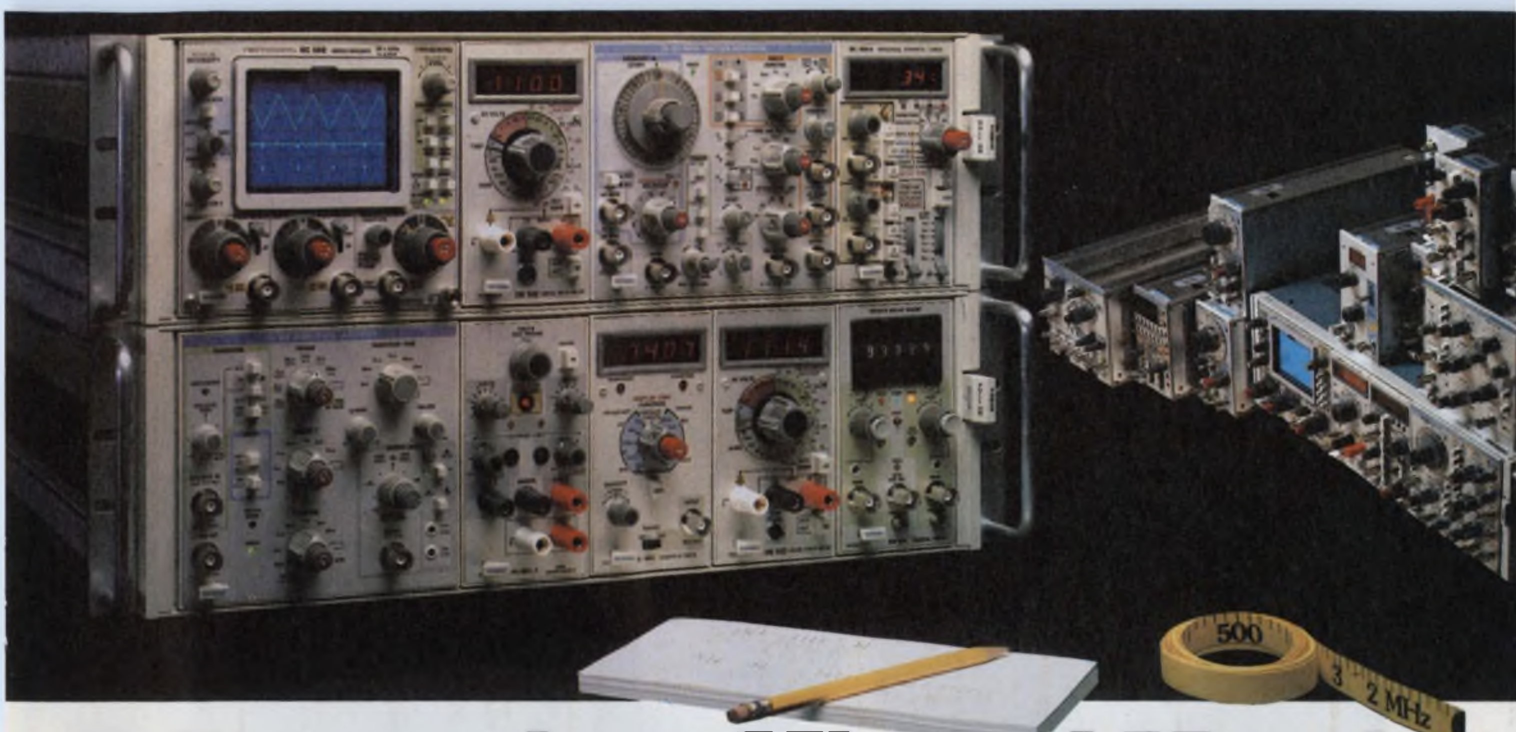
The Defense Mapping Agency is now using a voice-input system to put hydrographic data on ocean-depth measurements into its computer at Suitland, Maryland.

The voice system was developed by the Air Force's Rome (New York) Air Development Center in conjunction with Threshold Technology of Delran, NJ, and is based on the analysis of voice-frequency patterns. Operators at the DMA's Hydrographic Center have trained the system to recognize 14 words and numbers.

As the numbers are read-in for each depth entry, a visual display gives an immediate feedback to allow the operator to correct any errors. Each operator's speech patterns are prerecorded to create an individual speech program, which the system converts into a digital format. This is done by repeating the word to be added to the program 10 times. Speech patterns are averaged out, and a general pattern for each word is established.

Capital Capsules:

The National Bureau of Standards is planning a major increase in its program to develop new federal data-processing standards, as required by Public Law 89-306—the so-called Brooks Act named after its sponsor, Rep. Jack Brooks (D-TX). Funding would nearly triple from $6.4-million this year to $21-million in the new budget. The over-all NBS budget would go from $71.5-million to $94.3-million, the largest jump in the organization's history—if Congress approves. . . .**The first of 19 passive tactical reconnaissance systems will be delivered by Litton Industries Amecon Div. (College Park, MD)** late next year to the Air Force for installation on RF-4C aircraft. The firm won a $30-million production contract late last year after a successful development program it began in 1971. The reconnaissance system is designed to spot enemy radar systems around surface-to-air missile (SAM) sites. The company previously installed similar passive detection systems on the Navy's E-2C aircraft.



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Wherever your rack might be, in aircraft, in a van, a ship or a submarine, TM 500 can help trim your space requirements and save valuable dollars. Every extra inch consumed by monolithic racks on a crowded production floor or in a specially equipped van costs hundreds, even thousands of dollars. When figuring your rack cost, extra size and weight can really add up to mean extra dollars. Because of its convenient, compact size more of TM 500 fits into less rack space.

And because TM 500 mainframes, plug-ins and accessories are designed and manufactured by Tektronix, you can get technical assistance, parts and service all across the U.S.A. and in 50 other countries around the world.

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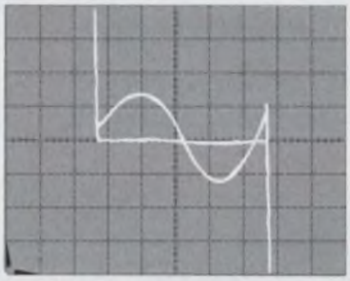

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Editorial

The typewriter

Charlie's new job as chief engineer brought with it a large corner office. Charlie liked it. He didn't spend an inordinate amount of time at it, but he did take a few hours, with his secretary, to furnish the office more to his tastes and comforts. He got a few plants, pictures and souvenirs and sprinkled them around the place. After all, he would be spending lots of hours there.

But something was lacking, and Charlie couldn't work effectively. Ah—a typewriter. So he sent a requisition for a typewriter, indicating that any old typewriter would do. He didn't object to a good electric, but a 20-year-old manual would be fine. And then came the trouble. The head of the Office Services Department asked if his secretary wasn't suitable. "Oh sure, she's fine," he responded. Then, in the course of the next few days, a small army of people came to ask mysterious questions relating to this typewriter until, finally, Charlie's boss gave him some avuncular advice.

"Charlie," he said, "you aren't entitled to a typewriter. You are Management Code Level 7. You're suppose to be issued a pencil and a pad. Your secretary is supposed to type for you. Nobody above Code 4 ever gets a typewriter."

"But that's ridiculous," Charlie told him. "My handwriting is atrocious. Even I can't read it. And while I certainly use my secretary a lot, I do a lot of my thinking at the typewriter, I make quick notes to myself, to you and to my people on the typewriter. I brew up ideas at the machine. When I have an idea, I want to put it on paper right away, and if I did it in handwriting, we'd need a Sanskrit expert to decipher it. Hell, if we can't manage it through channels, I'll buy my own typewriter."

Well, Charlie won. And for weeks he was the talk of the office, as people would wander by and point with amazement at the executive with the typewriter—a man at Management Code Level 7, no less.

In time, Charlie hopes to break down a lot of other organizational structures that get in the way of getting things done.

George Rostky

GEORGE ROSTKY
Editor-in-Chief

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FOCUS on Scientific Calculators

Picking a scientific calculator is getting tougher all the time, despite the fact that the number of calculators to choose from—and manufacturers—has gone down rapidly over the last three years. But what the industry has lost in numbers, it has more than gained in calculating features and computing power. Keyboards have been improved. LED and fluorescent-display technologies have been refined. And more computing power has been packed into all machines, with top programmable calculators beginning to take over for computer terminals. Reliability has been upgraded—and so has service availability.

Jim McDermott
Eastern Editor

Unfortunately, increased machine complexity is making it harder to compare units. And a fast-growing generation of powerful user-programmable calculators is further confusing the picture.

Three years ago, you could get only one hand-held programmable, the $795 HP-65—today there are more than 15 new ones. They range from a $35 Sinclar unit with 36 program steps to a $300 Texas Instruments TI-59 with several hundred program steps to a $750 Hewlett-Packard HP-97 with a 224-step program and

The continuous CMOS memory of the HP-25C retains data stored in its 49-step program memory as well as that in eight addressable registers. Special functions often used, but not preprogrammed in the machine, can be stored.

Fifty fully merged program steps of the TI-57 store up to 150 keystrokes. Eight multi-use, addressable memories store data, calculation results, and intermediate answers. The machine has full editing capabilities.

a printer.

Specifying a calculator, no matter what type, is not as straightforward as specifying components or hardware, because the specs aren't generally comparable. That is, purely personal factors, like experience and habit, play a major role in your choice. For example, it's up to you to decide how readable a display is, and how the keys feel when you enter data. And the type of arithmetic operation you choose—algebraic or reverse-Polish notation—may be the one you have become most comfortable with.

And finally, with the growing preponderance of programmables come many new considerations—not only machine architectures and programming features, but also the availability and quality of software and programming-teaching materials.

Where do you start?

If you use a calculator just to do some simple math once or twice a week, you'll have no problem picking one. Several suitable machines selling from $30 to $50 have powerful preprogrammed trigonometric, logarithmic and other math functions. Scientific notation

Table 1. Calculator keyboard functions.

Instructions to calculator

CE or CLX	Clears entry (previous entry and memory unaffected)
CLR	Clears calculator
ENTER or ENT or ▲	Enters number into stack*
R↓	rolls stack to review contents
=	Completes pending operation+
(and)	Parentheses+
X ⇄ Y	Exchanges x and y register contents
Last X	Recalls last x entry*
CHS or +/−	Changes sign
EEX or EE	Enters exponent (for scientific notation)
FIX	Fixed notation
SCI	Scientific notation
ENG	Engineering notation (n x $10^{3,6,9}$...)

*RPN only +Algebraic only

Scientific functions

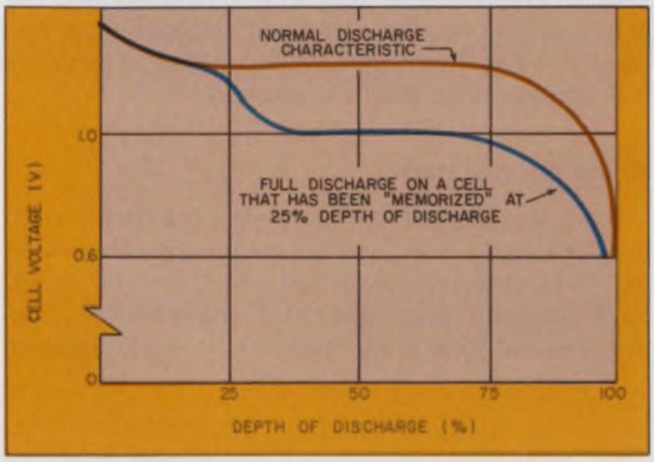
DEG	Sets angular functions in degrees mode
RAD	Sets angular functions in radians mode
GRD	Sets angular functions in grads mode
tan or tan^{-1}	Computes tangent or arc tangent
sin or sin^{-1}	Computes sine or arc sine
cos or cos^{-1}	Computes cosine or arc cosine
tanh	Computes hyperbolic tangent
sinh	Computes hyperbolic sine
cosh	Computes hyperbolic cosine
π	Displays pi (3.14159...)
→H.MS or D.MS	Converts displayed decimal hours (or degrees) to hours/min./sec. format
→H or $D.MS^{-1}$	Converts displayed hours/min./sec. to decimal hours (or degrees)
→R or P/R^{-1}	Rectangular coordinate conversion
→P or P/R	Polar coordinate conversion

Mathematical functions

+	Addition
−	Subtraction
x	Multiplication
÷	Division
1/x	Computes reciprocal of displayed number
%	Computes x percent of y
x^2	Squares displayed number
$\sqrt{x}$	Extracts square root of displayed number
y^x	Raises number in y register to power in display
$\sqrt[x]{y}$	Extracts xth root of previously entered number
log	Computes common log of number
10^x	Raises 10 to the power in display
ln	Computes natural log of number in display
e^x	Raises e (2.718...) to the power in display
x!	Computes factorial (1 x 2 x 3...x n)

Statistical functions

Σ+	Summations
Σ−	Negative summation (for deleting data)
S	Standard deviation
$\bar{x}$	Mean (arithmetic average)
LR or TL	Linear regression
$\hat{y}$	Linear estimate
VAR	Variants
r	Correlation coefficient
N.D.	Normal distribution
POISS	Poisson distribution
GAUSS	Gaussian distribution
BINOM	Binomial distribution



1. **A "memory" effect in NiCd rechargeable cells** results in an apparent loss of capacity with repetitive charge-discharge cycles. This effect is reversible and can be cured by giving the cell a deep discharge and a recharge.

as well as 12 digits—10 mantissa and 2 exponent—are now found in low-cost units.

For once-in-a-while use, get one of the low-cost LED or fluorescent-display units that runs on AA dry cells. Keeping nickel-cadmium batteries recharged when a calculator is idle most of the time is a nuisance. Or buy an LCD model, and forget the batteries for a year.

But if you're going to make serious, professional use of a calculator, you're going to have to look long at several key features:

- The kind of arithmetic programmed into the machine. It may be ordinary algebra, algebra with a hierarchy, or reverse-Polish notation.
- Keyboard design and accessibility.
- Display types and viewability, the number of digits and special display features.
- Care and feeding of batteries.
- Power of preprogrammed math, trigonometric, statistical and other functions.
- Use of floating point, scientific and engineering notations.
- Accuracy.
- Basic programmable features.
- Printer applications.
- Programmable machine features.
- Software and its availability.

Which arithmetic?

You'll probably feel most at home using a calculator with the math system you've grown up with—say, ordinary algebra. But two other math systems, algebra with a hierarchy and reverse-Polish notation, may be better in the long run because they are more efficient (use less keystrokes) and can solve complex problems easier and faster.

Ordinary algebra, the simplest and most straightforward, is found in all scientific calculators except those of Texas Instruments and Hewlett-Packard. TI's calculators use algebra with a special hierarchy while HP's line incorporates reverse-Polish notation.

Ordinary algebraic operations are, for the most part, executed in the sequence you enter them. For example:

$$2 + 3 \times 4 = 20.$$

For long strings of calculations, make sure that your machine has at least two levels of nested parentheses, but preferably more—as well as a one or two-register memory. Canon's F-7 calculator, for one, has seven levels of parentheses and two registers.

An algebraic-entry system with hierarchy, together with a pair of parentheses keys, makes up what TI calls its Algebraic Operation System (AOS). Its problem-solving capabilities are comparable to those of HP's reverse-Polish (RPN), but for most problems AOS requires more keystrokes.

If you were brought up on ordinary algebra, AOS may be somewhat confusing at first. Where a calculator using ordinary algebra obeys you and performs the arithmetic in the entering order, an AOS calculator grabs your key entries, both function and digit, sorts out the data in the order it wants, and performs the calculations in its own sequence. The TI-59, for example, defies you to set up an equation any other

With a 36-step program capacity, this vest-pocket Sinclair programmable calculator handles frequently used programs in math, physics and engineering. For $35 the machine and a library of 290 programs are supplied.

Silver-oxide cells provide 700 hours of use for this Casio fx-3000 calculator with a liquid-crystal display. This type display permits packaging the power of a 38-function, 10-digit machine in a slim billfold case.

way than the machine wants it. Computations are always performed in the following order:

1. Special single-function key entries, such as those for trig and log functions, and squares, square roots, reciprocals and conversions.
2. Powers and other roots.
3. Multiplications and divisions.
4. Additions and subtractions.

In other words, if you were to key in the previous equation, the answer wouldn't be 20:

$$2 + 3 \times 4 = 14$$

With AOS the 3 and 4 are first multiplied, and 2 is then added.

The battle of keystrokes

But is AOS more efficient than RPN? This continuing controversy has been joined by calculator users on both sides. Examples have been created that "prove" one or the other to be more efficient. This, of course, can be done by selecting problems specially suited to one calculator architecture and not the other.

But the pros and cons of the efficiency of one arithmetic system over another become more or less academic, because TI concedes that RPN is somewhat more efficient than AOS architecture. However, Richard Cuthbert, applications manager for TI's professional calculators, points out that the general need for more keystrokes per program by TI machine users is intentional.

"It's intrinsic that you use more space with the AOS architecture," Cuthbert says. "But we have deliberately taken this approach to make it easier for the user to program. Our AOS, like higher-level languages in large computers, takes more room than assembly language. But assembly language is a lot tougher for the neophyte. While our approach imposes additional overhead, we have a lot more storage in the machine."

RPN does save a few keystrokes. But there's much more to choosing a calculator language than counting keystrokes. The machine itself should be adaptable to the user's background and needs. A survey of HP and TI users has shown that, by and large, those who have learned to operate programmable machines of one type or another become "addicted" to the machine they learned on. As a matter of fact, over 2000 calculator owners belong to an HP Users Club and 500 to a TI Users Club, both of which are unaffiliated with the manufacturers.

Graduating from an algebraic calculator to an RPN can be a problem because data in the RPN system are entered and manipulated differently. The RPN procedure is a lot like the entry of data into computers.

With algebraic entry, the arithmetic functions of plus, minus, times, or divide by are placed between the numbers of a two-number operation. But with RPN entry the arithmetic function is placed after both members of a two-number operation.

In other words, for problems having two numbers and one arithmetic operator, the first number is keyed in and saved in a stack register by pressing an ENTER key. The second number is keyed in and followed by the arithmetic operator. An expression like $(3 \times 4) + (5 \times 7)$ would be evaluated in an RPN machine by the following steps:

3 ENTER 4 × (12.00 is displayed),

5 ENTER 7 × (35.00 is displayed)

+ (47.00 is displayed).

While RPN, like AOS, is at first awkward for those accustomed to working with algebraic system entry, users experienced with both AOS and RPN say that with frequent use, they become either as proficient or more proficient at using RPN.

Keyboards are growing

Unfortunately, the amount of keystrokes isn't determined simply by the math language you choose. Because of the abundance of functions preprogrammed into all of today's advanced scientific calculators, keyboards have two, and in some cases, three functions assigned to one key. The more functions per key, the more keystrokes it takes to solve a problem. Try to pick a calculator with more single-function keys for faster and more accurate keyboard operation.

Some calculators signify data entry with keys that snap or click when they are depressed, so you don't have to verify each entry visually. One Sharp calculator even has keys that "beep." But other calculators have keys with a very light touch and no positive feel, which means that you've got to watch the display to make sure a number or function is entered. That type of key is more prone to unintentional multiple-digit entry on low-quality keyboards. Not surprisingly, most users prefer the more reliable snap action keys and their tactile feedback.

Keys should be far enough apart so that you can operate them without accidentally depressing an adjacent key. One indication of a good keyboard is that the number keys are somewhat larger or spaced farther apart than the rest of the keys.

A frequently neglected but important consideration is to make sure that your calculator has a moisture barrier under the keyboard to keep liquids like coffee from getting into the keyswitch or into the calculator circuitry.

Check off your functions

Finally, inspect the keyboard markings to verify whether or not a calculator has all the key-addressable functions you'll need—arithmetic, trigonometric, statistical or whatever. One calculator specialist suggests that you draw up a list of the formulas and equations on the basis of those you regularly use, those employed occasionally, and those encountered infrequently.

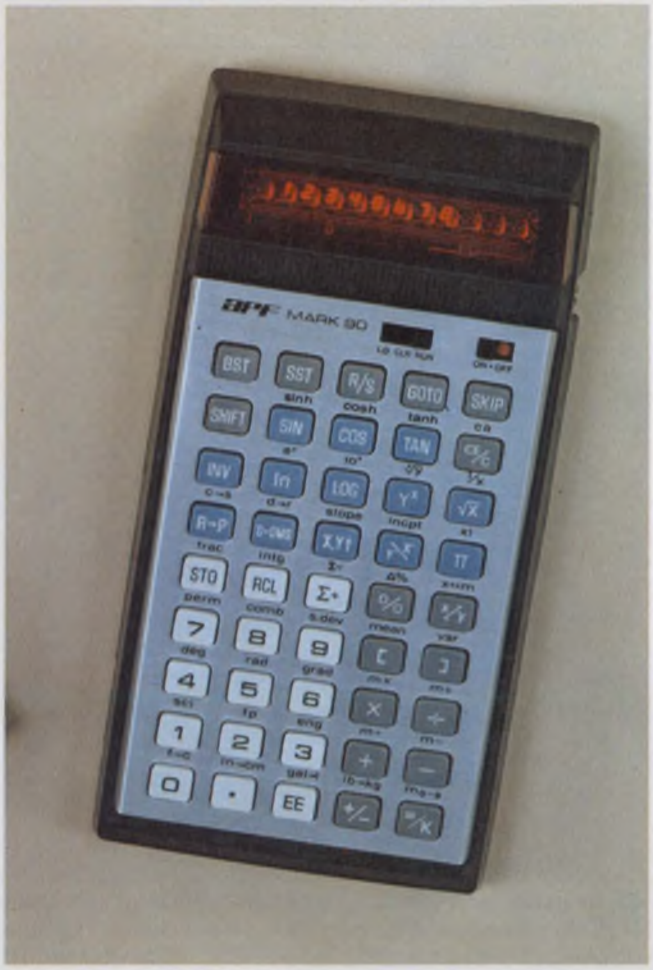
Check your list against the Table, which contains key-addressable functions that will be needed for a wide range of problems. Not all of these come on all calculators. And whether the machine is costly or inexpensive doesn't necessarily have any bearing on whether certain functions are contained.

For example, anyone who wants to work hyperbolic problems won't find the special keys on the high-priced HP-67 or HP-97. But solutions are included in HP's $35 Math Pac I software.

Texas Instruments doesn't do any better with its TI-58 or −59, which have no hyperbolics on the keyboard. The company recommends the formulas in a standard math handbook.

What's happened is this: The hyperbolic keys and functions have been sacrificed in most programmable calculators (the APF MK 90 is an exception) to make room for other programming keys and functions. The point is, compare your math-function list carefully with the keyboards you look at. Other functions may have been omitted, too.

Another thing: You may be able to calculate the values of a function only through extra keystrokes. For example, with most calculators you determine the value of an inverse function by striking an "F" or transfer key to access that function on a second key. But TI has packed so much computing into the TI-58 and TI-59 that it takes an added keystroke to get at the inverse sine. But this is a trade-off you can probably live with.



Over 70 preprogrammed functions are available in this 72-step programmable calculator, the MK 90 by APF Electronics. Five keys control program loading or running. Data are stored in 10 registers. Full editing features are provided for program debugging.

Today's engineering calculators display very large or very small numbers in scientific notation. On some machines when the displayed numbers exceed a certain maximum value or drop to less than a specified minimum, the display automatically switches to this notation. On others, you do the switching.

Scientific notation consists of a mantissa that carries the significant digits of a number, and a two digit exponent, which in most cases ranges from 10^{-99} to 10^{99}. The mantissa commonly consists of 8 or 10 displayed digits, with two or three undisplayed digits carried in the machine.

Engineering notation—a form of scientific notation in which the exponent is a multiple of 3, is also common. It is particularly desirable for problems in the electronics field. Many machines offer a special key (EE or ENG) for converting floating-point into engineering notation.

Another desirable feature to look for in advanced calculators is a fixed-point key (FIX), which allows you to select the number of digits to be displayed after a decimal point. If the digits in the calculated result or the original entry exceeds the number selected with the FIX key, the calculator automatically rounds the least-significant digit displayed, while continuing to perform all calculations.

Look at displays

Having gone over keyboards, you should literally look at displays. Your eyes are the best judge, for a display should be easy and comfortable to read. The two most common displays for scientific calculators are red LEDs and the blue-green electrofluorescent units. Unfortunately they both demand a relatively high battery current. But liquid-crystal displays, which substantially reduce battery current and boost battery life a thousand hours or so, are emerging in slim preprogrammed calculators, such as APF Electronics' MK 8602, Casio's fx-3000, Commodore's LC63SR and Sharp's EL-5806.

LED displays vary in quality. Watch out for the display that enlarges tiny digits with plastic bubble-type lenses. Its field-of-view is narrow, and the calculator must be positioned exactly right for decent viewing—which literally can give you a pain in the neck.

In addition to showing data, a display indicates errors, entry of false data, overflow, underflow, data in memories and a low battery. Unfortunately, the low-battery indication generally is as effective as idiot lights on automobiles. When it flashes, pull over and stop calculating until you plug in a new battery pack or put the charger on.

Does your calculator lie?

Assuming now that you've made a tentative selection of a calculator, the next question is: "Can I trust it?"

The answer is: "Most of the time, yes. But not exactly all of the time." For example, try the following exercise on your machine: Enter 2, and take its square root 20 times. Now hit the square key 20 times. The answer should be exactly 2. But it won't be. An HP-97 will give you 1.999897829. A TI-59 will give you 1.99999681. And a National Semiconductor 4660 will give you 1.99993871.

Take another example: Subtract two functions that are mathematically equal. The answer should be zero. But the calculator may not display that. For instance, take a TI-59 and subtract the cos of 45° (0.7071067812) from the sin of 45° (0.7071067812). A remainder of −7. −13 is displayed, showing that there is a discrepancy in the 13th digit.

Irregularities like these occur because designers have to fit algorithms into digit strings of a given length—and at a specified cost. The designer may have decided to chop off guard digits, additional digits used in calculators to preserve the accuracy of results. For example, the TI-59 displays 10 digits, but actually uses 13 for most operations. For some functions the 13th digit is chopped off. More accurate results would be obtained if the 13th digit were first rounded off by adding 5, then chopped.

The program memory in this 128-step programmable PC-1201 calculator by Sharp can be partitioned into 13 separate programs; or it can hold 12 subroutines. A CMOS memory powered by silver-oxide cells hold a program for a year, which is equal to silver-cell life.

Anomalies in equations used to fit functions within a machine's architecture may sometimes be unknown even to the designer. They will be found only when the calculator gets into the field.

So what do you do about it? Where can you find out whether or not there may be some unexpected errors associated with the functions and numerical ranges you'll be most concerned with?

That's not easy to answer. Some Owners Manuals list the expected accuracies of various functions within stated calculation boundaries. They frequently point out that "accuracy is low around singular and deflection points." But how low? How do you find out? Other manuals ignore the problem entirely.

Don't try to get inside information from the manufacturers. Many of the errors are the result of discontinuities in proprietary machine algorithms. To openly identify critical data regions could give the competition useful insight into a calculator's architecture.

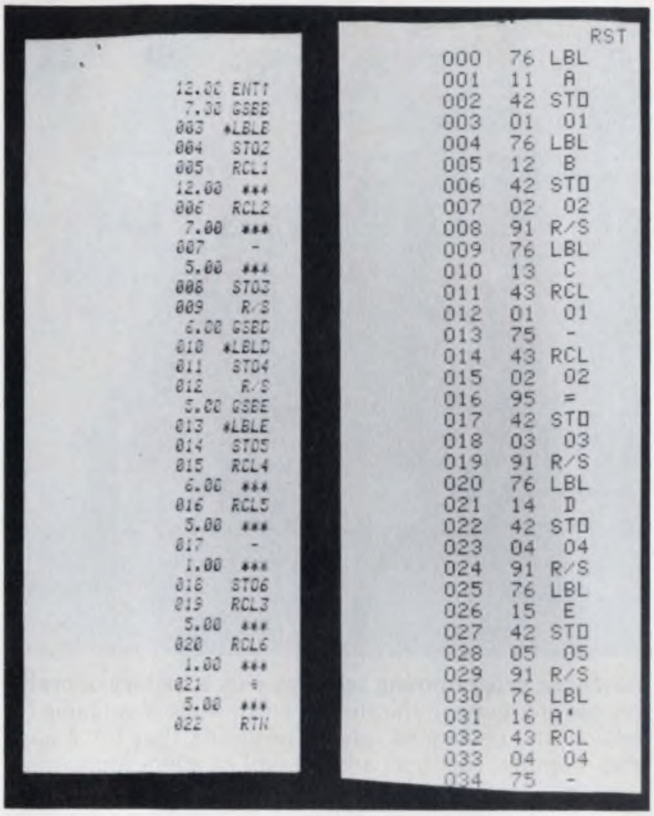
Discrepancies uncovered by calculator users have been reported to two private groups—the HP-65 Users Club, and the SR-52 Users Club.

Excellent information on calculator inaccuracies appears in reports by Dr. William Kahan, professor

Table 2. Comparison of scientific calculators and key features.

						Arithmetic notation			Preprogrammed functions																																	
																											Statistical functions															
Calculator mfgr.	Model	List Price, $	No. of keys	[1]Display type	[2]Arithmetic type	Floating point, digits displayed	Scientific, mantissa & exponent	Engineering	Trig functions & inverses	Hyperbolic functions & inverses	Decimal deg/rad/grad functions	Deg/rad & inverse conversions	Deg/min/sec to decimal angle	Decimal angle to deg/min/sec	Polar to rectangular & inverse conversion	Logarithms (bases 10, e)	Antilogs (bases 10, e)	Change sign (+/−)	Reciprocal (1/x)	Square (x^2)	Square root ($\sqrt{x}$)	n-th power (y^x)	n-th root ($\sqrt[x]{y}$)	Pi (π)	Conversions, metric	Factorials (n)	Summations (Σx, x^2, n)	Mean value	Variance	Standard deviation	Permutation (nPr)	Combination (nCr)	Linear regression	Trend line	Slope and intercept	x/y registers exchange	x/memory registers exchange	Program memory, no. of steps	Parentheses or stack registers, no.	Data memories or registers, no.	Programmable software: magnetic cards (M); solid-state (S)	Special features: see footnote
Hewlett-Packard	*HP-97	750	55	L	RPN	10	10/2	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•			•	•		•						•	•	224	4	26	M	3
	*HP-67	450	35	↓	↓	10	10/2	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•			•	•		•						•	•	224	4	26	M	
	*HP-19C	345	31	↓	↓	8	8/2	•	•		•		•	•	•	•	•	•	•	•	•	•	•	•			•	•		•						•	•	98	4	30		3,4
	*HP-29C	195	30	↓	↓	8	8/2	•	•		•		•	•	•	•	•	•	•	•	•	•	•	•			•	•		•						•	•	98	4	30		4
	*HP-27	175	30	↓	↓	8	8/2	•	•		•		•	•	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•			•	•	•	•	•		4	10		
	*HP-25C	160	30	↓	↓	8	8/2	•	•		•		•	•	•	•	•	•	•	•	•	•	•	•			•	•		•						•	•	49	4	8		4
	*HP-25	125	30	L	RPN	8	8/2	•	•		•		•	•	•	•	•	•	•	•	•	•	•	•			•	•		•			•	•	•	•	•	49	4	8		
Texas Instr.	*TI-59	300	45	L	AOS	10	10/2	•	•			•			•	•	•	•	•	•	•	•	•	•			•			•						•	•	480	9	60	S,M	5
	*TI-58	125	45	↓	↓	10	10/2	•	•			•			•	•	•	•	•	•	•	•	•	•			•			•						•	•	240	9	30	S	5
	*TI-57	80	40	↓	↓	10	10/2	•	•			•			•	•	•	•	•	•	•	•	•	•			•			•						•	•	50	9	8		
	SR-51-II	60	40	L	AOS	10	8/2	•	•	•		•			•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•			•	•	•	•	•		9	3		
	PC-100A	200	(Printer for TI-58/59)			10	10/2	← N.A. →																																		6
Sharp Electronics	*PC-1201	90	40	F	OA	10	10/2		•		•		•	•	•	•	•	•	•	•	•	•	•	•		•	•	•		•							•	128	3	12		4,7
	*EL-5001	50	39	F	↓	10	10/2		•	•	•		•	•		•	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•					•	see note	2	2		8,12
APF Electronics	*MK 90	60	45	L	↓	8	8/2	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•	•	•	72	4	10		9
	MK 56	50	45	L	↓	8	8/2	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•	•	•		4	10		9
	MK 8601	35	38	LX	↓	8	8/2	•	•	•		•			•	•	•	o	•	•	•	•	•	•			•	•	•	•	•	•	•	•	•	•	•		2	2		
Casio	fx-120	30	39	F	↓	10	8/2	•	•	•			•	•	•	•	•	•	•	•	•	•	•	•	•		•			•	•	•				•	•		6	1		
	fx-3000	50	39	LX	↓	10	8/2	•	•	•			•	•	•	•	•	•	•	•	•	•	•	•	•		•			•	•	•				•	•	8/2	2	1		
Canon	F-7	80	36	L	↓	8	8/2	•	•		•		•	•	•	•	•	•	•	•	•	•	see note	•	•	•													7	2		10
Nat I Semi.	NS108	50	38	LX	↓	10	8/2		•	•	•	see note	•	•	•	•	•	•	•	•	•	•		•		•	•	•	•	•	•	•				•	•		2	1		11
Sinclair	Programable	35	19	L	OA	8	5/2		•			•				•	•	•	•	•	•																•	36	1	1		

*Programmable calculators (see text) 1. L = LED; F = flourescent; LX = liquid crystal 2. OA = ordinary algebra; AOS = hierarchical alegbra; RPN = reverse-Polish notation 3. Calculator has integral printer 4. Calculator has CMOS memory for long-term program storage. 5. Program and data memories can be exchanged. See text. 6. Printer has full alpha-numerical and plotting capability. 7. Can subdivide program memory into 13 programs or 12 subroutines. 8. Calculator has six thumbwheel-accessible programs built in. 9. Converts cartesian to spherical coordinates and inverse. 10. Has cube root instead of n-th root 11. Has decimal-degree to radian to grad and inverse conversions. 12. Six thumbwheel programs include: (1) Linear and polynomial plots; (2) Statistics; (3) Quadradic equations; (4) Polynomial integration; (5) Complex number algebra and coordinate conversion; (6) Vector algebra and coordinate conversions.



Thermal-printer tapes show a trace listing of a simple program executed on an HP-97 (left) and a verification listing of program steps (right) produced by a TI PC-100A printer controlled by a TI-59 in the printer cradle.

of Mathematics and Computer Science at the University of California at Berkeley. Kahan specializes in numerical error analysis and has conducted independent studies and reported them in "Can You Count on Your Calculator?" and "And Now for Something Completely Different, the Texas Instruments SR-52."

One simple way to find out if and where your calculator has errors is to perform a forward-function calculation and then an inverse-calculation with functions and values in the region of suspected inaccuracies. The displayed answer should be identical to the original entry. If not, there is an error in the forward-function or the inverse, or both.

For example, take the cos of 0.05°. Then press the inverse-function ($\cos^{-1}$) key. The answer probably won't be 0.05. Try the same approach on the sine and tangent functions.

You can use the forward-inverse method on other functions, such as natural logs and antilogs. The natural log of zero, or of a negative number, should indicate ERROR. Make this check in the vicinity of 2, say, from 1.99 to 2.04, and in the vicinity of 1. Use the following table to verify your results:

Number	ln
1.1	$9.53101798043247 \times 10^{-2}$
1.01	$9.95033085316808 \times 10^{-3}$
1.001	$9.99500333083532 \times 10^{-4}$
1.0001	$9.99950003333083 \times 10^{-5}$
1.00001	$9.99995000033333 \times 10^{-6}$
0.99999	$-1.00000500003333 \times 10^{-5}$
0.9999	$-1.00005000333358 \times 10^{-4}$
0.999	$-1.00050033358353 \times 10^{-3}$
0.99	$-1.00503358535014 \times 10^{-2}$
0.9	$-1.05360515657826 \times 10^{-1}$

STEP	KEY			KEY CODE			STEP	KEY			KEY CODE		
0	C	x→M	0		55	00	32			=			84
1		F	HLT		F	12	33			↕			45
2	L	x→M	1		55	01	34		RM	5		65	05
3		F	HLT		F	12	35			↕			45
4	R_s	x→M	2		55	02	36		F	→rθ		F	64
5		F	HLT		F	12	37		x→M	6		55	06
6	R_p	x→M	3		55	03	38			↕			45
7		F	HLT		F	12	39		x→M	7		55	07
8		x→M	4		55	04	40		RM	2		65	02
9			x			54	41			+			74
10			2			02	42		RM	3		65	03
11			x			54	43			x			54
12		F	π		F	41	44		RM	0		65	00
13			=			84	45			=			84
14		x→M	4		55	04	46			↕			45
15		F	x^2		F	44	47		RM	5		65	05
16			x			54	48			↕			45
17		RM	0		65	00	49		F	→rθ		F	64
18			x			54	50			↕			45
19		RM	1		65	01	51			+/−			82
20			−			64	52		M+	7		75	07
21			1			01	53			↕			45
22			=			84	54			÷			44
23			+/−			82	55		RM	6		65	06
24		x→M	5		55	05	56			↕			45
25		RM	4		65	04	57			=			84
26			x			54	58			↕			45
27		RM	0		65	00	59		RM	7		65	07
28			=			84	60		F	→xy		F	74
29		x→M	0		55	00	61			↕			45
30			x			54	62		x→M	7		55	07
31		RM	2		65	02	63			↕			45

MEMORY				LABEL			
s		4	$f \rightarrow 2\pi f$	s		4	
t		5	$1 - \omega^2 LC$	t		5	
0	C → ωC	6	R_1/R_2	0		6	
1	L	7	$\theta_1 - \theta_2$	1		7	
2	R_s	8		2		8	
3	R_p	9		3		9	

2. **Program lists, like this one for solving series-resonant circuit problems,** are found in Sharp's PC-1201 software manual. Each program is supplied with a sample problem and step-by-step directions for its execution.

Another check is to add mathematically equal functions of opposite sign, or subtract equal functions of the same sign:

$$\tan 89.99° + \tan 90.01° = ?$$

$$\sin 45° - \cos 45° = ?$$

The answer should be zero.

Can I count on my battery?

Having determined whether or not your calculator can be trusted, don't forget to check the batteries. Nickel-cadmium rechargeable batteries are the work-horses that power the vast majority of scientific calculators. But they're sensitive to heat and to cold. Not only that, a perfectly good cell may stubbornly resist taking a charge. And continuous overcharge will cut capacity. And continuous deep discharge will do worse.

To get maximum, continuous useful life and dependability from NiCd batteries, you'd better know their properties and characteristics. Unfortunately, calculator manufacturers offer little help. For example, take the following statement from a "Battery Care" section of an otherwise excellent 300-page User Manual. The manual defines the point of battery discharge as follows: "If the calculator fails to turn on you should substitute a charged battery pack, if available, for the one in the calculator."

A typical NiCd battery pack consists of two or three AA-sized, sealed cells, each with a nominal voltage of about 1.25 V. Pressure-relief seals are designed into the cells so that when internal pressure builds up, it can be relieved.

Most calculators use what are termed "slow-charge" batteries that are designed to be fully charged in "14 to 16 hours, or overnight." One reason is that these batteries are not harmed by a continuous overcharge. However, a sustained overcharge does lower the discharge voltage.

Note that nickel-cadmium batteries apparently lose capacity from repetitive use patterns. This phenomenon, known as "memory," acts like this: If you charge your battery fully each night, and discharge it by 25% during each working day, after a while the battery develops a memory that makes it think it has only 25% of its original capacity (see Fig. 1): It acts like a battery that is only one-fourth its actual size. So whereas the calculator should normally operate off the battery for, say, four hours, it will now last less than one.

Fortunately, "memory" is only temporary and can be corrected easily: Subject the battery to a deep discharge, then recharge it to restore it to its original performance. One calculator manufacturer suggests that a battery occasionally be discharged by leaving the calculator on until the display digits go out, then recharging it fully. To avoid the situation in the first place, all you have to do is make your charge-discharge patterns random.

Attention: Don't subject the battery to extended deep discharges, such as those caused by neglecting to turn the calculator off for a day or two. Two bad things will happen. First, since the two or three cells in the battery packs don't have identical charge capacities, one usually discharges to 0 V before the others. It is then reverse-charged by the voltage in the other cell or cells, and hydrogen gas is generated internally. The resultant pressure rise may then vent through the pressure-relief seal, with a loss of battery moisture.

Second, a deeply discharged cell is more likely to short internally than one that is fully charged. That's because a fully charged cell has sufficient energy to vaporize, or clear, the shorted path. A near-dead cell won't have enough energy to do so.

Advanced programming features plus a battery-operated printer are found in the HP-97. The printer is valuable for editing and debugging, giving printouts that trace each step number, function and results of every step.

Nickel-cadmium batteries are designed to live in an ambient of 20 C (68 F) room temperature. Charging them at greater than, or much less than 20 C shortens their life. Don't make a practice of charging your calculator batteries in a cold room. Or in a hothouse.

Fully charged NiCd batteries, standing idle at 20 C, lose about 1% of their charge per day because of chemical self-discharge. So in about a month or so, the battery will have lost about half its capacity, which calls for a recharge.

Hint: To keep idle batteries charged for extended periods, wrap them in a moisture-proof bag and store them in the food—not freezer—compartment of your refrigerator. The $\approx$ 40 F temperature reduces the normal self-discharge to one-fourth, and extends the 50% discharge time to over six months. Caution: Be sure the batteries are warmed to room temperature before recharging.

So far, you've been trying to select a scientific calculator in general. But a new breed—calculators you can program—is fast emerging, and you'd better be ready for them.

The year of the programmables

As 1975 was the year of the preprogrammed scientific calculator—more than 40 kinds were available then—1978 is the year of the programmables. Five out of eight of HP's scientific machines can be programmed, as can three out of five of TI's new line. Programmables are also appearing from APF Electronics, Casio, Commodore, Sharp and Sinclair.

Programmable calculators are "grown-up" preprogrammed machines that tell you, in effect, "Leave the driving to us." They can learn a sequence of keyed-in instructions and automatically execute that sequence on command. They store constants and other data. The program sequence, or list, is stored in a program memory while the data are stored in registers that can be accessed by the program.

To teach a programmable calculator a program, you switch to a PRGM or LEARN mode and enter a problem in a sequence of keystrokes dictated by the calculator's program list. The needed software may be prepared by the calculator manufacturer, or you can write it as an original program.

To execute the program, you switch the machine to a RUN mode, key-in initial problem values and let the program take over. You'll save a substantial amount of time when you have to solve similar problems over and over: You can use the same program, instead of going through single-key entry of every step. Great? Sure. But wait.

Turn the calculator off. Then turn it back on and try to run the program. Chances are, you can't, because the program was wiped out when the power went off. Now you have one important yardstick for comparing programmables: In one class of machines, the program must be keyed in again when the power is turned back on. So if your problems involve 100 or 200 program steps, get to work early. Or leave your calculator plugged into the charger and turned on as long as you want to keep the program in. However, when you do so, you'll be trading inconvenience for potential battery trouble.

One way to retain the program is to use low-power CMOS memories, which, with an auxiliary battery, keep the program and its data for months after a calculator is shut off. Such memories are designed into the \$160 HP-25C, \$195 HP-19C and the \$345 printer-equipped HP-19C. Sharp's \$90 PC-1201 has a standby CMOS memory, powered by two silver-oxide cells, that will hold program information for about a year.

Magnetic cards also keep programs. Machines like the \$300 TI-59 come with a magnetic-card handler and can store programs on the cards and read them back at any time. Magnetic cards are also used in the \$450 HP-67 and \$750 HP-97. In addition, libraries of prerecorded or "canned" programs are available in HP's Engineering Application Pacs.

The newest approach to programs that won't vanish when the machine is turned off is the Solid-State Software ROM modules that plug into the TI-58 and 59. The Master Library module, which corresponds to HP's Standard Pac of magnetic cards for the 67 and 97, has some 5000 program steps that provide 25 different programs in mathematics, geometry, statistics, engineering conversions, finances and games. Each of the programs can be loaded into the program memory and data registers with a few keystrokes, and run independently. Or the program can be called in by the machine to run as a subroutine of a larger program.

A universal and frequently vexing problem with programmables is how to debug a program you have written. For most programmables, debugging is a time-consuming operation that requires you to single-step through the entire program listing, comparing the program step numbers and associated key codes (two-digit numbers that tell which keys were depressed to enter the program) that appear in the display against your master list. If a mistake has been made, you may have to delete or back step, or add steps, moving other portions of the program forward or backward. And you must repeat the single-step check of the program until the listing is correct.

The answer to a programmer's prayer for aid in debugging is found in printers that can be called on to list or trace through a portion of or an entire program. Such printers are incorporated into HP's 19C and 97. And TI has produced a free-standing print/security cradle, the PC-100A, in which the SR-52, SR-56, TI-58 and TI-59 can be mounted and locked in place. Locking-in helps solve another problem—theft.

HP's printer machines have a limited alphanumeric capability that identifies the kind of program step entered as well as other functions keyed into the program, for instance, ENT (enter), ST01 (store data in register 1), SIN, TAN, etc. TI, however, has taken a giant stride with its \$200 PC-100A printer, which, when used with the TI-58 and TI-59, can produce full alphanumerics plus 29 other useful symbols.

Not only can users of PC-100A list and trace program steps, but program headings and user-prompting phrases (up to 20 characters wide) such as "ENTER INDUCTANCE" can be printed. In addition, you can make simple plots of data, such as sine curves, directly from the keyboard or automatically under program control.

Both HP and TI printers use nonimpact, thermal print heads. "Whisper-quiet operation" is claimed for both. After listening for a while, though, you may feel that the sound is more like a stage whisper.

Programmable benchmarks

The power and performance of most programmable calculators generally can be described by the following criteria:

- The number of program steps that can be held.
- The number of data registers.
- The ability to manipulate program steps to edit a program.
- The presence, or absence, of user-definable LABEL keys or other keys that identify a program or program segment simply by pressing the defined key.

Comparing some of the lower-cost calculators, you find that Sinclair's 18-key Cambridge Programmable —the world's smallest programmable—has a 36-step program memory. APF's 45-key, \$70 MK 90 has 72 program steps and 10 user-accessible data memories. Advanced program-editing features include single-step, forward and backward program verification as well as jump commands.

Sharp's $90 PC-1201, with a permanent CMOS program memory, has 40 keys, 128 program steps, 12 data registers and 1 test register. It also has 12 user-addressable labels and can hold up to 12 subroutines. Conditional and unconditional subroutine jumps are possible, and full editing keys are included. As an added attraction, the entry of each program step is verified by a "beep."

An unusual calculator, the Sharp EL-5001, as six "most-used" engineering programs hard-wired into a program memory. These programs are selected by a six-position thumbwheel switch. They are equivalent to keyed-in programs ranging from 30 to over 150 program steps. For electronic designers, the machine has programs, impedance calculations, vector analysis, quadratic stability analysis, polynomial integration, and statistics. For more details, see Table 2 and News Scope, ED 3, Feb. 1, 1978, p. 21.

All these programmables use an ordinary algebraic language. You can, by studying manuals and looking at the machines, make reasonable comparisons.

Comparisons May Be Different

But you'll have a hard time comparing the performance of powerful machines like the HP-67/97 and the TI-58/59. First of all, data are entered and processed differently in each. And while the two architectures produce essentially the same results, they don't go about it in the same way. In fact, directly comparing the features of some of these machines may give only part of the story.

For example, TI's brochure on the 57/58/59 compares the 224-step program memory of the HP-67/97 with the TI-59's maximum number of program steps (960). Looks like TI is ahead, right? But not if you look at the TI-59 architecture.

When the TI-59 is turned on, the program memory is configured with 480 steps, and there are 60 associated data registers, each able to store eight program steps. The TI-59 architecture permits you to allocate the data registers to program steps or the program memory to data. But if the machine is in the 960 program-step configuration, it can't store data, and you've got problems.

Using the 960 steps as your basis for comparison obscures the fact that the exceptionally versatile TI-59 can allocate nearly all the registers to data to handle a short program with many numbers, or allocate those registers to program steps for a long program with many operations, but few variables.

Meanwhile, HP contends that to get the 67/97's true capability, you should multiply 224 by 3. So-called "fully merged" codes are used in the HP architecture, which means that three keystrokes may be combined and executed as just one program step.

An independent printer that can be used with TI's SR-52, SR-56, TI-58 and TI-59, the PC-100A has a full line of alphanumerics plus 29 other useful symbols. A worthwhile feature is a lock that secures the calculator in place.

Some comparisons start out as direct, but end up giving you more to consider. For example, both the TI-59 and the HP-67/97 have magnetic card read/write units, with TI claiming a capacity of 480 steps per card, against 224 for HP. But HP counters with the intelligence built into its "smart" card reader. When you load a card into an HP machine, its reader knows which side of the card carries the first 112 steps and which carries the second. And it also knows if a step contains data or a program. And you don't need to tell the 67/97 the status and flags.

With the 67/97, you can also write a program that turns the card reader on automatically and pulls a card through—calculating all the while. With this technique, program cards can be chained together to give, at least theoretically, an infinite number of program steps. The TI-59's reader has this feature.

You can keep comparing calculator features, but it will all boil down to this: No single programmable has all of the most desirable features. Because so much processing and memory and control and computing powers are packed into the advanced hand-held marvels, it's tough to make meaningful comparisons from spec sheets and brochures.

Veterans of the programmable "wars" will tell you to beg or borrow a programmable from a friend; or get one on a trial basis. Working with a calculator, you will learn in a few days what you may not learn even after months of second-hand research and study.

The power of any programmable calculator is only as good as the programs that run it. But program development is expensive, and you pay more for machines supplied with program libraries. But the cost goes down when you consider the many hours you'd spend generating just a few of your own programs. And with ready-made programs, you can start out immediately.

One good thing about writing your own, however, is that as you develop a personal approach, your store-bought programs may not seem as good as they should be. You may want to rewrite them to make them shorter, easier to keep track of, or simply more comfortable to work with.

A major software benchmark when considering a programmable is the quality and depth of the machine's documentation. Check that the Owners Handbook or Owners Manual is comprehensive, and thoroughly describes the programming keys and their functions. And be sure there are plenty of clear sample programs with step-by-step explanations.

With the lower-cost machines, the Owners Manual will usually provide just a few programming examples. One exception is Sharp's PC-1201 programmable. Its instruction manual contains clear descriptions of the programming functions of the machine, along with a good sampling of test programs. But the bonus is a 266-page Application Manual listing 92 programs for math, statistics, electronics, engineering and other problems (See Fig. 2).

Preceding each program listing is its basic formula, a sample problem, and key-by-key directions for executing the program. Also, the program can be stored indefinitely in its special CMOS memory.

Software and documentation for HP and TI machines are ahead of the rest of the competition. And both companies continue to improve and enlarge their sizable libraries and Owners Manuals to capture a larger share of the programmable-calculator market.

In addition to their own software, both companies support in-house User Libraries of programs submitted by calculator owners. In line with this, newsletters from both manufacturers pass on program hints and announcements contributed by subscribers. HP's newsletter is "HP Key Notes" and TI's is the "PPX Exchange Newsletter."

For the new TI-58 and TI-59 machines, TI's Solid-State Software library modules include the Master Library, which comes with the calculator, and Applied Statistics, Aviation, Marine Navigation, Surveying and Real Estate/Investment. No EE library is available, and at the time of writing there hasn't been any indication that one will be. For TI-programmable-calculator users, another source of software news is the SR-52 Users Club in Dayton, OH, which reports on all TI models.

Software for HP's 67/97 machines is available in two forms. One is a 40-book series of $10 "User Library Solutions," each containing 10 to 15 programs. Purchased separately they would cost $35 to $45. One book covers electrical engineering. Four books handle mathematics and three more have programs for chemistry, optics and physics. For these calculators, $35 magnetic-card Application Pacs are also available.

One independent source of HP program information and news is the HP Users' Club in Santa Ana, CA. The 2000-member club swaps programming techniques, applications and programs in its newsletter.

What about your old software?

Suppose you already have a programmable and want to step up to a new machine. You ask plaintively, "What do I do with the software that I've already spent a bundle on? Can I transfer my programs, say, from an SR-52 to a TI-59, or from an HP-65 to an HP-67?"

Yes you can. And HP and TI newsletters have run articles telling how. But an ELECTRONIC DESIGN survey of long-term users of both kinds of machines elicits the following advice: Transfer programs from old libraries directly, and you'll lose efficiency in the translation. The best and quickest approach is to rewrite them according to the new machine's rules.

The thousands of HP and TI programmables now in use have also created a demand for software not available from the manufacturers. To satisfy this demand, calculator-software houses are appearing. One is the International Software Clearinghouse in Estacada, OR, and another is Horizons Technology, Inc., in San Diego. ■■

Want more information?

Readers interested in learning more about the calculators mentioned in this article and of similar machines available may contact the manufacturers listed below or consult ELECTRONIC DESIGN'S GOLD BOOK. Types of calculators produced are indicated by the letters following the listing: P—preprogrammed; K—key programmable; M—magnetic-card programmable; S—solid-state-module programmable.

For readers who wish to learn more about the activities and services of the private calculator User's Clubs and of the software houses, the addresses are included below.

APF Electronics, Inc., 444 Madison Ave., New York, NY 10022. (212) 758-7550. P, K **Circle No. 501**

Canon, Inc., 10 Nevada Dr., Lake Success, NY 11040. (516) 488-6700. P **Circle No. 502**

Casio, Inc., 15 Gardner Rd., Fairfield, NJ 07006. (201) 575-7400. P, K. **Circle No. 503**

Commodore Business Machines, 901 California Ave., Palo Alto, CA 94306. (415) 326-4000. P, K **Circle No. 504**

Hewlett-Packard, 1000 N.E. Circle Blvd., Corvallis, OR 93770. (503) 757-2000. P, K, M. **Circle No. 505**

Kingspoint Corp., 104 Harbor Dr., Jersey City, NJ 07305. (201) 432-7707. P. **Circle No. 506**

National Semiconductor, 1177 Kern Ave., Sunnyvale, CA 94086. (408) 732-5000. P, K. **Circle No. 507**

Sharp Electronics Corp., P.O. Box 588, Paramus, NJ 07652. (201) 265-5600. P, K. **Circle No. 508**

Sinclair Radionics, Inc., 115 E. 57th St., New York, NY 10022. (212) 355-5005. P, K. **Circle No. 509**

Texas Instruments, P.O. Box 53, MS 5842, Lubbock, TX 79408. (806) 747-3737. P, K, M, S. **Circle No. 510**

Software clubs and houses:

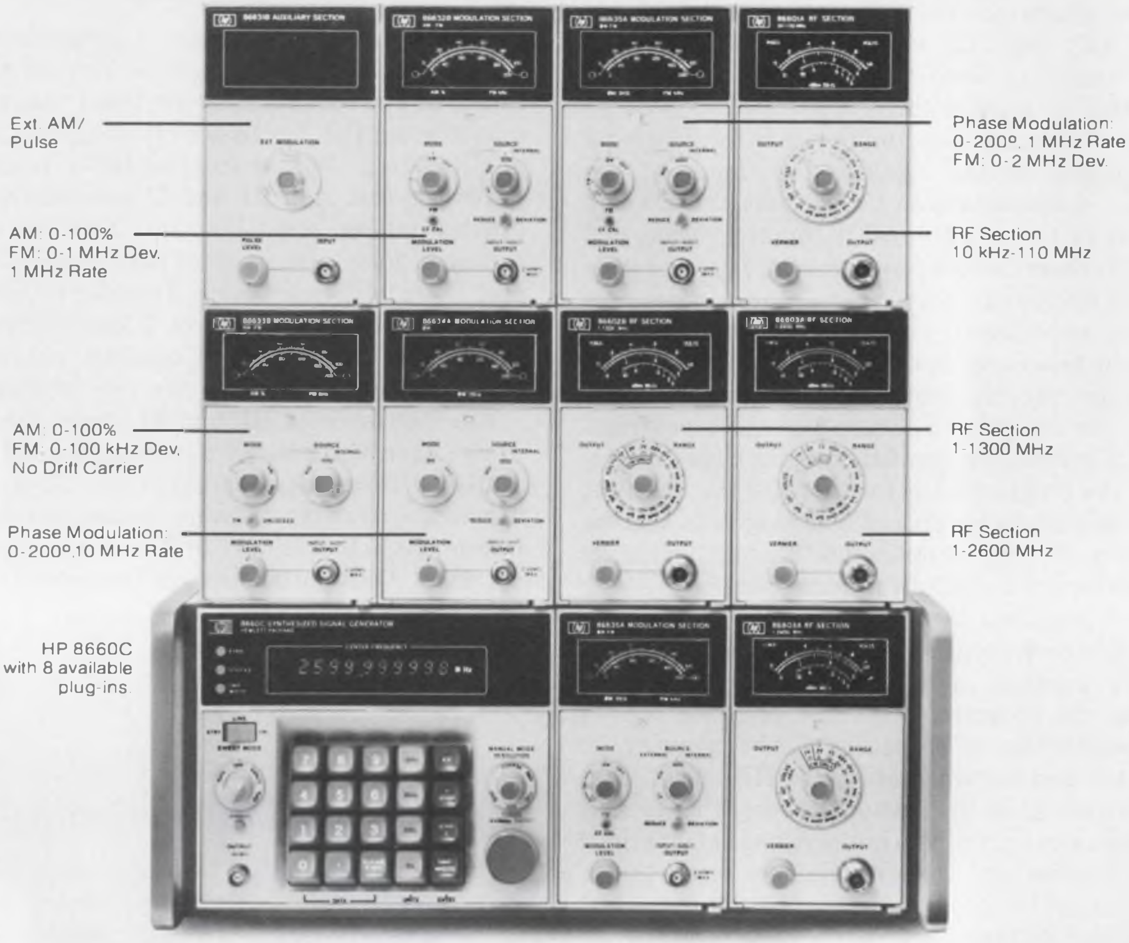
HP Users Club, Richard J. Nelson, 2541 W. Camden Pl., Santa Ana, CA 92704. (714) 639-7810.

SR-52 Users Club, Richard C. Vanderburgh, 9459 Taylorsville Rd., Dayton, OH 45424. (513) 255-6502.

International Software Clearinghouse, Route 2, Box 965, Estacada, OR 97023. (503) 631-2214.

Horizons Technology, Inc., 8333 Clairemont Mesa Blvd., San Diego, CA 92111. (714) 292-8331.

PRECISION SIGNALS



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CIRCLE NUMBER 65

HYBRID

IN A MARKET FULL OF DROPOUTS, OUR NEW REGULATORS ARE PHI BETA KAPPA.

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CIRCLE NUMBER 165

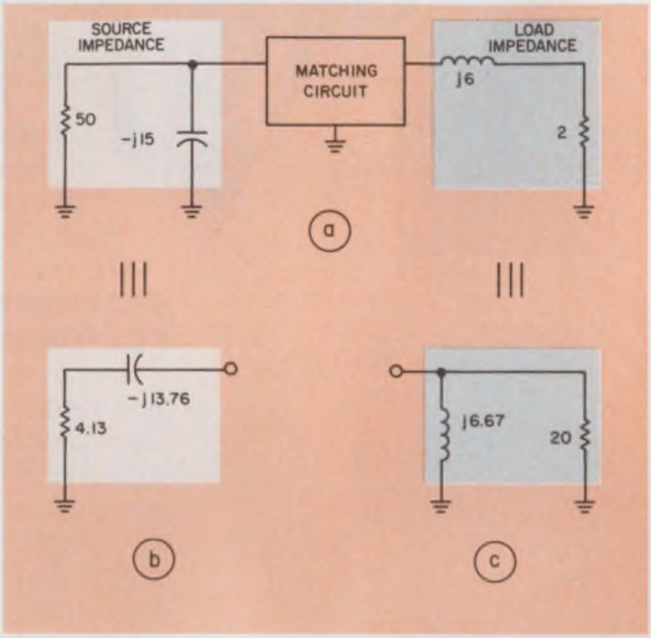
Simplify conjugate bilateral matching

of complex impedances. A unified approach provides practical L, Pi or T solutions with a low-cost programmable calculator.

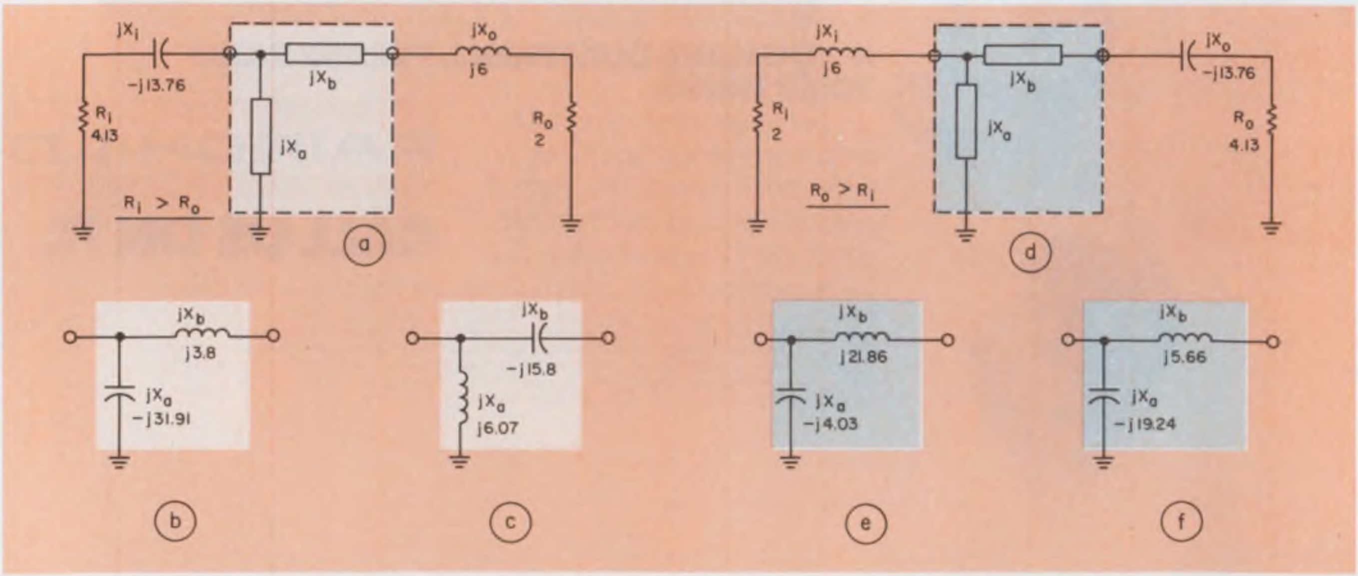
Matching complex impedances is an everyday but tedious circuit-design problem, especially in rf work. Now you can save time and reduce errors with five programs for an HP-25 that quickly and easily calculate L, Pi or T-circuit solutions for conjugate bilateral matching of a load to a source. One program solves L circuits, and the Pi and T circuits each need two. A sixth program helps the calculations by providing series-to-parallel or parallel-to-series conversion configurations of the impedances to be matched.

The programs for the three matching circuit configurations—L, T and Pi—handle all impedance-matching combinations in a unified way, which isn't possible with most other methods. With the many manual methods you may have used, to reduce the large amount of labor involved, you were often forced to employ widely differing and "ingenious" approaches for each problem. Usually, each approach was limited to a specific configuration. And the simplifying assumptions you used often produced large errors.

Andrzej B. Przedpelski, Vice President of Development, A.R.F. Products Inc., 2559 75th St., Boulder, CO 80301.



1. **The first step in matching impedances** is to convert the source and load impedances (a) into the most convenient form for doing the subsequent calculations. Parallel configurations (b) can be converted to series, and vice versa (c), depending upon use of an L, T or Pi.



2. **An L-section matching circuit** (a) can have two solutions—a low (b) and high-pass form (c)—when $R_i > R_o$. However, by reorienting the L matcher (d) so that $R_o < R_i$, you can often obtain two more solutions (e and f).

Table 1. Parallel/Series/Parallel/Transformations

Display Line	Display Code	Key Entry	Remarks	Registers	
00				R_0	
01	24 02	RCL 2			
02	15 71	(g) x=0			
03	13 15	GTO 15		R_1	R_p
04	15 22	(g) 1/x			
05	24 01	RCL 1			
06	15 22	(g) 1/x		R_2	X_p
07	15 09	(g)→P			
08	15 22	(g) 1/x			
09	14 09	(f)→R		R_3	R_s
10	23 03	STO 3	R_s		
11	74	R/S			
12	21	x⇄y		R_4	
13	23 04	STO 4	X_s		
14	74	R/S			
15	24 04	RCL 4		R_5	
16	24 03	RCL 3			
17	15 09	(g)→P			
18	15 22	(g) 1/x		R_6	
19	14 09	(f) →R			
20	15 22	(g) 1/x			
21	23 01	STO 1	R_p	R_7	
22	74	R/S			
23	21	x⇄y			
24	15 22	(g) 1/x			
25	23 02	STO 2	X_p		
26	13 00	GTO 00			

Step	Instructions	Input Data/Units	Keys		Output Data/Units
1	STORE	R_p	STO	1	
		X_p	STO	2	
		O	STO	3	
		O	STO	4	
	OR				
		O	STO	1	
		O	STO	2	
		R_s	STO	3	
		X_s	STO	4	
2	CALCULATE		R/S		R_s or R_p
			R/S		X_s or X_p
3	RECALL (TO CHECK)		RCL	1	R_p
			RCL	2	X_p
			RCL	3	R_s
			RCL	4	X_s

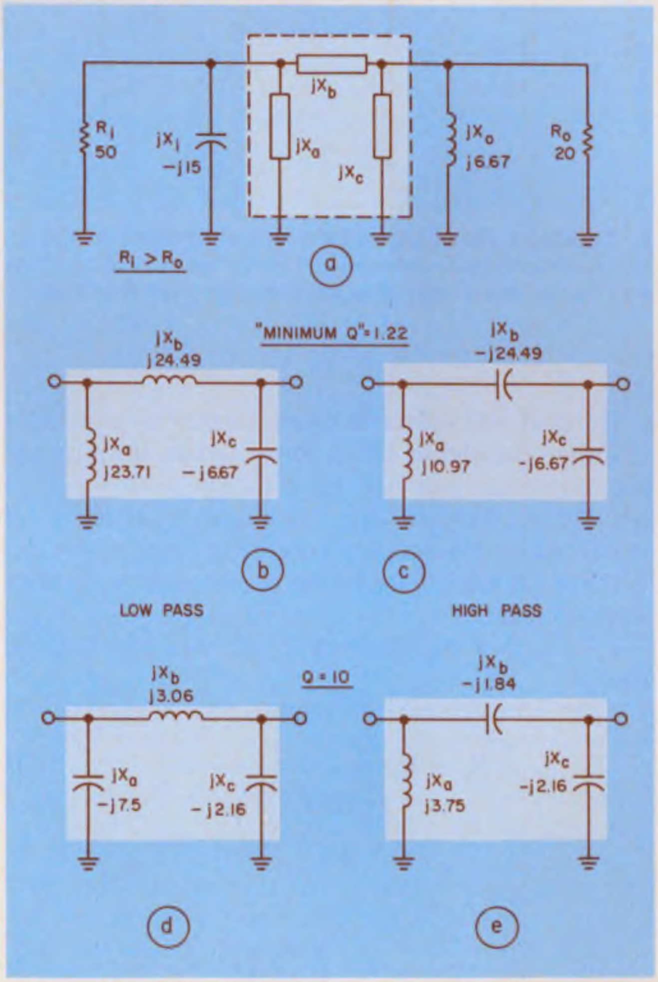
The HP-25 fits the bill because it has just the amount of memory needed. Although the programs aren't the shortest possible, they have been written so that they can be converted easily for use on an algebraic-type calculator. A calculator without the programming feature also can be used; however, some flexibility is lost and errors will increase.

While the HP-25 programs don't provide the optimum matching solution automatically, they allow you to perform rapid "trials" of the three matching-circuit configurations with all possible solutions of each.

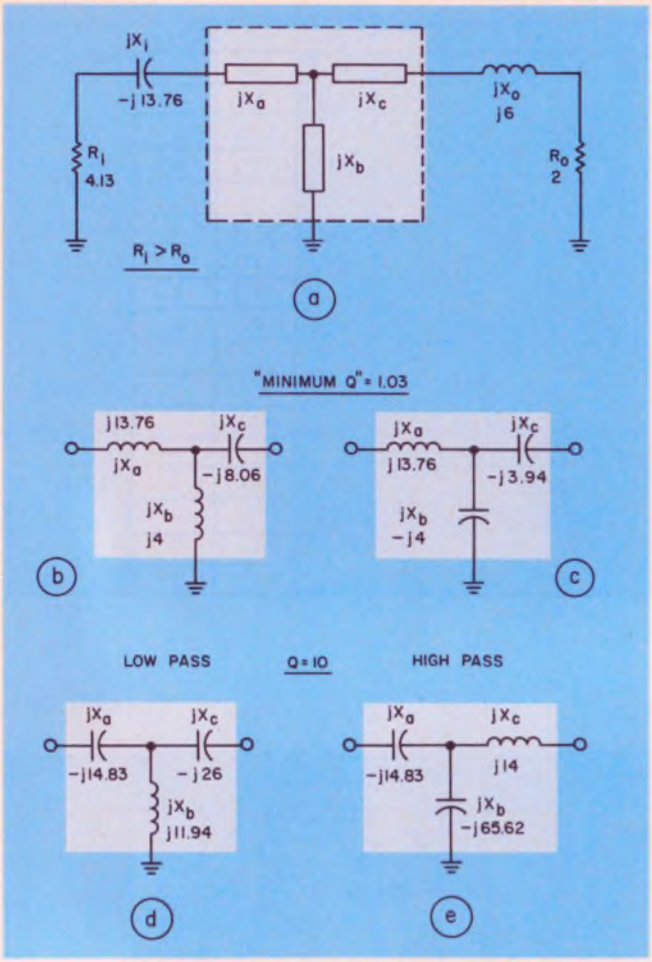
Your choice of configuration is usually dictated by:

- Whether you desire a low or a high-pass circuit.
- The effect of including stray and coupled-circuit reactances as part of the matching circuit's components.
- How much bandwidth the matching circuit should have. Unfortunately, the programs can't work directly with bandwidth: They employ the matching circuit's Q. As a matching network's Q goes up, the circuit's bandwidth goes down. Also, the greater the difference between the real parts of the matched impedances, the less bandwidth the matching circuit will have.

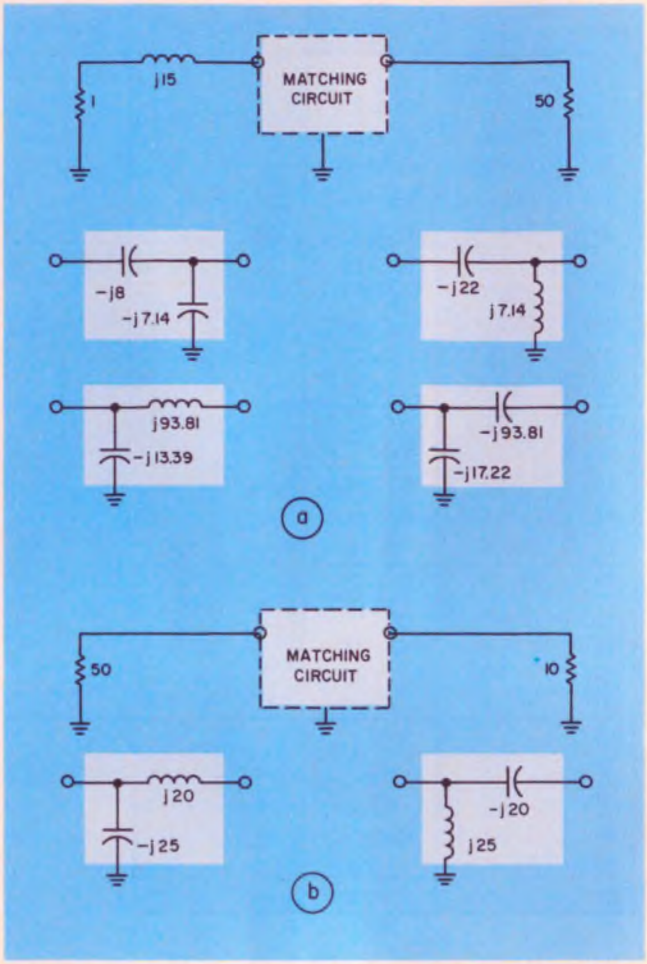
But before you start the calculations, you may have to convert the forms of the load and source impedances into series or parallel forms.



3. **Pi-section matching circuits** (a) allow you to choose circuit Q. Wideband matching is obtained with "minimum-Q" solutions (b and c); more selective circuits (d and e) are solved with Q = 10.



4. **T-section matching circuits are equivalent** to Pi-sections, but physical considerations, component size, costs and layout may lead you to one type over the other.



5. **The load may have no reactive impedance** (a) or both source and load may have no reactive impedance (b), but the programs can handle either case.

The load and source impedances may be physically in either parallel or series form. But to simplify the computations, you will have to calculate series or parallel equivalents, depending upon your choice of matching-circuit configuration (Fig. 1a):

- For an L or T matching circuit, you work with series forms.
- For a Pi matching circuit, you work with parallel forms.

The transformations require four formulas:

$$R_s = R_p \frac{1}{1 + \left(\frac{R_p}{X_p}\right)^2}, \qquad (1)$$

$$X_s = X_p \frac{\left(\frac{R_p}{X_p}\right)^2}{1 + \left(\frac{R_p}{X_p}\right)^2}, \qquad (2)$$

$$R_p = R_s\left[1 + \left(\frac{X_s}{R_s}\right)^2\right], \qquad (3)$$

$$X_p = X_s \frac{1 + \left(\frac{X_s}{R_s}\right)^2}{\left(\frac{X_s}{R_s}\right)^2}. \qquad (4)$$

Subscripts "p" denote parallel resistances and reactances and subscripts "s" denote series.

The program that performs these transformations (Table 1) uses polar coordinates, because polars need fewer steps. Parallel values stored in registers $[R_1]$ and $[R_2]$ are transformed to series values and stored in registers $[R_3]$ and $[R_4]$, or series stored in $[R_3]$ and $[R_4]$ are transformed to $[R_1]$ and $[R_2]$. But before you enter data always remember to clear the two registers not used to enter data.

Note: The program's R/S steps (11, 14 and 22) can be deleted, but then the answers won't be displayed,

Table 2. L Section matching

Display Line	Display Code	Key Entry	Remarks	Register	Contents
00				R_0	Q
01	24 02	RCL 2			
02	24 01	RCL 1			
03	15 09	(g)→P		R_1	R_i
04	15 22	(g) 1/x			
05	14 09	(f)→R			
06	15 22	(g) 1/x		R_2	X_i
07	24 03	RCL 3			
08	71	÷			
09	01	1		R_3	R_o
10	41	—			
11	14 02	(f)$\sqrt{x}$			
12	23 00	STO 0	Q	R_4	X_o
13	74	R/S			
14	24 03	RCL 3			
15	61	X		R_5	X_a
16	24 04	RCL 4			
17	41	—			
18	23 06	STO 6	X_b	R_6	X_b
19	74	R/S			
20	24 01	RCL 1			
21	15 02	(g) x^2		R_7	
22	24 02	RCL 2			
23	15 02	(g) x^2			
24	51	+			
25	24 00	RCL 0			
26	24 01	RCL 1			
27	61	X			
28	24 02	RCL 2			
29	51	+			
30	71	÷			
31	32	CHS			
32	23 05	STO 5	X_a		
33	74	R/S			
34	24 00	RCL 0			
35	32	CHS			
36	13 12	GTO 12			

Step	Instructions	Input Data/Units	Keys		Output Data/Units
1	STORE	R_i	STO	1	
		X_i	STO	2	
		R_o	STO	3	
		X_o	STO	4	
2	CALCULATE		R/S		Q
	LOWPASS		R/S		X_b
	CONFIGURATION		R/S		X_a
3	RECALL		RCL	1	R_i
	(TO CHECK		RCL	2	X_i
	LOWPASS)		RCL	3	R_o
			RCL	4	X_o
			RCL	5	X_a
			RCL	6	X_b
4	CALCULATE		R/S		-Q
	HIGHPASS		R/S		X_b
	CONFIGURATION		R/S		X_a
5	RECALL		RCL	1	R_i
	(TO CHECK		RCL	2	X_i
	HIGHPASS)		RCL	3	R_o
			RCL	4	X_o
			RCL	5	X_a
			RCL	6	X_b

just stored. Delete the store steps (10, 13, 21 and 25), and the answers will be displayed only.

The complex source and load impedances shown in Fig. 1a will be used throughout to illustrate application of the programs. The parallel source impedance was transformed into serial form (Fig. 1b) and the series load impedance into parallel (Fig. 1c) with the program in Table 1. In solving matching problems, you use the appropriate form depending upon the matching circuit.

Using L matching circuits

If the impedances to be matched happen to be in series form, a simple L matching circuit is a good first approach to solving the matching problem (Fig. 2a). The applicable equations for obtaining the impedances of a matching L are

$$X_a = \frac{R_i^2 + X_i^2}{QR_i + X_i} \tag{5}$$

and

$$X_b = QR_o - X_o, \tag{6}$$

where Q is defined as

$$Q = \pm\sqrt{\left(\frac{R_i\left[1 + \left(\frac{X_i}{R_i}\right)^2\right]}{R_o} - 1\right)} \tag{7}$$

And the program for solving these equations is in Table 2.

Note that since Q can be positive or negative, X_a and X_b can have a low or a high-pass configuration. (Figs. 2b or 2c). Most other methods for matching with an L consider only the low-pass solution. While such an approach always gives a valid answer, your application might be better served with a high-pass matching circuit.

Furthermore, note in Fig. 2a that X_a is attached to the port facing the external network with the highest resistance, since $R_i > R_o$. Again, while other methods

Table 3. Pi Section matching (Lowest Q)

Display Line	Display Code	Key Entry	Remarks	Registers	
00				R_0	Q
01	24 04	RCL 4			
02	32	CHS			
03	23 07	STO 7	X_c	R_1	R_i
04	74	R/S			
05	24 01	RCL 1			
06	24 03	RCL 3		R_2	X_i
07	71	÷			
08	01	1			
09	41	—		R_3	R_o
10	14 02	(f) $\sqrt{x}$			
11	23 00	STO 0	Q		
12	74	R/S		R_4	X_o
13	24 03	RCL 3			
14	61	X			
15	23 06	STO 6	X_b	R_5	X_a
16	74	R/S			
17	24 00	RCL 0			
18	24 01	RCL 1		R_6	X_b
19	15 22	(g) 1/x			
20	61	X			
21	24 02	RCL 2		R_7	X_c
22	15 22	(g) 1/x			
23	51	+			
24	15 22	(g) 1/x			
25	32	CHS			
26	23 05	STO 5	X_a		
27	74	R/S			
28	24 00	RCL 0			
29	32	CHS			
30	13 11	GTO 11			

Step	Instructions	Input Data/Units	Keys		Output Data/Units
1	STORE	R_i	STO	1	
		X_i	STO	2	
		R_o	STO	3	
		X_o	STO	4	
2	CALCULATE		R/S		X_c
	LOWPASS		R/S		Q
	CONFIGURATION		R/S		X_b
			R/S		X_a
3	RECALL		RCL	0	Q
	(TO CHECK		RCL	1	R_i
	LOWPASS)		RCL	2	X_i
			RCL	3	R_o
			RCL	4	X_o
			RCL	5	X_a
			RCL	6	X_b
			RCL	7	X_c
4	CALCULATE		R/S		-Q
	HIGHPASS		R/S		X_b
	CONFIGURATION		R/S		X_a
5	RECALL		RCL	0	-Q
	(TO CHECK		RCL	1	R_i
	HIGHPASS)		RCL	2	X_i
			RCL	3	R_o
			RCL	4	X_o
			RCL	5	X_a
			RCL	6	X_b
			RCL	7	X_c

usually limit the configuration to this orientation and thus you are assured of valid solutions, you often can get two more solutions by turning the L circuit around.

In Fig. 2d, the input and output circuits are interchanged, so that $R_o > R_i$. Both new solutions, Figs. 2e and 2f, have low-pass configurations.

It's wise to explore all possibilities for the most convenient or economical component selections. If you prefer a low-pass solution, Fig. 2f might be a better compromise of inductor-vs-capacitor sizes than Figs. 2a or 2e. But if you want a high-pass matching circuit, your only choice is Fig. 2c.

However, with the $R_o > R_i$ arrangement, you don't always get a viable solution—the valve of Q could come out imaginary. For example, if X_i in Fig. 2d is reduced from j6 to j2, the answer is unusable. In such a case, the program will provide automatically an "error" indication in step 11 to show that Q is imaginary.

Matching with a Pi or T circuit

But if you want to be assured of the widest possible bandwidth you must use a Pi or T matching circuit.

A Pi or T matching circuit uses one more component than the L, but gives you more flexibility in choosing bandwidth. To get the maximum possible bandwidth, you must use a so-called "minimum-Q" solution, which also provides the lowest insertion loss for components having the same Q value.

For a Pi matcher, the parallel forms of the input and output circuits of Fig. 1a are used (Fig. 3a) and the applicable equations are

$$X_c = -X_o, \tag{8}$$

$$X_b = R_o Q_{min}, \tag{9}$$

$$X_a = \frac{-1}{\dfrac{1}{X_i} + \dfrac{Q_{min}}{R_i}}, \tag{10}$$

where the minimum Q is

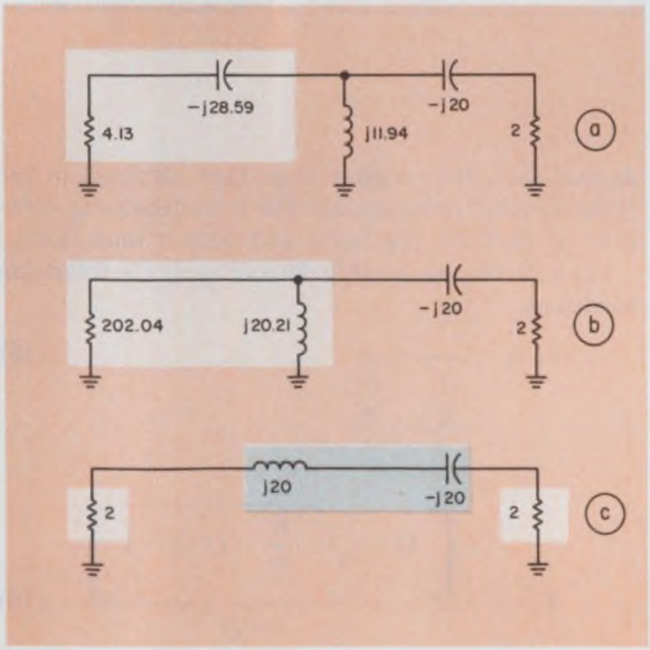
$$Q_{min} = \pm\sqrt{\frac{R_i}{R_o} - 1}. \tag{11}$$

The program in Table 3 gives a low-pass and a high-pass configuration for the positive and negative values of Q_{min}. Calculated matching sections for these two cases are shown in Figs. 3b and 3c.

Table 4. T Section matching (Lowest Q)

Display Line	Display Code	Key Entry	Remarks	Registers
00				R_0 Q
01	24 01	RCL 1		
02	24 03	RCL 3		
03	71	÷		R_1 R_i
04	01	1		
05	41	—		
06	14 02	(f) $\sqrt{x}$		R_2 X_i
07	24 00	STO 0	Q	
08	74	R/S		
09	24 02	RCL 2		R_3 R_o
10	32	CHS		
11	23 05	STO 5	X_a	
12	74	R/S		R_4 X_o
13	24 01	RCL 1		
14	24 00	RCL 0		
15	71	÷		R_5 X_a
16	23 06	STO 6	X_b	
17	74	R/S		
18	24 03	RCL 3		R_6 X_b
19	24 00	RCL 0		
20	61	X		
21	24 04	RCL 4		R_7 X_c
22	51	+		
23	32	CHS		
24	23 07	STO 7	X_c	
25	74	R/S		
26	24 00	RCL 0		
27	32	CHS		
28	13 07	GTO 07		

Step	Instructions	Input Data/ Units	Keys		Output Data/Units
1	STORE	R_i	STO	1	
		X_i	STO	2	
		R_o	STO	3	
		X_o	STO	4	
2	CALCULATE		R/S		Q
	LOWPASS		R/S		X_a
	CONFIGURATION		R/S		X_b
			R/S		X_c
3	RECALL		RCL	0	Q
	(TO CHECK		RCL	1	R_i
	LOWPASS)		RCL	2	X_i
			RCL	3	R_o
			RCL	4	X_o
			RCL	5	X_a
			RCL	6	X_b
			RCL	7	X_c
4	CALCULATE		R/S		-Q
	HIGHPASS		R/S		X_a
	CONFIGURATION		R/S		X_b
			R/S		X_c
5	RECALL		RCL	0	-Q
	(TO CHECK		RCL	1	R_i
	HIGHPASS)		RCL	2	X_i
			RCL	3	R_o
			RCL	4	X_o
			RCL	5	X_a
			RCL	6	X_b
			RCL	7	X_c



6. **To check a solution** such as the T section in Fig 4d, you add the source side's series configuration to the left series impedance of the T (a). Then the left-side capacitor and resistor, converted to a parallel form, are combined (b). Finally, reconverting the left side to series shows that the reactances cancel and real parts are equal (c).

Note the following precautions for the program:

- If you have no X_i or X_o value, store the number 10^{99} (infinity) in its place.
- Orient the Pi so that R_i is always larger than R_o.

Also note that reactance X_c is the same in both low and high-pass solutions.

Similarly, a T matching circuit with characteristics like the Pi can be used for wideband work. Now, the series form of the input and output circuits is used (Fig. 4a), and the applicable equations are

$$X_a = -X_i, \tag{12}$$

$$X_b = \frac{R_i}{Q_{min}}, \tag{13}$$

$$X_c = -(X_o + R_oQ_{min}), \tag{14}$$

where Q_{min} is defined as in Eq. 11 for Pi matchers, and also, only where $R_i > R_o$. Table 4 contains the program for solving these equations. Figs. 4b and 4c show the solutions.

Table 5. Pi Section matching (Higher selectivity)

Display Line	Display Code	Key Entry	Remarks	Registers
00				R_0 Q
01	24 00	RCL 0		
02	24 01	RCL 1		
03	71	÷		R_1 R_i
04	24 02	RCL 2		
05	15 22	(g) 1/x		
06	51	+		R_2 X_i
07	15 22	(g) 1/x		
08	32	CHS		
09	23 05	STO 5	X_a	R_3 R_o
10	74	R/S		
11	24 00	RCL 0		
12	15 02	(g) x^2		R_4 X_o
13	01	1		
14	51	+		
15	23 06	STO 6		R_5 X_a
16	24 03	RCL 3		
17	61	X		
18	24 01	RCL 1		R_6 X_b
19	71	÷		
20	01	1		
21	41	—		R_7 X_c
22	14 02	(f) $\sqrt{x}$		
23	23 07	STO 7		
24	24 00	RCL 0		
25	51	+		
26	24 01	RCL 1		
27	61	X		
28	24 06	RCL 6		
29	71	÷		
30	23 06	STO 6	X_b	
31	74	R/S		
32	24 07	RCL 7		
33	24 03	RCL 3		
34	71	÷		
35	24 04	RCL 4		
36	15 22	(g) 1/x		
37	51	+		
38	15 22	(g) 1/x		
39	32	CHS		
40	23 07	STO 7	X_c	
41	74	R/S		
42	24 00	RCL 0		
43	32	CHS		
44	23 00	STO 0		
45	13 02	GTO 02		

Step	Instructions	Input Data/Units	Keys		Output Data/Units
1	STORE	Q	STO	0	
		R_i	STO	1	
		X_i	STO	2	
		R_o	STO	3	
		X_o	STO	4	
2	CALCULATE		R/S		X_a
	LOWPASS		R/S		X_b
	CONFIGURATION		R/S		X_c
3	RECALL		RCL	0	Q
	(TO CHECK		RCL	1	R_i
	LOWPASS)		RCL	2	X_i
			RCL	3	R_o
			RCL	4	X_o
			RCL	5	X_a
			RCL	6	X_b
			RCL	7	X_c
4	CALCULATE		R/S		X_a
	HIGHPASS		R/S		X_b
	CONFIGURATION		R/S		X_c
5	RECALL		RCL	0	-Q
	(TO CHECK		RCL	1	R_i
	HIGHPASS)		RCL	2	X_i
			RCL	3	R_o
			RCL	4	X_o
			RCL	5	X_a
			RCL	6	X_b
			RCL	7	X_c

However, additional solutions are possible with Pi and T matching circuits with larger Qs. Where an L matcher has at most four solutions, both Pi and T matchers can have almost unlimited numbers, depending on your choice of Q.

You can design Pi and T circuits for almost any desired selectivity higher than that obtained in the "minimum-Q" calculations. The L matcher's Q, however, is fixed by the input and output impedances.

For a Pi refer back to Fig. 3a and apply the following equations:

$$X_a = -\frac{1}{\frac{1}{X_i} + \frac{Q}{R_i}} \tag{15}$$

$$X_b = \frac{R_i\left[Q + \sqrt{\frac{R_o}{R_i}(1+Q^2)-1}\right]}{1+Q^2} \tag{16}$$

$$X_c = \frac{1}{\frac{1}{R_o}\sqrt{\frac{R_o}{R_i}(1+Q^2)-1} + \frac{1}{X_o}} \tag{17}$$

Table 6. T Section matching (Higher selectivity)

Display Line	Display Code	Key Entry	Remarks	Registers	
00				R_0	Q
01	24 00	RCL 0			
02	24 03	RCL 3			
03	61	X		R_1	R_i
04	24 04	RCL 4			
05	51	+			
06	32	CHS		R_2	X_i
07	23 07	STO 7	X_c		
08	74	R/S			
09	24 00	RCL 0		R_3	R_o
10	15 02	(g) X^2			
11	01	1			
12	51	+		R_4	X_o
13	24 03	RCL 3			
14	61	X			
15	23 06	STO 6		R_5	X_a
16	24 01	RCL 1			
17	71	÷			
18	01	1		R_6	X_b
19	41	—			
20	14 02	(f) $\sqrt{x}$			
21	24 01	RCL 1		R_7	X_c
22	61	X			
23	32	CHS			
24	24 02	RCL 2			
25	41	—			
26	23 05	STO 5	X_a		
27	74	R/S			
28	24 06	RCL 6			
29	24 06	RCL 6			
30	24 01	RCL 1			
31	71	÷			
32	01	1			
33	41	—			
34	14 02	(f) $\sqrt{x}$			
35	24 00	RCL 0			
36	51	+			
37	71	÷			
38	23 06	STO 6	X_b		
39	74	R/S			
40	24 00	RCL 0			
41	32	CHS			
42	23 00	STO 0			
43	13 02	GTO 02			

Step	Instructions	Input Data/Units	Keys		Output Data/Units
1	STORE	Q	STO	0	
		R_i	STO	1	
		X_i	STO	2	
		R_o	STO	3	
		X_o	STO	4	
2	CALCULATE		R/S		X_c
	LOWPASS		R/S		X_a
	CONFIGURATION		R/S		X_b
3	RECALL		RCL	0	Q
	(TO CHECK		RCL	1	R_i
	LOWPASS)		RCL	2	X_i
			RCL	3	R_o
			RCL	4	X_o
			RCL	5	X_a
			RCL	6	X_b
			RCL	7	X_c
4	CALCULATE		R/S		X_c
	HIGHPASS		R/S		X_a
	CONFIGURATION		R/S		X_b
5	RECALL		RCL	0	-Q
	(TO CHECK		RCL	1	R_i
	HIGHPASS)		RCL	2	X_i
			RCL	3	R_o
			RCL	4	X_o
			RCL	5	X_a
			RCL	6	X_b
			RCL	7	X_c

But now Q can be almost any value higher than the "minimum Q" obtained from Eq. 11 (or in step 11 of Table 3). The program to solve Eqs. 15, 16 and 17 is in Table 5. If you try to use a value of Q lower than the "minimum Q," the program provides an "error" indication in step 22. Above the minimum Q, only one value of Q is impossible:

$$Q = -\frac{R_i}{X_i} \tag{18}$$

An "error" indication in step 7 of Table 5 signifies this condition. Actually, Eq. 18 is a legitimate value for Q. Such a Q makes X_a equal to infinity (an open circuit), which reduces the Pi to an L configuration.

If, for example, you choose Q = 10, which is larger than the "minimum Q" of 1.22 obtained in Figs. 3b and 3c, you get the solutions in Figs. 3d and 3e.

Similarly, for a T configuration, refer again to Fig. 4a where now, the following equations apply:

$$X_c = (-X_o + R_oQ) \tag{19}$$

$$X_a = -R_i\sqrt{\frac{R_o}{R_i}(1+Q^2)-1} - X_i \tag{20}$$

$$X_b = \frac{R_o(1+Q^2)}{Q+\sqrt{\frac{R_o\,(1+Q^2)}{R_i}-1}} \tag{21}$$

And the program for their solution is in Table 6.

As in the case of a Pi, the value of Q can be any value higher than that obtained in program-step 7 of Table 4 for a "minimum-Q" T.

If you again choose Q = 10, as was done for the Pi, which is larger than the "minimum Q" of 1.03 obtained for the solutions in Figs. 4b and 4c, you get the solutions in Figs. 4d and 4e.

For values of Q smaller than the "minimum Q," the program provides an "error" indication in step 20. Note that for $Q = X_o/R_o$, X_c becomes zero, and the T configuration becomes a simple L, as was the case with the Pi configuration under the conditions of Eq. 18.

Handling special cases

All sources and loads, however, don't necessarily contain reactive components. When either the input or output impedances, or both, have no capacitance or inductance, the number of possible matching solutions is reduced. Fig. 5a is an example of no reactive component in the output circuit and the four L solutions you can get for it. But if you attempt to obtain Pi and T "minimum-Q" solutions for the matching circuits, they will come out identical to the four L solutions.

For larger Qs (higher selectivity), the number of Pi and T solutions is virtually unlimited. But with no reactances in both the source and load, only two L solutions are obtained (Fig. 5b).

Verify with parallel/series transformations

Finally, you can easily verify that your matching circuit has no errors. You merely use the series/parallel transformations several times and add the resultant reactances. The input and output resistances should become equal, and all reactances should cancel.

As an example, insert Fig. 4d into Fig. 4a and add the series reactances. You get Fig. 6a. Convert either side, say, the left side, to a parallel configuration and combine the two parallel reactances to get Fig. 6b. Now convert the left-side parallel configuration of Fig. 6b to series and you get Fig. 6c, which shows that you have satisfied the conjugate bilateral matching requirements—the reactances cancel and resistances match.■■

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Acknowledgement

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Predict noise in digital systems

caused by transmission-line reflections. All you need is a programmable calculator to solve the lattice diagram.

Reflections on transmission lines are a major source of noise in digital systems, but you can predict them easily with a lattice diagram. To determine the reflective voltages for the diagram, you have to perform numerous calculations. But with a programmable calculator like the SR52 that's easy too.

Fig. 1a which shows a digital transmission system contains a step generator of voltage E with an output impedance, Z_S, an interconnecting transmission line of characteristic impedance Z_O, and a line termination, Z_L. Fig. 1b shows the lattice diagram for the circuit of Fig. 1a, and the equations that must be solved to determine the voltage at every step.

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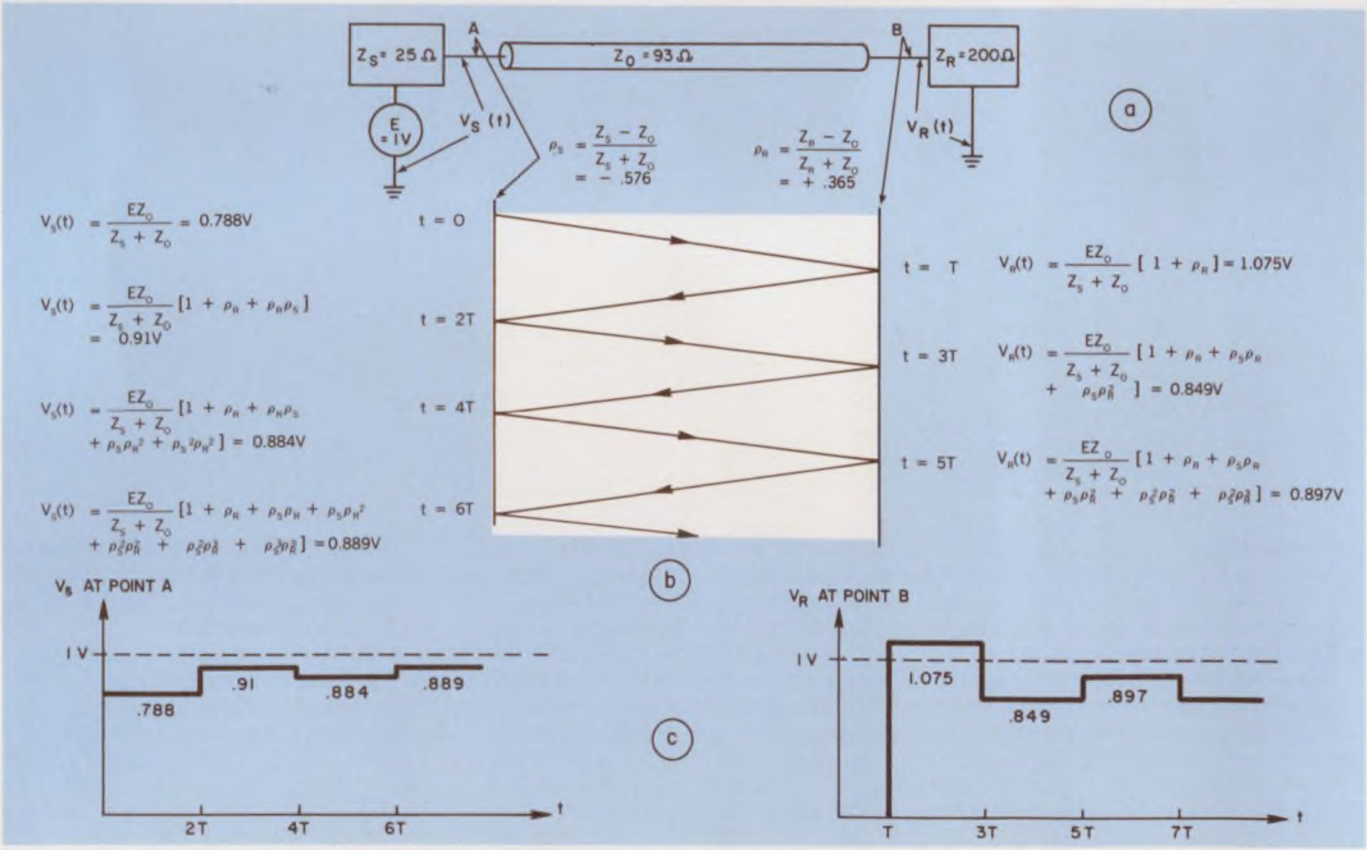
The lattice diagram graphically represents the signal being reflected back and forth between signal generator and load (see box). The voltages traveling left to right are identified as V_S (send-side), and right to left as V_R (receive-side). The incident and reflected voltages at points A and B combine to form successively smaller steps (Fig. 1c).

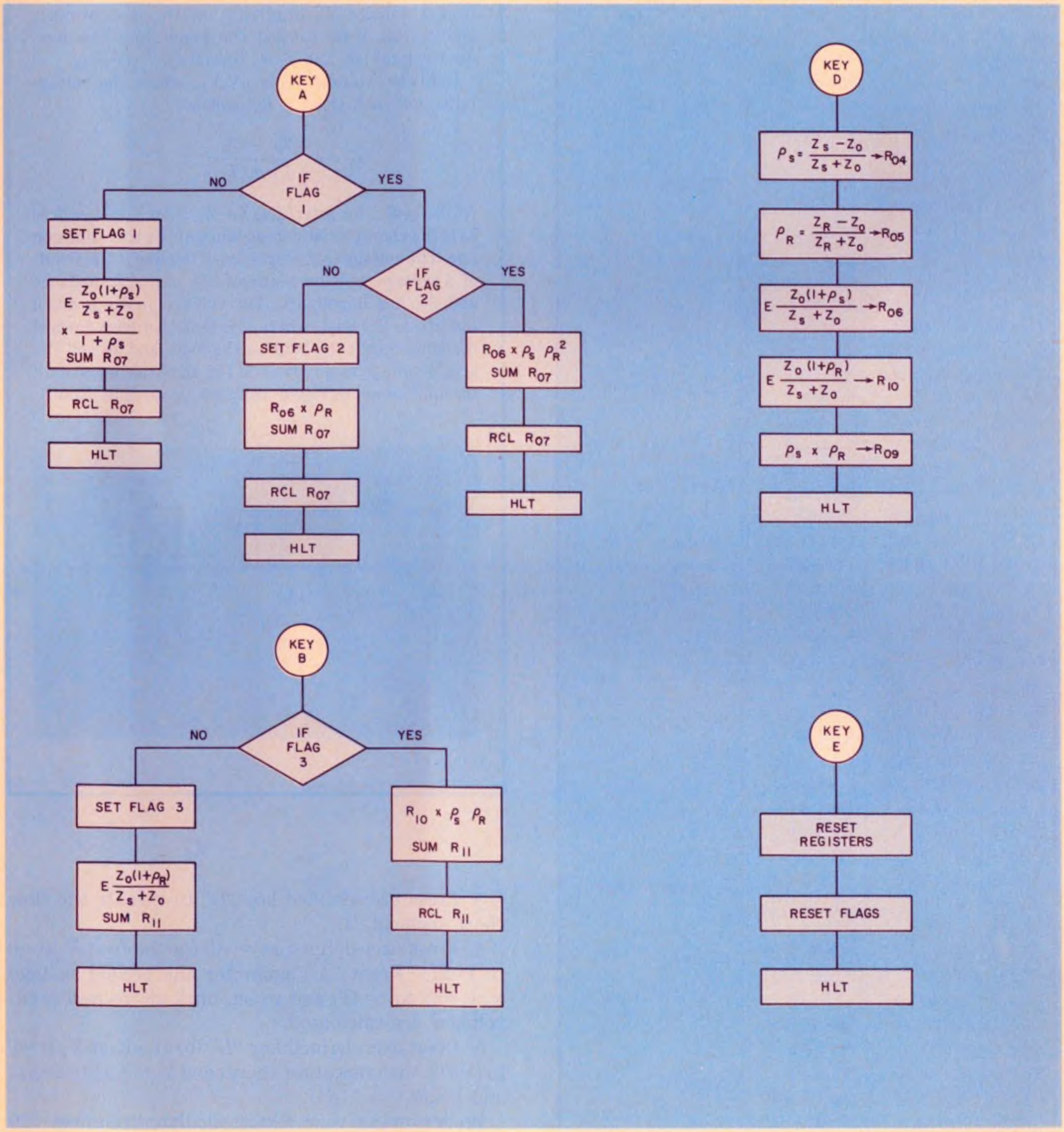
Fig. 2 shows the flow chart for a program to calculate these voltages. Execute the program on an SR52 calculator with the following steps:

1. Clear all registers and flags by pressing user-defined key "E."
2. Enter circuit parameters (Z_O, Z_S, Z_R, E) into registers R_{00} through R_{03} as follows:

Register	Content
R_{00}	Z_O
R_{01}	Z_S



1. **A step voltage from generator E** travels down a transmission line until it hits a load (a). If both the generator and the load are not properly matched, a diminishing part of the wave is reflected back and forth, as represented by the lattice diagram (b). At points A and B the waves add up to form the total voltage (c).



2. **The flow chart for calculating a lattice diagram** consists of four segments. The user-defined keys determine which will be executed: clear flags (E) calculate common factors (D), calculate send (A) and receive (B) voltages.

LOCATIONS	CODES	KEYS	COMMENTS
000 002	81 46 15	HLT *LBL E	RESET REGs.
003 004	47 86	*CMs *rset	RESET FLAGs.
005 007	46 14 53	*LBL D (	CALCULATE $\rho_S = \frac{Z_S - Z_0}{Z_S + Z_0} \rightarrow R_{04}$
008 010	43 00 01	RCL 0 1	
011 014	75 43 00 00	— RCL 0 0	
015 018	54 55 53 43	) ÷ (RCL	
019 022	00 01 85 43	0 1 + RCL	
023 026	00 00 54 95	0 0) =	
027 029	42 00 04	STO 0 4	
030 033	53 43 00 02	(RCL 02	CALCULATE $\rho_R = \frac{Z_R - Z_0}{Z_R + Z_0} \rightarrow R_{05}$
034 037	75 43 00 00	— RCL 0 0	
038 041	54 55 53 43	) ÷ (RCL	
042 045	00 02 85 43	0 2 — RCL	
046 049	00 00 54 95	0 0) =	
050 052	42 00 05	STO 0 5	
053 056	43 00 00 65	RCL 0 0 ×	CALCULATE $E\frac{Z_0\,(1+\rho_S)}{Z_S + Z_0} \rightarrow R_{06}$
057 060	43 00 03 65	RCL 0 3 ×	
061 064	53 01 85 43	(1 + RCL	
065 068	00 04 54 55	0 4) ÷	
069 072	53 43 00 00	(RCL 0 0	
073 075	85 43 00	+ RCL 0	
076 078	01 54 95	1) =	
079 081	42 00 06	STO 0 6	
082 085	43 00 06 65	RCL 0 6 X	CALCULATE $E\frac{Z_0\,(1+\rho_R)}{Z_S + Z_0} \rightarrow R_{10}$
086 089	53 01 85 43	(1 + RCL	
090 093	00 05 54 95	0 5) =	
094 097	55 53 01 85	÷ (1 +	
098 101	43 00 04 54	RCL 0 4)	
102 105	95 42 01 00	= STO 1 0	
106 109	43 00 04 65	RCL 0 4 ×	CALCULATE $\rho_R \times \rho_S \rightarrow R_{09}$
110 113	43 00 05 95	RCL 0 5 =	
114 117	42 00 09 81	STO 0 9 HLT	
118 121	46 11 60 01	*LBL A *if flg 1	CALCULATE $E\frac{Z_0\,(1+\rho_S)}{Z_S + Z_0} \times \frac{1}{1+\rho_S} \rightarrow$ SUM R_{07}
122 125	01 04 03 50	1 4 3 *st flg	
126 129	01 43 00 06	1 RCL 0 6	
130 133	55 53 01 85	÷ (1 +	
134 136	43 00 04	RCL 0 4	
137 139	54 95 44	) = SUM	
140 142	00 07 81	0 7 HLT	
143 146	60 02 01 06	*if flg 2 1 6	CALCULATE $R_{06} \times \rho_R \rightarrow$ SUM R_{07}
147 150	08 50 02 43	8 *st flg 2 RCL	
151 154	00 06 65 43	0 6 × RCL	
155 158	00 05 95 42	0 5 = STO	
159 162	00 08 44 00	0 8 SUM 0	
163 167	07 43 00 07 81	7 RCL 0 7 HLT	
168 171	43 00 08 65	RCL 0 8 ×	CALCULATE $R_{06} \times \rho_S \rho_R^2 \rightarrow$ SUM R_{07}
172 175	43 00 09 95	RCL 0 9 =	
176 179	42 00 08 44	STO 0 8 SUM	
180 182	00 07 43	0 7 RCL	
183 185	00 07 81	0 7 HLT	
186 189	46 12 60 03	*LBL B *if flg 3	CALCULATE $E\frac{Z_0\,(1+\rho_R)}{Z_S + Z_0} \rightarrow$ SUM R_{11}
190 193	02 00 02 50	2 0 2 *st flg	
194 197	03 43 01 00	3 RCL 1 0	
198 201	44 01 01 81	SUM 1 1 HLT	
202 205	43 00 09 65	RCL 0 9 ×	CALCULATE $R_{10} \times \rho_S \rho_R \rightarrow$ SUM R_{11}
206 209	43 01 00 95	RCL 1 0 =	
210 213	42 01 00 44	STO 1 0 SUM	
214 216	01 01 43	1 1 RCL	
217 219	01 01 81	1 1 HLT	

*denotes the second key function

3. **The SR52-program** requires 219 entries.

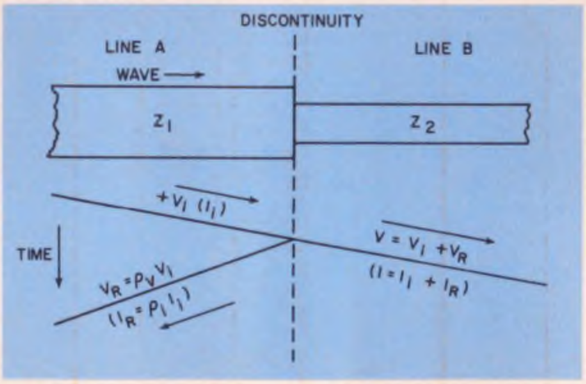
Transmission line reflections

Signal reflections on transmission lines occur whenever a wave encounters an impedance different from that of the original line. Such a discontinuity can stem from a change in the transmission line. In the general case, an incident voltage (V_I) and incident current (I_I) wave travel along a transmission line with impedance Z_1. When they encounter a discontinuity of impedance Z_2, a reflected voltage V_R originates at the discontinuity and travels back toward the generator. The incident voltage on line B is, therefore, $V_I + V_R$.

Reflected voltage $V_R = \rho V_\bullet V_I$, where the voltage reflection coefficient is defined as

$$\rho_V = \frac{Z_2 - Z_1}{Z_2 + Z_1}$$

At the generator interface, $Z_1 = Z_G$, and $Z_2 = Z_0$, where Z_0 is the characteristic impedance of the transmission line. The voltage that starts down the line is the result of a voltage division between the source impedance and the line impedance. The voltage proceeds down the line to the load, where it is reflected back toward the generator, then back to the load, and so on. The actual voltage at any time is the algebraic sum of all the individual reflected voltages up to that time.



R_{02} Z_R
R_{03} E

3. Press user-defined key "D" to execute the flow chart segment D.

4. Press user-defined key "A" for the first V_S (t=0 to t=2T). Press "A" again for the second voltage V_S (t=2T to t=4T) and so on, until all desired send-voltages are calculated.

5. Press user-defined key "B" for the first V_R (t=T to t=3T), then repeat for the second V_R (t=3T to t=5T) and so on.

Programming your SR52 calculator requires 220 keystrokes. They are listed in Fig. 3, in groups of two to four instructions. ■■

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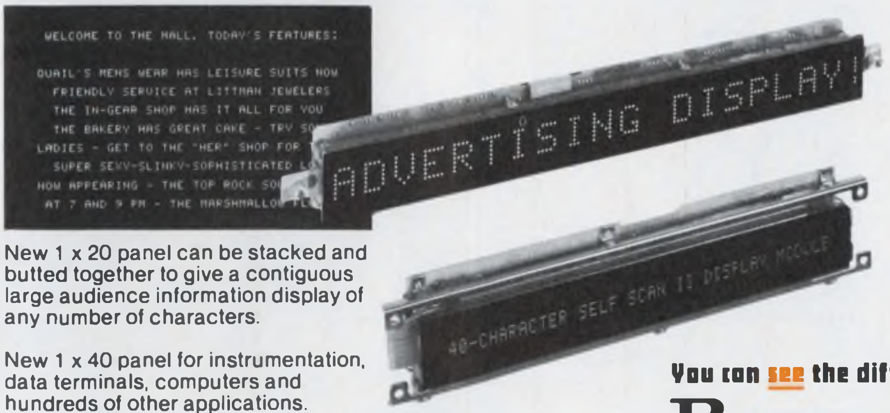

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Reduce sampling errors by adding an RC network to your sample-and-hold

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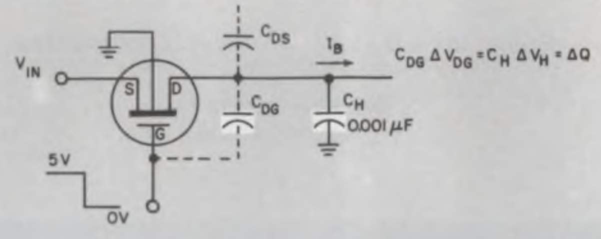
Sampling errors are caused when the drain-to-gate capacitance of a sample-and-hold's switching FET draws off charge from the holding capacitor. In Fig. 1, R_3 and C_c form a network for controlling the amount of charge injected into holding capacitor C_H. Of course, small values of C_H are required to allow a full charge to accumulate during the sampling period.

But small holding capacitors are affected by the FET's drain-to-gate capacitance, C_{DG}. The value of C_c is selected to be larger than the FET's expected C_{DG}. When the FET's gate voltage switches from high to low, C_c's voltage goes from low to high, which provides a charge pulse equal and opposite to that of the FET's capacitance.

To understand the RC network's effect, examine a sampling-circuit model without the network (Fig. 2) and see what happens. The step voltage on the FET's gate causes C_{DG} to take a charge, which comes from holding capacitor C_H. Assume that C_H is charged to 1 V and C_{DG} of the dual MOSFET is 2 pF. Then the charge on C_{DG} is:



2. **Drain-to-gate capacitance of a sample-and-hold's switching FET** causes charge to be drawn off holding capacitor C_H. If charge isn't restored, the result is sampling errors.

$$Q = C_{DG}\,(\Delta V),$$

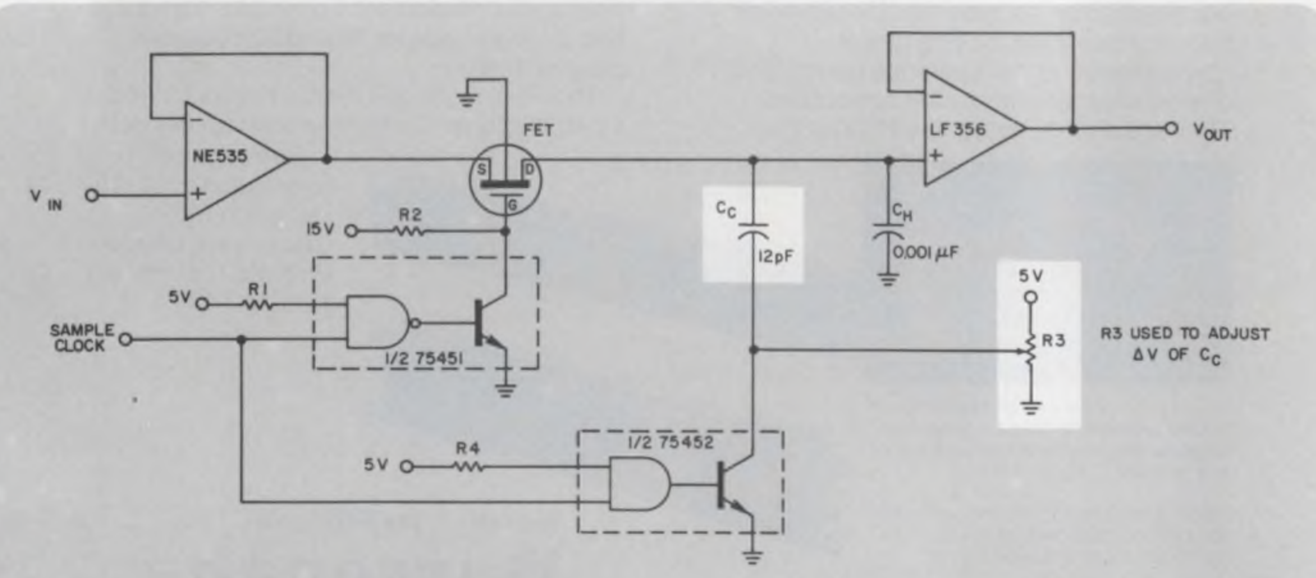
where $\Delta V = 15 - 1$, or 14 V.

Therefore:

$$Q = 2 \times 10^{-12}\,(14) = 28 \times 10^{-12} \text{ coulombs.}$$

The effect on C_H is:

$$V = \frac{\Delta Q}{C_H} = \frac{28 \times 10^{-12}}{1 \times 10^{-9}} = 28 \text{ mV.}$$



1. **Lost charge can be restored to holding capacitor C_H** by adding the R_3, C_c compensation network to a fast sample-and-hold circuit. The network controls the amount of charge injected into C_H.

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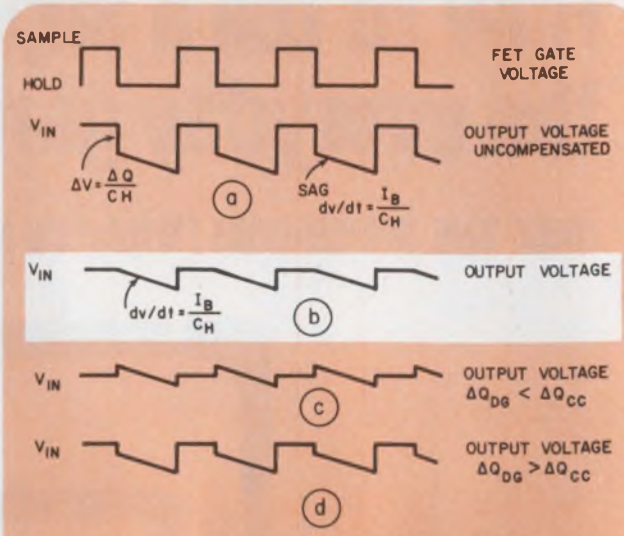
Without an RC network, the uncompensated voltage appears as in Fig. 3a, where the step error is ΔV. In fact, the step error can even exceed the total sag, dv/dt, of the hold circuit. You can get a smaller error by reducing the FET's gate voltage, but the resulting increase in on-resistance causes other problems. Choosing C_c as 12 pF (Fig. 1) with a C_{DG} of 2 pF limits the step error as shown in Fig. 3b. Fig. 3c and 3d show output error for other values of C_c.

Unfortunately, FET capacitance varies with drain-to-gate voltage, so the injected charge can be completely canceled only at one potential. If you know what voltage range to expect on C_H, you can compensate for errors by adjusting R_3.

Bob Marshall, Jr., Applications Engineer, Signetics Corp., 811 E. Arques Ave., Sunnyvale, CA 94086.

CIRCLE NO. 311



3. **A sample-and-hold's uncompensated output (a) shows an error, ΔV,** caused by loss of charge on the holding capacitor. Adding an RC network to the circuit reduces the error (b), but the capacitor's value must be greater than C_{DG}, or the error (c) and (d), won't be minimized.

A simple level shifter lets an IC modulator accept a unipolar input signal

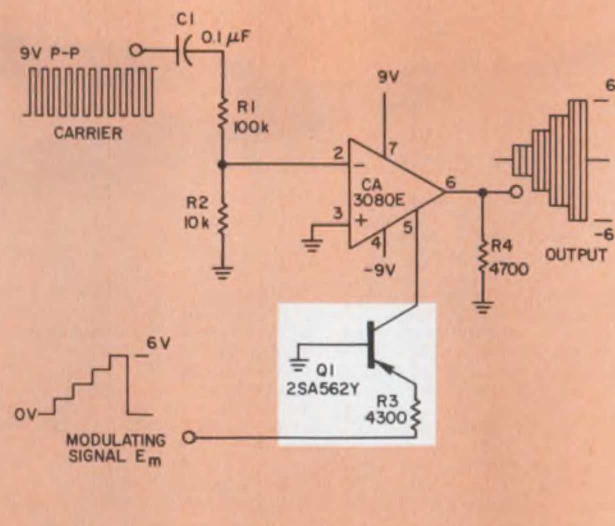
With a single transistor and resistor acting as a controlled current source (see figure), you can shift the operating point of an IC modulator to accept a positive-going modulating signal. The IC, a CA3080E transconductance amplifier (RCA), has its g_m input (pin 5) internally clamped near the negative-supply potential. A signal applied through Q_1 and R_3 to pin 5 produces a modulated envelope at the output. Its amplitude is directly proportional to current flowing into the g_m input, and the value of R_3 determines that current. Since the collector and emitter currents of Q_1 are equal, current into g_m is simply E_m/R_3.

When E_m is at any value below the base-emitter breakdown voltage of Q_1, no current is delivered to pin 5, and the output is zero. In a typical modulation application, however, a positive-going modulating signal must produce an output whose carrier amplitude is near zero only when the modulating voltage is zero. So to eliminate this small offset, you can bias Q_1's base slightly negative, instead of grounding it as in the figure.

For Q_1, choose a general purpose pnp type having a low I_{cbo}. The carrier should be about 1-V pk-pk at the amplifier input. And the network formed by C_1, R_1 and R_2 is designed to interface with CMOS for coupling a high-level signal to the amplifier input.

Dale Hileman, Engineering Services Manager, Sphygmetrics, Inc., Woodland Hills, CA 90290.

CIRCLE NO. 312



Adding current source Q_1, R_3 to this modulator allows the circuit to generate a modulated output proportional to a unipolar modulating signal.

The 8080 A/D & D/A Advantage

super-software supplied • fast, on-card DMA logic • 80 (to 256) channel expansion from just 2 cards

Datel's SineTrac 800 has it. SineTrac 800 slide-in A/D and D/A cards provide a complete analog "front-end" inside your Intel MDS-800 or SBC-80/10/20 microcomputers.

SineTrac 800 is ideal for industrial data logging, process loops, and high speed data acquisition systems.

The A/D card contains 32 single-ended or 16 differential channels with 12-bit resolution. An A/D Expander card offers 48 additional channels. Thus, two cards give 80 single-ended or 64 differential channels! Card addressing allows expansion to 256 channels. Throughput is 20 microseconds with rates up to 36,000 samples/second in DMA mode.

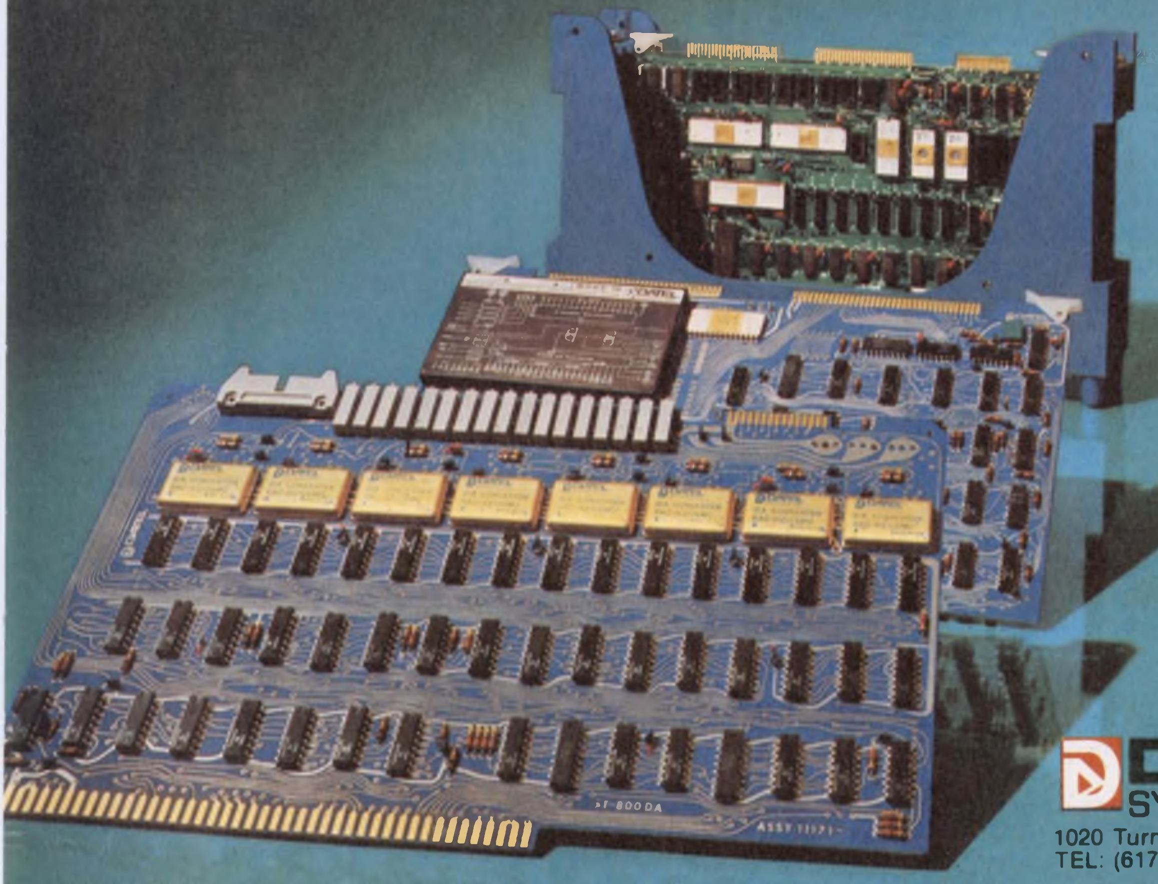
SineTrac D/A cards contain either 8 channels or 4 channels.

More SineTrac system advantages include on-card start and final address register/counters to save time and CPU housekeeping, and an adjustable IC scan clock with interrupt-flagged scan markers for event-triggered or internal scan starts.

The paper tape diagnostic test programs, supplied, allow channel calibration and a multi-scan accuracy test with decimal printout. The programs diagnose error conditions, give a descriptive TTY printout between selected channels, and continuously loop for scope or logic analyzer trouble-shooting.

A/D or D/A cards are $650* (singles). Write today for complete details.

*U.S.A. domestic prices only.



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CIRCLE NUMBER 31

Inexpensive circuit monitors voltage conditions in battery-operated equipment

For about a buck, you can build a circuit that lights a warning LED when battery voltage in portable equipment falls outside of design limits. Not only does the circuit (Fig. 1) eliminate expensive and bulky meters; it uses only one IC, an LM2905/3905 precision timer from National (about $0.60 apiece for a 3905) and three stable 1/4-W resistors, in addition to the LED.

A 3905, which operates over the range of 4.5 to 40 V, contains a floating transistor (pins 6 and 7), which can pull a load to ground or supply referenced loads of up to 40 V and 50 mA. Also built-in is a 3.15-V regulator with a 2-V divider, which establishes a trip point between reference and ground. The relationship between the LED activating voltage and external resistors is found from the following equation:

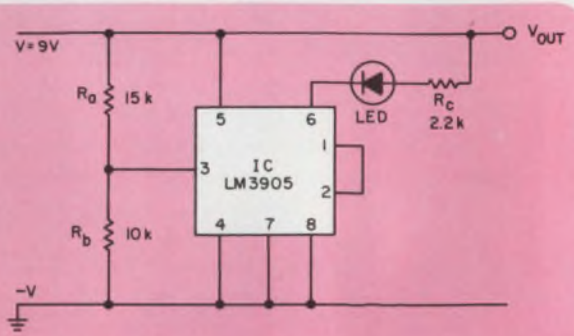
$$\frac{R_b(V)}{R_a + R_b} = 2,$$

where V is the activating voltage.

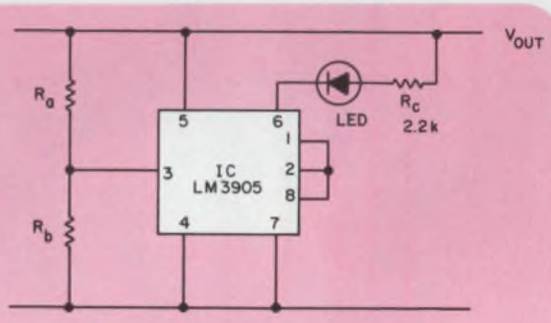
Assume that the battery in Fig. 1 is a 9-V transistor type whose voltage must fall to 5 V to light the LED. You can choose a value for either R_a or R_b, and solve for the unselected resistor using the equation. Resistor R_c is a LED current limiter. Simply by changing the external wiring of the 3905, you can use the same circuit to detect an overvoltage condition (Fig. 2). Note that pin 8 of the IC, grounded in Fig. 1, is tied to pins 1 and 2 in the overvoltage circuit.

Michael Bozoian, Consultant, Consulting Service in Electronics, 702 Fifth St., Ann Arbor, MI 48103.

CIRCLE NO. 313



1. **This inexpensive circuit detects low voltage conditions** in battery-operated equipment, and eliminates the need for expensive and bulky meters.



2. **If you rewire pin 8 of the IC,** the circuit of Fig. 1 is able to detect an overvoltage condition.

IFD Winner of October 25, 1977

Tom Gross, T. A. O. Gross & Associates, Lincoln, MA 01773. His idea "Flyback-Inverter Efficiency Increases when the Transformer Is Loaded Properly" has been voted the Most Valuable of Issue Award.

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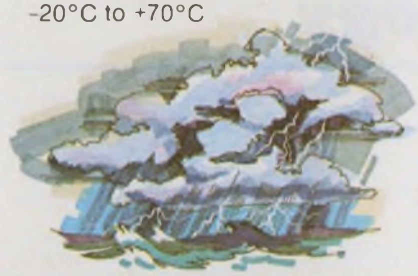
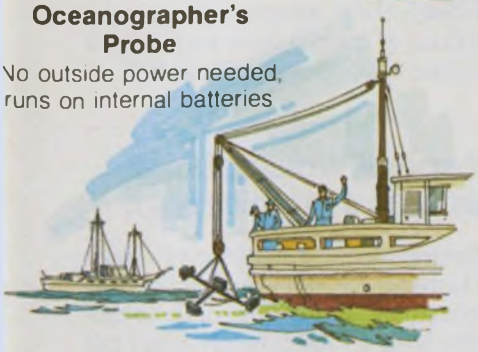
Portable Weather Station
Rain or shine, arctic or desert, -20°C to +70°C



Geophysical Monitor
Event-triggered recording to save tape, batteries and for fast computer data-spotting

Traffic or Noise Level Logger
Accepts analog or digital (event counter) inputs

Oceanographer's Probe
No outside power needed, runs on internal batteries



Log your Analog Data on Digital Tape Cassettes . . .

Biomedical Data Recorder
Optional 5 mV differential amplifier for low level detectors.

Pollution and Environmental Logger
Crystal CMOS clock can command different scan periods

DATEL'S DL-2 DATA LOGGER

An Important New Tool- Choose Datel's DL-2 Cassette Data Logger for unattended standby recording of multi-channel, slowly-varying analog samples. The DL-2 samples up to 64 high level or low level analog channels, digitizes them to 12-bit binary coding and records them on a cassette at 5 samples per second. Also recorded are a one year calendar clock with one second resolution produced by an internal CMOS crystal oscillator. And external digital samples (up to 36 bits) may be recorded at any time. Analog scans are started automatically from a preset front panel scan timer with intervals from one second up to 30 hours.

The all-CMOS electronics of the DL-2 and stepper-motor transport consume only one watt while recording and microwatts while powered-down between scans. A set of batteries in the front cover will power the DL-2 for a year or longer, recording up to 120,000 samples. Or external +12VDC or AC power may be used.

The DL-2 features a high-quality instrumentation amplifier (down to ±5mV full scale input) and weather-proof housing and connectors suitable for −10°C to +60°C environments. (−40°C optional)

A companion DL-2R Cassette Reader offers a convenient playback front end to a minicomputer, microprocessor, TTY, CRT terminal or modem telephone coupler.

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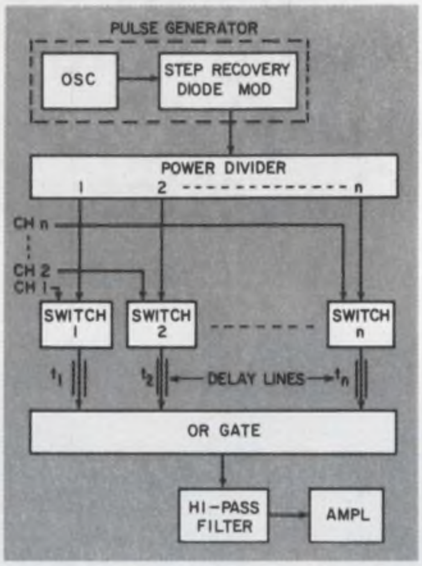
Multiplexer does big job with simple components

A new multiplexer with a pulse repetition rate of 5 Gbit/s is made of simple components—yet it can be used in high-capacity fiber-optic communications systems in place of complex optical multiplexing techniques currently being developed.

In the multiplexer, developed at the Chalmers University of Technology in Goteborg, Sweden, an oscillator drives a step-recovery diode to produce a low-duty-cycle pulse train. The pulse train is then passed through a power divider and split into a number of microstrip lines, each of which can be individually switched on and off by p-i-n diodes. The switched outputs are passed through microstrip delay lines, then combined by an OR gate (a passive circuit that is the inverse of the power divider).

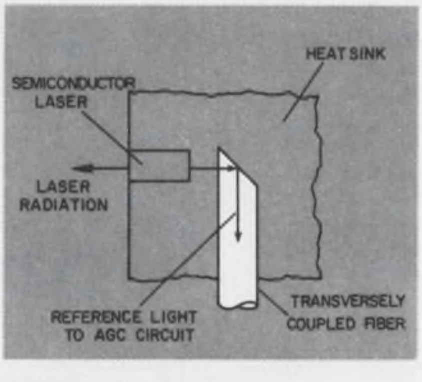
The delay lines are adjusted so that the delay for the nth channel is t_n - (n−1) t_p/n where t_p is the period of the input-pulse train. The output is a train of evenly spaced pulses with a pulse-repetition frequency equal to n times the input PRF.



Multiplexers have been constructed showing a 5-Gbit/s output PRF and signal-to-distortion ratio of 12 dB. But the Chalmers developers believe that 10-Gbit/s can be achieved and the signal-to-distortion ratio improved using attenuators ahead of the p-i-n diodes.

Backward laser radiation is detectable and usable

The backwards-emitted light of a semiconductor is useful as a signal for the AGC circuitry that stabilizes a laser's output power. But commercial laser diodes are usually packaged so that the backwards-emitted laser light can't be detected by an axially positioned fiber. Now a simple technique, developed by R. Bosch GmbH Geschaftsbereich Fernsehanlagen in Darmstadt, W. German, allows the backward laser radiation to be picked up and fed to the AGC system.



A 45° face is formed at the end of a fiber, which is positioned with its axis perpendicular to the laser light, and its sloping end facing away from the laser.

A 10% coupling efficiency, adequate for AGC applications, can be achieved by cutting a plastic fiber with a blade. The coupling efficiency of silica fibers has not yet been measured. But careful polishing of the end faces may achieve coupling efficiencies of 70 to 90%.

Fiber-optic microphone has wide dynamic range

Optical fibers have been used almost exclusively for data-communications applications. But a fiber-optic microphone with a wide dynamic range has been demonstrated at London's University College.

The microphone is the result of investigations of the interaction between coherent light propagating along a fiber and acoustic waves incident on it. In a fiber, small changes in the refractive index phase-modulate light being sent through it. An acoustic wave striking the fiber causes pressure variations that then modulate its refractive index. Because optical wavelengths are small, appreciable phase shifts can be caused by low levels of acoustic power.

Typically, the pressure sensitivity of a single-mode silica or glass fiber is 6×10^{-5} rad/Nm² where N is in Newtons. In experiments, a fiber 1 km long, wound to occupy a volume of only 10 cm³, detected a pressure change of 10^{-6} N/m with 1 mW optical power at the detector converting phase modulation to audio signals. This is some 26 dB below the weakest sound that can be perceived by the human ear. The linear dynamic range is about 180 dB for a 1-m length of optical fiber.

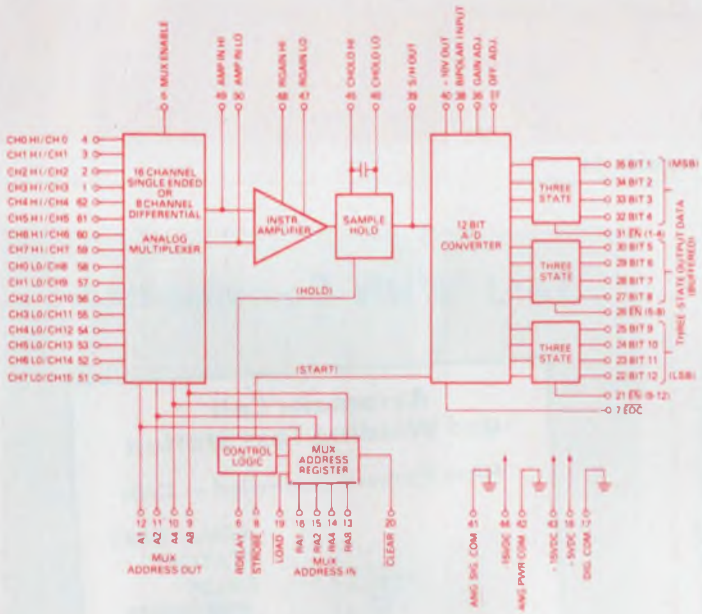
The microphone's sensitivity is increased by increasing the optical power carried by the fiber. With 1W of optical power, the limit for currently available fibers, acoustic powers below the threshold of hearing can be detected by only 30 m of fiber.

Inverter problem solved

Size and weight problems of the isolating transformer used in high power inverters is said to have been overcome by the use of high-frequency transformers in a technique developed by ERA Ltd. in England.

Complete, 12-Bit Microcircuit Data Acquisition System

Datel has it...



HDAS-16 & HDAS-8

- ▶ 16 Channels, Single-Ended (HDAS-16)
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- ▶ Priced at $295.00* (1-9)

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Datel's HDAS — the first complete 12-bit data acquisition system in a single, miniature package. Using thin-film hybrid fabrication, it challenges modular data acquisition systems on performance and price. Its excellent performance and reliability are also available in versions for full MIL-Spec operation over −55 to +125C. The HDAS 62-pin package measures only 2.3 x 1.4 x 0.24 inches (58 x 36 x 6 mm).

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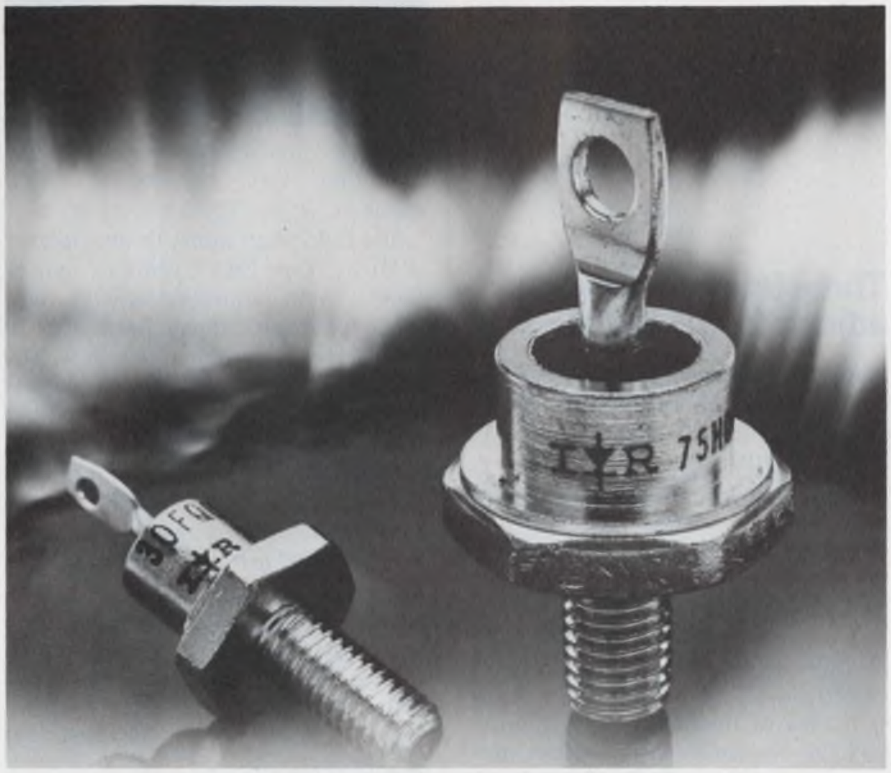
CIRCLE NUMBER 33

CIRCLE NUMBER 34

CIRCLE NUMBER 35

CIRCLE NUMBER 36

Schottky power diodes run at high junction temperatures



International Rectifier, 233 Kansas Street, El Segundo, CA 90245. Bob Del Vecchio (213) 322-3331. P & A: See text.

Pushing the operating temperatures up and reducing the reverse currents, International Rectifier's families of extended-range Schottky diodes pack more punch into power-supply designs. The diodes can operate at up to 175 C—a 25-C increase over available devices. As a result, you get either more current-handling capability or less heat-sink area.

Typical of the new devices is the 75HQ family, 75-A diodes with reverse-voltage capabilities of 30 or 45 V. Reverse currents for the diodes range from 15 mA at a junction temperature of 100 C to 150 mA at a T_j of 150 C. The maximum forward voltage drop for the diodes is as high as 0.9 V at 25 C and a forward current of 150 A (peak), and as low as 0.74 V at 175 C and 150 A (peak).

The Schottky diodes, since they operate at junction temperatures up to 175 C, permit the ambient temperature of the power supply they are used in to rise—typically from 40 to 70 C. Or, ratings can be kept the same but the heat-sink area reduced—by 20 to 40%, according to estimates.

Not only are the 75HQ diodes able to handle the high continuous currents, but they are also sturdy. The maximum peak one-cycle nonrepetitive surge current is 1000 A and the maximum I^2t for fusing is 4150 A^2S for 5 to 8.3 ms and 2275 A^2S for 1.5 ms.

Housed in stud-mount DO-203AB cases (formerly called DO-5), the diodes have a case-to-sink thermal resistance of 0.25 C/W. Mounting torque for the 1-oz devices is 30 lb-in., maximum. All diodes have an operating junction temperature range of −65 to 175 C.

Also available is a 30-A series of high-temperature diodes, the 30HQ family. Reverse currents are less than half those of the 75HQ devices and forward-voltage drops are about the same as the 75HQ units.

Compared to other high-current Schottky diodes, the 75HQ series offers 80% less reverse leakage current than its closest competitor, the MBR75 made by Motorola (Phoenix, AZ). The lower leakage minimizes the problem of thermal runaway—one of the major causes of Schottky diode failures.

Another competing diode series, the SD51, is available from TRW (Lawndale, CA). Every diode in this group also handles 75-A loads, but has higher reverse currents and a lower maximum operating junction temperature.

Prices for International Rectifier's 30HQ and 75HQ diodes start at $4.48 for the 30-A, 30-V device and range up to $7.08 for the 75-A, 45-V diode, both in 100-unit quantities. Delivery of samples is from stock, and production quantities require four weeks.

International Rectifier **CIRCLE NO. 302**
Motorola **CIRCLE NO. 303**
TRW **CIRCLE NO. 304**

Speedy power transistors take high voltage

General Semiconductor Industries, P.O. Box 3078, Tempe, AZ 85281. Jim Williams (602) 968-3101. $4.95 to $6.00 (100 qty); stock.

Models XGSR7530, XGSR7535 and XGSR7540 feature a V_{CEO} of 300, 350 and 400 V. Each is both current-gain and saturation-voltage rated at 7.5 A. Peak collector current is 15 A. Collector saturation voltage is typically 0.3 V and switching speed is less than 1 μs. Packaging is the TO-3 metal case.

CIRCLE NO. 305

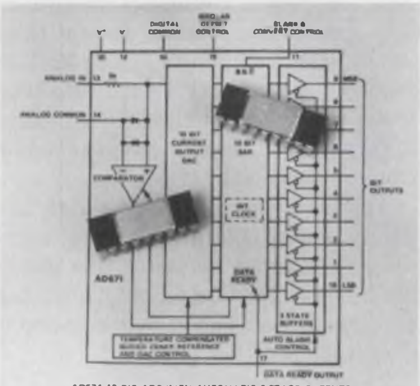
Bridge rectifiers rate 27.5 A, 3-phase

Electronic Devices, 21 Gray Oaks Ave., Yonkers, NY 10710. Dennis Dean (914) 965-4400. Free samples.

A line of 3-phase, full-wave bridge rectifiers is rated at 27.5 A. Peak reverse voltage ratings are 50, 100, 200, 400, 600, 800 and 1000 V. Maximum surge current is 300 A. The bridges are 1.5 × 2 × 0.406 in. and can be mounted on a heat sink or chassis.

CIRCLE NO. 306

Bipolar a/d converter delivers 10-bit output



AD571 10 BIT ADC WITH AUTOMATIC 3-STATE OUTPUTS FOR SINGLE LINE CONTROL

Analog Devices, Route 1 Industrial Park, P.O. Box 280, Norwood, MA 02062. Jeff Riskin (617) 329-4700. Stock.

Built using I^{2}L technology, the AD571 is a complete, 10-bit analog/digital converter. On a single chip is a d/a converter, voltage reference, clock, comparator, successive approximation register and output buffer. The AD571 performs a complete conversion to 10-bit accuracy ±1/2 LSB with no missing codes in 25 μs. There are three versions available; the J suffix for fully guaranteed 10-bit performance at 25 C (9 bits from 0 to 70 C), the K suffix for a full 10 bits over 0 to 70 C, or the S suffix for −55 to +125 C operation. The guaranteed full-scale temperature coefficients of 88, 44, and 40 ppm for each version, respectively, are the total TC errors of all the components in the circuit.

CIRCLE NO. 307

Transistors switch 1 A and are MIL qualified

Silicon Transistor, Katrina Rd., Chelmsford, MA 01824. Bill Schromm (617) 256-3321. $3.38/$4.30; bonded stock.

JAN-2N3740 and JAN-2N3741 silicon power transistors are qualified to MIL-S-19500/441A. They are rated for a V_{CEO} of 60 and 80 V, respectively, and continuous collector current of 1 A. The dc gain is 30 to 100 at an I_C of 250 mA, and the collector-emitter saturation voltage is specified at 0.6 V at 1 A. The devices are in TO-66 cases.

CIRCLE NO. 308

High-speed op amp has 15-MHz bandwidth

Texas Instruments, P.O. Box 5012, M/S 308 (Attn: LM318), Dallas, TX 75222. Dale Pippenger (214) 238-3527. $1.64 to $10.08 (100 qty); stock.

The LM318 high-speed operational amplifier has a typical small-signal bandwidth of 15 MHz and a slew rate of 50 V/μs min. The op amp has internal unity-gain frequency compensation. External compensation may be added for optimum performance. Supply voltage can range from ±5 V to ±20 V.

CIRCLE NO. 309

Three-terminal regulator adjusts from −1.2 to −37V

National Semiconductor, 2900 Semiconductor Dr., Santa Clara, CA 95051. Dave Whetstone (408) 737-5856. $2.80 to $13.60 (100 qty); stock to 4 wks.

Negative three-terminal adjustable regulators, the LM137 series, are 1.5-A devices. The regulators have internal current limiting, thermal shutdown and safe-area compensation. The output voltage shifts 0.2% max when a 10-W pulse is applied for 10 ms. Ripple rejection is 75 dB and rms output noise is 0.003% of the output voltage up to 10 kHz. The series covers output voltage from −1.2 to −37 V in TO-3, TO-5, TO-220 and TO-202 cases.

CIRCLE NO. 310

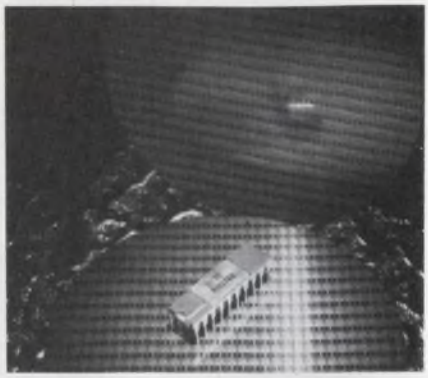
Dual op-amps have high input impedance

RCA Solid State, Route 202, Somerville, NJ 08876. (201) 685-6423. $0.55 (chip) to $1.73 (100 qty); stock.

The CA3240 and CA3240A dual op amps have gate-protected MOSFET transistors in the input circuit for high input impedance (1.5 × 10^{12} Ω), low input current (10 pA at ±15 V) and high-speed. The op amps have, respectively: max input offset voltages of 15 mV and 5 mV, input offset currents of 30 pA and 20 pA and max input currents of 50 pA and 40 pA. The dc supply voltage can range from 4 to 36 V and the common-mode input voltage can swing to 0.5 V below the negative supply rail. Package options are 8-lead or 14-lead plastic DIPs.

CIRCLE NO. 320

Programmable circuit multiplexes 8 lines

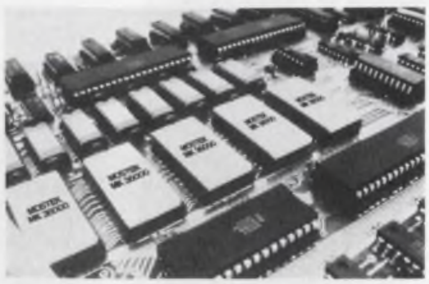


Raytheon Semiconductor, 350 Ellis St., Mountain View, CA 94040. (415) 968-9211. $4.25 (100 qty); stock.

The field programmable multiplexer (PMUX), Type 29693, contains four 8-line-to-1-line multiplexers with common select and input lines and 10 electrically programmable inputs. The 20-pin device has 10 buffered inputs and four outputs. The 10 input lines form a matrix with 32-bit lines. At each junction of the horizontal inputs with the vertical bit lines, there is a diode-fuse combination connecting the two. The bit lines are then routed to four one-of-eight multiplexers controlled by three "select" inputs. The select lines determine which multiplexer inputs are connected to the three-state output drivers.

CIRCLE NO. 321

64-k ROM features 200-ns access time



Mostek, 1215 W. Crosby Rd., Carrollton, TX 75006. Derrell Coker (214) 242-0444. See text; 6 wks.

The MK 36000 64-k ROM operates at a 200-ns access time and requires only 200-mW active power (max) and 25-mW standby power. The device operates from a single +5-V power supply with 10% tolerance. Other system features include full TTL-compatible inputs and outputs. The three-state output can drive two TTL loads and 100 pF. The price for the plastic package is $49.00 in 500 quantity with a $1000 refundable masking charge.

CIRCLE NO. 322

Don't waste money and ruin PROMs. Move up to a first-rate programmer.

What defines a first-rate programmer?
A first-rate programmer is easy to use, safe (U.L. listed), reliable, backed with a long-term warranty, and flexible enough to handle advances in PROM technology, a combination you get only with a Pro-Log programmer.

Our systems take the mistakes out of programming.
Our Series 90 PROM Programmer walks you through the programming process so there's less chance for misprogramming. Separate sockets for master and copy PROMs make it impossible to accidentally destroy a valuable master.

Vendor-approved programming, full portability, free 2-year warranty.
Using vendor-approved PROM personality modules, Pro-Log's field-proven programmers program every major MOS and bipolar PROM. They also program generic PROM families and do gang programming. They weigh less than 20 pounds so they go where you need them. And they're backed by the longest warranty in the industry, 2 full years parts and labor.

A first-rate programmer is economical, too.
A complete Series 90 consists of a master control unit, a PROM personality module, and options. An M900 master control unit costs only $1,800. An M920 PROM Duplicator master control unit costs only $1,145. Single PROM personality modules cost from $325 to $450. Generic modules start at $350. Gang modules which program 8 PROMs simultaneously are $895. All modules come U.L. listed and fit both the M900 and the M920. Options include CMOS RAM buffer (to 4K bytes), RS-232 (terminal or modem) interface, TTY, parallel interfaces, paper tape reader, U.L. listed erase light, checksum option, and Auto-baud.*

Find out what else a truly first-rate programmer has to offer.
Call or write for a free pamphlet giving you comparison checkpoints. Pro-Log Corporation, 2411 Garden Road, Monterey, CA 93940. Phone (408) 372-4593.

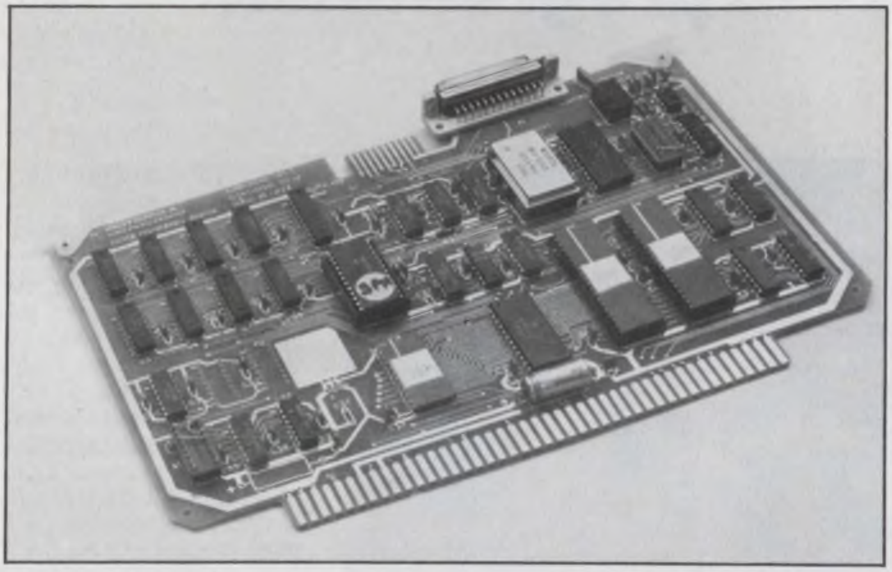
*Trademark, Pro-Log Corporation.

PRO-LOG CORPORATION

Microprocessors at your fingertips.

CIRCLE NUMBER 38

System monitor keeps track of microcomputer performance



Motorola Microsystems, 3102 N. 56th St., Phoenix, AZ 85018. Wes Patterson (602) 244-6815. P&A: See text.

Although system monitors are routinely used to analyze the performance of large computer systems, they cost too much for most microcomputer applications. But for just $1045 Motorola's System Performance Monitor gives the micro user the monitoring capability of units costing several thousand dollars.

Connecting directly to a microcomputer's address bus, the SPM periodically samples the μC system's address lines, and accumulates the results to produce a map of memory addresses with corresponding frequencies of reference. Samples collected in the program-storage region may be used to correlate processor activity with specific program segments. One result is that software bottlenecks can be identified and quantitative information provided about the performance limits they impose. Or, critical program segments may be identified for reorganization or optimization. Or, if a high-level language is being used for software development, certain subroutines may be identified for recoding in assembly language.

An autonomous single-board microcomputer system, the SPM measures 5.75 × 9.75 in. and is physically and logically bus-compatible with Motorola's EXORciser μP development system and the Micromodule series of OEM microcomputer boards. Jumpers enable the SPM to adapt logically to other microcomputer bus structures, with physical adaptation left to the user.

As seen from the bus, the SPM is a passive device; it doesn't disturb the measured system. During operation, 12 address bits from the monitored bus are latched and sampled by the SPM approximately 6000 times per second. Data from each sample accumulate in one of 256 4-byte counters. Bus observations may be run for almost a week without losing data. Samples may be collected within a specified memory region of 4, 16 or 64 kbytes. Experiments over smaller regions produce greater detail in the results.

Samples collected in the data-storage region of memory may provide such additional useful information as the efficiency of a particular buffer-management algorithm. Since I/O in the M6800 μP is memory-mapped, the SPM can also collect information about I/O activity. In addition, processor utilization may be derived from bus-utilization information collected by the SPM. This can be used to project maximum system capacity, or to quantify improvements over previous measurements.

(continued on page 84)

CIRCLE NUMBER 39

PMI announces two

monolithic 10-bit DAC's.

Good news! Two new ten-bit digital-to-analog converters from the folks who know how to make them monolithically. And each is completely "complete." Includes internal reference and output op amp. They are fast (1.5 μsec settling time), with voltage outputs, yet consume only 350mW (max) over the entire military temp range (−55°C to +125°C).

DAC-05: Sign-magnitude coding (sign-plus-ten-bits).

DAC-06: Two's complement coding.

Both DACs are available now specified over the full temp range. Off the shelf to MIL STD-883A Level B. Reliability is enhanced by 100% burn-in, hermetic packaging for all parts, PMI's famous triple passivation, low noise process and no laser trimming.

Data sheets are ready. Parts are <u>on</u> the shelf. Write, wire or phone. Precision Monolithics, Inc., 1500 Space Park Drive, Santa Clara, CA 95050. (408) 246-9222. TWX: 910-338-0528.

PMI®

CIRCLE NUMBER 9

MICRO/MINI COMPUTING

(continued from page 80)

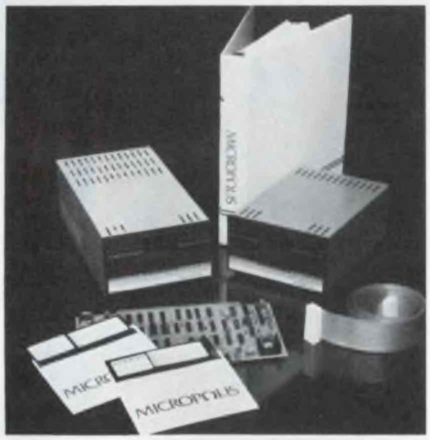
A control-console keyboard is used to initialize the starting memory address and memory block size for each measurement experiment. Results are retrieved via console printer or CRT and reported both as a percentage of samples occurring in each memory segment within the measured region and as a histogram. Bus utilization is reported as busy bus cycles, which are sampled as a percentage of the total cycles sampled.

Since the console isn't needed except to initialize the SPM and to retrieve results, the EXORciser console device may be shared for this function. A serial RS-232 interface is included with the SPM, and a current-loop interface adapter is available as an option.

Delivery of the board is from stock.

CIRCLE NO. 301

Thrifty disc drive holds 143 kbytes



Micropolis, 7959 Deering Ave., Canoga Park, CA 91304. (213) 703-1121. $695.

The 1041 series of disc drives includes software, S-100 bus compatible controller and 143-kbyte capacity. Model 1041 packages a drive, enclosure, cabling and connectors, disc operating system and disc-extended Basic for integration into any 8080A or Z80 microcomputer. Model 1042 adds a power supply and dc regulators for desktop use. The drives are hard-sectored into 16 sectors, each 256 bytes long; total tracks per surface is 35. Both offer transfer rates of 250 kbits/s at an average rotational latency time of 100 ms. Access time, track to track, is 30 ms and recording density is 5162 bits/in.

CIRCLE NO. 323

Full-function computer fits on desk top

IBM, P.O. Box C-1645, Atlanta, GA 30301. Bill Shaffer (404) 231-3201. $9875 to $32,925.

The IBM 5110 is a desktop computer that houses a central processing unit, a typewriter-like keyboard with a 10-key calculator pad and a 1024-character display screen. Main memory holds 16 k, 32 k, 48 k or 64 kbytes of data, depending on the unit selected. The computer is available in two models. Offering either magnetic tape or diskette storage, the Model 1 stores 204 kbytes per tape cartridge or 1.2 Mbytes on a single diskette. The Model 2 allows diskette storage only. Up to two IBM 5114 diskette units, each housing a maximum of two diskette drives, can be attached to the 5110 for an on-line diskette capacity of 4.8 Mbytes.

CIRCLE NO. 324

Memory module contains more than 1 Mbyte

EMM Commercial Memory Products, 12621 Chadron Ave., Hawthorne, CA 90250 (213) 644-9881. $0.10/bit

The Megabyte Module memory is configured as 1,114,112 × 8 (8,912,896 bits), which is 524,288 bits in excess of 1 Mbyte. The additional 64-kbyte capacity allows the use of various error checking methods while maintaining a 1-Mbyte capacity for data. The memory is a random-access, two-wire, 1-1/2D core memory, packaged on a single pluggable PC card. An available chassis can take up to four modules, two I/O cards, and a power supply within 17-1/2 in. of vertical rack space. The memory module operates at 2 μs in the read/restore and clear/write modes with an access time of 1.2 μs.

CIRCLE NO. 325

Low-end computer uses PDP-8 processor

Digital Equipment, Maynard, MA 01754. Joe Nahil (603) 884-5101. $12,600; 8 wks.

The Datasystem 308 uses a PDP-8 video data processor and is for data processing that requires a single terminal. A typical system consists of a video date processor with 32 kbytes of memory, dual floppy-disc file system, and a minidesk. The 308 uses the COS-310 operating system whose program includes DIBOL, a business-oriented language. COS-310 files and the DIBOL language permit the user to transfer programs and data to larger systems by appropriate media.

CIRCLE NO. 326

Bulk magnetic eraser is hand held

Printcraft Systems, 11-17 Beach St., New York, NY 10013. Don Hubbinett (212) 966-0001. $22.50.

The UL-approved hand-held bulk tape/card eraser electronically restores magnetic cards, cassettes, discs and reel-to-reel recording tapes to "like new" blank recording condition. The process can be performed off line in quantity for either general reuse or for information security. The eraser guards against one program from running into a previously recorded program should a stop code be missed.

CIRCLE NO. 327

Personal computer uses Z80 CPU

Realistic Controls, 404 W. 35 St., Davenport, IA 52086. (800) 553-1863. $2495.

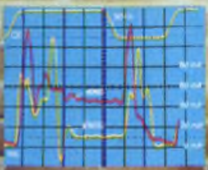
REX, a total microcomputer system, is fully assembled with a Z80 CPU, 24-k RAM, video output, keyboard, microfloppy-disc drive, cabinet, power supply and optional extended-disc Basic and ANSI Fortran IV. The system includes an S-100 motherboard, up to 64 k of RAM (24 k standard), bootstrap and monitor PROM and power-fail and vectored-interrupt circuitry.

CIRCLE NO. 328

Intel delivers a better 22-pin 4K RAM for people who are never quite satisfied.

For some people "good enough" is never quite good enough. In 1972 we introduced the industry's first 22-pin 4K RAM, the 2107. But we weren't content to stop there. So we followed with the 2107A. Then in 1975 the 2107B. Now, introducing the 2107C. Compare it with any 4K dynamic RAM. The results are sure to put a smile on your face.

The 2107C delivers a new standard of performance. Access time: 150 ns. Power consumption: 40% lower than the TMS 4060 or our own 2107B. Current spikes: significantly lower than competitor's parts means less system noise with the 2107C. Supply tolerance: ±10% in all power supplies gives you the widest system operating margins available anywhere.



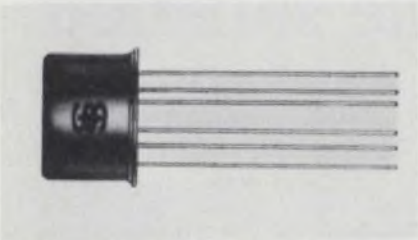
Best of all, the 2107C is already in volume production and available in both hermetic and plastic packages. Plan now to upgrade your systems now using our 2107B or any of its second sources. For a complimentary P2107C evaluation sample and data sheet, contact your Intel sales office. To order, contact Almac/Stroum, Component Specialties, Cramer, Hamilton/Avnet, Harvey Electronics, Industrial Components, Pioneer, Sheridan, Wyle/Elmar, Wyle/Liberty, L.A. Varah, Zentronics. Or write us. Intel Corporation, 3065 Bowers Avenue, Santa Clara, CA 95051.

	2107C-1	2107C-2	2107C
Maximum Access Time	150 ns	200 ns	250 ns
Maximum Read/Write Cycle	380 ns	400 ns	430 ns
Maximum I_{DD} Average	35 mA	33 mA	30 mA
Power Supply Tolerance	±10%	±10%	±10%

In Europe, Telex 24814, Brussels.
In Japan, Telex 28426, Tokyo.

CIRCLE NUMBER 44

Solid-state chopper comes in TO-5 case



Solid State Electronics, 15321 Rayen St., Sepulveda, CA 91343. Ed Politi (213) 894-2271. $89 (100 qty); 1 to 3 wks.

The NS8000A is a transformer-isolated solid-state chopper built with stabilized integrated silicon semiconductors in a TO-5 type enclosure. The max chopped current is 10 mA and the total device dissipation in free air is 0.5 W (2 W at 25-C case temp). The chopping frequency (limited by an internal transformer) ranges from 50 kHz to 1.5 MHz.

CIRCLE NO. 329

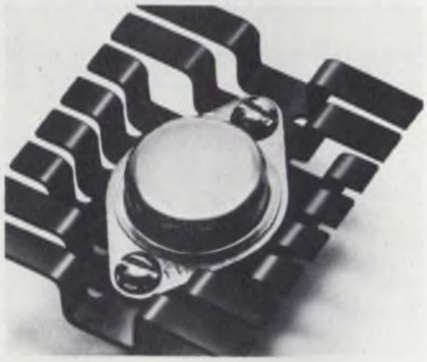
Large indicator lights are attention grabbers

Industrial Devices, 7 Hudson Ave., Edgewater, NJ 07020. (201) 224-4700. Free samples.

Large attention-getting panel indicator lights, Omni-Glow 2600, have built-in, round metal bezels that retain a lens. High dome-shaped, or low-profile flat or rounded lenses can be used. The indicators fit into a 7/8-in. diameter panel opening or in a keyed D-mounting hole. Either snap-fit or speednut mounting may be used. Lamps for the indicators are either standard or high-brightness neons or rugged wire-lead incandescents.

CIRCLE NO. 330

Low-profile heat sink fits TO-3 and TO-66



Aavid Engineering, 30 Cook Court, Laconia, NH 03246. (603) 524-4443. Free samples.

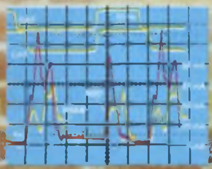
Heat sinks that feature a universal hole pattern, part numbers 5060 and 5061, also accommodate TO-3 and TO-66 case-style devices. The heat sinks are 0.375-in. high and fit PC boards spaced 0.5-in. between board centers. Both types come with black anodized finish.

CIRCLE NO. 331

Intel delivers the only 16-pin 4K RAM that's sure to keep you smiling.

You may or may not think of your memory system as a masterpiece. But one thing is certain, once you've reached volume production you're going to be reluctant to make major changes. That's why it is so frustrating to find that a supplier has painted you into a corner by deciding to stop delivering the part you want. Or by trying to switch you to a newer, non-compatible part.

Smile. Our 2104A 16-pin 4K RAM is the answer. It's a direct replacement for both the older 4096 metal gate and newer 4027 silicon gate parts. The 2104A keeps your production line moving without expensive re-design. Plug it in and you're ready to go.



The 2104A is best for your new designs, too. We've been delivering this part in volume since July, 1976. So you can count on Intel to deliver the quantity you need, when you need it.

Delivery is not the only reason to specify the 2104A. There's not a 16-pin 4K RAM anywhere with lower power consumption. And because the 2104A has significantly lower current spikes than other 16-pin 4K RAMs, there's less system noise. What it all means is that when you design your next system, it makes sense to design it using our 2104A.

	Maximum Access Time	Maximum Read/Write Cycle	Maximum IDD Average
2104A-1	150 ns	320 ns	35 mA
2104A-2	200 ns	320 ns	32 mA
2104A-3	250 ns	375 ns	30 mA
2104A-4	300 ns	425 ns	30 mA
2104A	350 ns	500 ns	30 mA

You can order the 2104A from distributor stock. Contact: Almac/Stroum, Component Specialties, Cramer, Hamilton/Avnet, Harvey Electronics, Industrial Components, Pioneer, Sheridan, Wyle/Elmar, Wyle/Liberty, L.A. Varah, Zentronics. Or write Intel Corp., 3065 Bowers Ave., Santa Clara, CA 95051.
In Europe, Telex 24814, Brussels.
In Japan, Telex 28426, Tokyo.

intel delivers.

COMPONENTS

Thermistor in glass bulb is indirectly heated

Fenwall Electronics, 63 Fountain St., Framingham, MA 01701. (617) 872-8841.

Thermistor K365 has a heating element and thermistor bead enclosed in a glass bulb. It is unaffected by changes in ambient conditions. When power is applied directly to the thermistor bead, temperature increases 1 C/0.015 W. Power of 0.04 mW to the heater indirectly heats the thermistor bead 1 C and changes the thermistor resistance, typically, from 50 to 15 kΩ.

CIRCLE NO. 332

RCD networks save board space

TRW Capacitors, 301 West "O" St., Ogallala, NE 69153. (308) 284-3611. 8 to 10 wks.

Resistor-capacitor-diode (RCD) networks save both circuit-board space and design time. The networks come packaged in axial-lead molded-plastic cases. Diodes have reverse-breakdown voltages of 1000 V with less than 50 mA of leakage current and max forward-voltages of 1.1 V at 1 A. Resistors, rated from 1/4 to 1/2 W, have values from 100 to 800 Ω. And metallized-Mylar capacitors have voltage ratings from 100 to 400 V and capacitances from 0.22 μF to 1 μF.

CIRCLE NO. 333

Slim DPM features 3-1/2 digit display

Fairchild Instruments & Controls, 1725 Technology Dr., San Jose, CA 95110. John Hatch (415) 962-2521. $33.

Model 30 3-1/2-digit DPM is a flat pack that operates on only 0.75 W at 5 V dc. With the display blanked, power is reduced to 0.05 W. The meter is available in a full-scale range of ±1.999 V with a resolution of 0.0005%. Higher ranges are obtained by the use of external resistor-divider networks. Accuracy is ±0.1% of reading, ±1 digit. The display is 0.5 in. high. The unit fits NEMA and DIN standard 0.44 × 3.59-in. panel cuts.

CIRCLE NO. 334

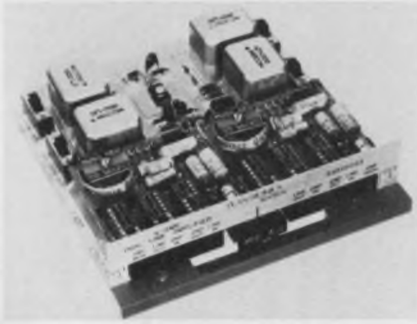
Cassette transport has accurate speed

MFE, Keewaydin Dr., Salem, NH 03079. Jim Saret (603) 893-1921. $560; 4 to 6 wks.

The Model 450B digital-cassette transport has a speed-control system that provides long-term speed accuracy at the heads without the use of a pre-recorded digital clock track. The transport is fully ANSI/ECMA compatible, allowing full interchange of cassette tapes with any other compatible system. Two data tracks are available allowing data storage up to 5.9 Mbits (720 kbytes) per cassette. Read/write speeds from 10 to 40 in/s are available providing data transfer rates up to 32 kbits/s using the bi-phase level encoding standard. Search speeds up to 80 in/s can be used.

CIRCLE NO. 335

Dual line amp has equalizer option

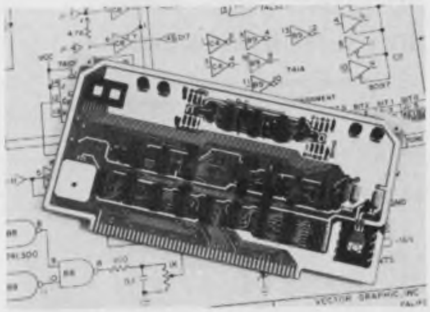


Plantronics Kentrox, 14335 N.W. Science Park Dr., Portland, OR 97229. (503) 643-1681. $155 (amplifier), $47 (equalizer); stock.

The Model 3300 dual line amplifier takes an optional line-amplitude equalizer that provides transmit and receive equalization in four-wire applications with DIP switches to select equalization. The amplifier has a power regulator and 70-dB power-supply-noise rejection. Simplex leads are provided. A switch selects 150, 600 and 1200-Ω input and output impedances. A visual indication of gain is provided.

CIRCLE NO. 336

Analog interface board handles many functions



Vector Graphic, 790 Hampshire Rd., Westlake Village, CA 91361. Lore Harp (805) 497-6853. $115; stock.

The multifunction analog interface board interfaces a μP with potentiometers, joysticks or voltage sources. An 8-bit digital port with latch strobe is used as a keyboard-input port. Tone-pulse generators also can be used to produce sounds for games or keyboard audio feedback. Also included are four a/d inputs, MWRITE logic and power-on jump capability for computers lacking a front panel.

CIRCLE NO. 337

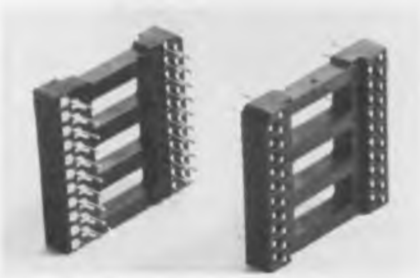
Adhesive tacks wires and terminates coils

Loctite, N. Mountain Rd., Newington, CT 06111. (203) 278-1280.

A wire-tacking adhesive system called the Tak Pak simplifies circuit-board engineering changes and lowers coil production costs with its instant-curing adhesive. Wires are tacked to circuit boards by first priming the bond area with wire-tacking accelerator. A drop of clear, thick wire-tacking adhesive is then applied to the wire. The material cures within 15 s. When terminating coil wires, adhesive is first applied to the wire. The accelerator is then applied and the drop cures in less than 5 s.

CIRCLE NO. 338

Flat sockets offer 42 to 62 pins for DIPs



Circuit Assembly, 3169 Red Hill Ave., Costa Mesa, CA 92626. Dick Foringer (714) 540-5490.

DIP sockets with 42, 52 and 64 pins fit calculator and microprocessor chips. The sockets provide four staggered rows of pins on 0.5-in. centers. A low-profile, open-design insulator body reduces component height.

CIRCLE NO. 339

DIP sockets provide up to 64 pins

Excel Products, 401 Joyce Kilmer Ave., New Brunswick, NJ 08903. (201) 249-6600.

Low-profile 800 Series DIP sockets include from 4 to 64 pins per socket. The bodies are Valox or FR4 glass epoxy, UL recognized and 94V-0 rated. With a height of 0.116 in., the sockets' pins come with 1, 2 or 3-level wrapped-wire posts, PC posts or bifurcated pins. Pins are plated with gold over nickel or tin plate, all to MIL specs.

CIRCLE NO. 340

Thick-film kit screens resistors and conductors

Methode Development, 7447 W. Wilson Ave., Chicago, IL 60656. (312) 867-9600. $200; stock.

A polymer thick-film evaluation kit permits experimentation with screen-printing resistors and conductors on PC boards. The technology eliminates many discrete components and can be used for multilayer or crossover conductors, or to eliminate circuit soldering or plating. Twelve 2-oz samples of resistor, conductor, insulator and solvent compounds, plus several samples of circuits and PC boards are included in the kit. One ounce of material will cover up to 500 in.^{2}.

CIRCLE NO. 341

Solderless wire terminal gives firm tool grip

Teledyne Ansonia, 1 Riverside Dr., Ansonia, CT 06410. Bob Sobolewski (203) 735-9311. Free samples.

Funnel-Crimp wire terminals have knurled barrels that give positive grips for holding when crimping and handling. An internal funnel guides the wire into the barrel and positions stripped wire for crimping. A built-in tool stop (sharp shoulder) eliminates mis-crimping. Tongue type terminals include rings, spades, flanged spades, locking spades, hooks and male/female disconnects. Color coding in red, blue and yellow identifies wire capacities from 22 to 10 AWG.

CIRCLE NO. 342

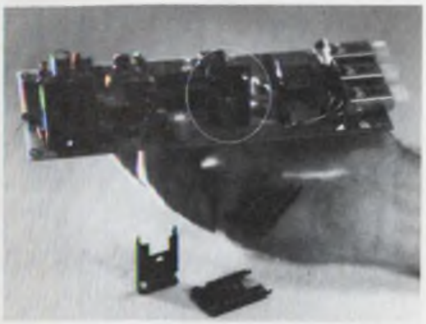
PC connectors designed for wave soldering

Viking Industries, 21001 Nordhoff St., Chatsworth, CA 91311. (213) 341-4330. See text; stock to 6 wks.

Type NK and NL PC connectors, for wave soldering, have round-contact tails instead of the square tails commonly used for wrapping. The round tails fit into smaller holes than the square tails and allow for more uniform solder joints. Contacts come on 0.1, 0.125 and 0.156-in. centers with two tail lengths. For standard wave soldering, a 0.2-in. tail is used. For the Raychem Solderpak system, a 0.25-in. tail is available. Pricing for a standard 40-position connector (3VH40/9JNK5) is $3.63 in 500 to 999 quantity.

CIRCLE NO. 343

Aluminum heat sink mounts vertically

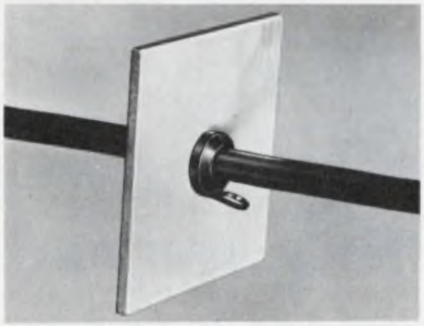


Tran-Tec, P.O. Box 1044, Columbus, NE 68601. Cliff Schroeder (402) 564-2748. $0.095; 5 wks.

The Series M1110 aluminum heat sink is for vertical mounting where space is limited. Dimensions above the circuit board are 1.25 high, 0.84 wide and 0.235-in. thick. Transistors mount by the use of a 0.14-in. diameter hole or a push-on clip. The heat sink takes plastic encapsulated transistors with TO-220, TO-202 or A2 cases.

CIRCLE NO. 344

Strain relief installs without tools



Weckesser, 4444 W. Irving Park Rd., Chicago, IL 60641. (312) 282-8626.

Nylon Straincheck bushings don't crimp or torture wire or cable and it can be installed without tools. The cable is laid in the bushing section, the bushing and cable inserted into the chassis and the locking member is pushed in over the cable into the open portion of the hole until it locks. The bushings fit type SC-J cable in 18/2, 16/2, 18/3 and 16/3 gauges.

CIRCLE NO. 345

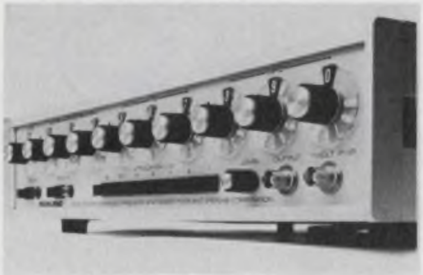
Alarm prevents theft or removal of equipment

Stajer, P.O.Box 1171, Lowell, MA 01853. (617) 458-3871. From $48.

Equipment Guard alarm systems protect all types of electrical equipment against theft or removal by detecting a cut or unplugged line cord. Slave units enable the user to expand the system. The alarm is useful in laboratories to ensure that important experiments are not interrupted by the unauthorized removal of test equipment.

CIRCLE NO. 346

Frequency synthesizer resolves 0.001-Hz

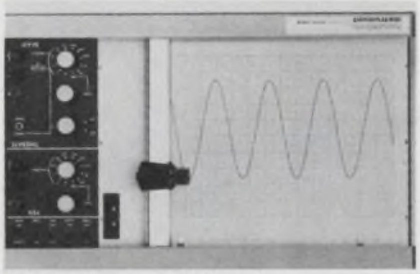


Rockland Systems, 230 W. Nyack Rd., West Nyack, NY 10994. David Kohn (914) 623-6666. $3440; 4 to 6 wks.

The Model 5100-13 frequency synthesizer has a frequency range from dc to 3 MHz with 0.001-Hz resolution across the entire range. The instrument provides absolute phase continuity in switching, fast switching (1.5-μs max programming delay), short-term stability of $\pm 1 \times 10^{-6}/°C$ and spectral purity of −70 dB spurious, −55 dB harmonic.

CIRCLE NO. 347

XY recorders use capacitance feedback



Houston Instrument, 1 Houston Square, Austin, TX 78753. Jim Bell (512) 837-2820. $895 to $1275.

The Type 100 Omnigraphic XY recorders use capacitance feedback transducers rather than slidewires or potentiometers in the servo positioners. Specifications include an accuracy of ±0.2%, linearity of ±0.1%, slew speed of 20 in./s, common-mode noise rejection of 140 dB, critical damping and sensitivity of 1 mV/in. The general-purpose versions include a switch for change from English to metric scaling, 11-position attenuators for the X and Y inputs and a zero check.

CIRCLE NO. 348

Multimeters feature LCD readouts

Non Linear Systems, P.O. Box N, Del Mar, CA 92014. (714) 755-1134. $99.50/$125.

Two digital multimeters, LM-300 (3-digits) and LM-350 (3½-digits) provide LCD numeric readouts for best viewing in bright sunlight. The meters measure ac and dc voltage, resistance, and ac and dc current. Options include a leather carrying case, a tilt stand case, a panel-mount flange, a 45-kV probe, an rms probe, rechargeable batteries and charger unit.

CIRCLE NO. 349

Bodine's PM drive family grows-

New 32D permanent magnet Control Motors and 32D-5F right angle gearmotors, perfectly matched with Bodine speed/torque controls. Continuous duty ratings of 1/12, 1/10 and 1/8 Hp at 2500 Rpm. See your Bodine Distributor or write for Cat. CDC-PM.

New 32-frame PM motors and gearmotors!

BODINE ELECTRIC COMPANY

ADE (After Delivery Economies) make Bodine a better fhp buy

Bodine Electric Company, 2500 W. Bradley Place, Chicago, IL 60618.

CIRCLE NUMBER 54

You've been looking for a more reliable solid-state relay.

Just look at this one.

A unique combination of dv/dt snubber, fusible-link protection in the trigger circuit, plus an overdesigned triac—all combine to protect against catastrophic system failure should the triac fail to turn on.

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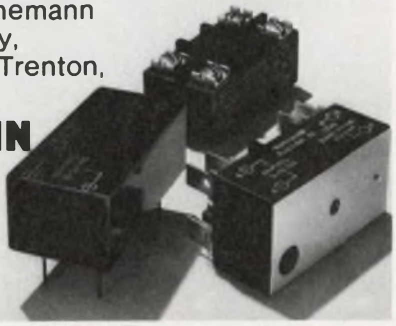
Call (609-882-4800) or write for further information. Heinemann Electric Company, Brunswick Pike, Trenton, NJ 08602.



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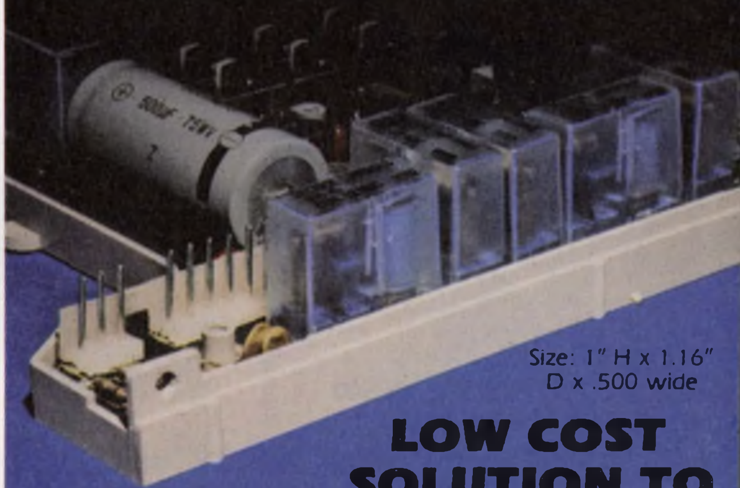
CIRCLE NUMBER 55

CIRCLE NUMBER 56 ▶

DELTROL'S HIGH CURRENT PRINTED CIRCUIT RELAYS



Size: 1" H x 1.16" D x .500 wide

LOW COST SOLUTION TO CONTROL SWITCHING PROBLEMS

Specification Data

Series Model AMP Rating	Contact Configuration	Coil Voltage DC	OHMS Resistance	Pull-In Voltage-DC (Max.)
404 (2 AMP) 405 (6 AMP)	SPDT SPST-NC SPST-NO	3 4.5 6 12 24 48	16 32 75 280 1100 3500	2.2 3.1 5 9.6 22.1 35.4
406 (2 AMP) 407 (6 AMP)	DPDT DPST-NC DPST-NO	3 4.5 6 12 24 48	11 25 45 170 740 2800	2.2 3.1 5 9.6 22.1 35.4

WT: 1/2 oz. — Op. Time: 10 Milliseconds — Release Time: 8 Milliseconds. Recognized Under the Components Program of Underwriter's Laboratories, Inc. File No. E37006.

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SEMI+™ gives you the best of both subtractive and additive.

You know, and we know, that additive and subtractive processes each have their strengths and their weaknesses. So Advanced Circuitry went back to the beginning. We took the best of both subtractive and additive circuit board processing. By integrating these two technologies, we came up with the **SEMI+** Process for plated-thru-hole boards.

It's a first in the printed circuit industry. You see, **SEMI+** combines the efficiencies and eliminates the typical problems found in the other two processes. As a partially *additive* process, **SEMI+** offers a high-yield product for the total range of circuit densities. As a partially *subtractive* process, it permits these circuits to be electroplated rather than chemically deposited as with additive. Use of ductile copper in this plating process yields the greatest single advantage of **SEMI+** when compared with fully additive processing — plated-thru-holes which are free of cracks following thermal cycling.

	SEMI+	Additive	Subtractive
Thermal shock failures	No	Yes	No
Undercut	No	No	Yes
Sliver free	Yes	Yes	No
Superior peel strength	Yes	No	No
Superior line definition	Yes	Yes	No
Many overplate combinations	Yes	No	Yes
Thick copper deposits economically feasible	Yes	No	Yes

The chart above outlines some of the other advantages of Advanced Circuitry's **SEMI+** Process. No undercut. No slivers and shorting. Superior peel strength. Superior line definition. Many overplate combinations. Thick, economical copper deposition.

All these features are possible due to selective electroplating without the degradation of conventional etching. This sounds simple enough, but you can be sure it has taken extensive development, prototyping, and design of separate facilities to bring **SEMI+** to its current level of performance. **SEMI+** has been tested at a major independent testing laboratory and meets or exceeds all requirements for MIL-P-55110. Just ask and we'll send you a copy of the report.

To explore the design possibilities and the cost efficiencies of **SEMI+** in your own operation, call us. Our sales engineers are prepared to answer your questions and study your requirements. With a quote in your hand, you can best consider the total benefits provided by Advanced Circuitry's **SEMI+** Process.

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CIRCLE NUMBER 57

Dumb terminal is CRT/printer combo

Lear Siegler/EID, 714 N. Brookhurst St., Anaheim, CA 92803. John Pagliaro (800) 854-3805. $3890.

The Dumb Connection peripheral package (ADM-3A video terminal, the Model 210 ballistic printer and interconnecting cable) gives the user the flexibility of both a video terminal and a 180-char/s receive-only serial printer. The ADM-3A has 59 data entry keys, a 24-line, 12-in. screen and 1920 char. Switches offer a choice of eleven baud rates (975 to 19,200 baud) and an RS-232 or 20-mA current-loop interface. The Model 210 prints bidirectionally at rates of 75 lines/min for 132 characters or 120 lines/min for 80-char lines.

CIRCLE NO. 356

Data modems operate at 2400 bits/s

Racal-Milgo, 8600 N.W. 41 St., Miami, FL 33166. R. Nathanson (305) 592-8600. $1092 to $1275; 2 wks.

The 24-LSI Mark II modem operates at 2400 bits/s and provides pushbutton test features. Included are internal error test, receive test, and analog and digital loopback tests. Nine LEDs provide continuous indication of key EIA interface signals and modem status. The modems are compatible with ICC 2200/24 and 24-LSI modems, and Western Electric 201B and 201C data sets. The modems allow full-duplex operation over four-wire point-to-point and multipoint dedicated lines, and direct operation over two-wire dial-up lines.

CIRCLE NO. 357

Paper-tape reader/punch is whisper-quiet

Data Specialties, 3455 Commercial, Northbrook, IL 60062. (312) 564-1800. $2335; 6 wks.

The SRP-3075 whisper-quiet paper-tape reader/punch with parallel or serial interface punches at speeds up to 75 char/s, and reads up to 300 char/s. The unit punches Mylar, Mylar laminates, oiled, unoiled, rolled and folded tapes without readjustment or modification.

CIRCLE NO. 358

Data terminal uses gas-discharge display

Computerwise, 4006 E. 137 Terrace, Grandview, MO 64030. (816) 765-3330. $995; stock.

The Transactor III data terminal includes a single-line 32-char gas-discharge display and a 53-key TTY-style keyboard. The terminal connects to any computer with an RS-232 or 20-mA current-loop interface or to a communications line through a modem. Switches select the operating mode, including 110 to 9600 baud speeds, full or half duplex, even/odd/no parity, and the station address. The standard unit supports ASCII-coded data. EBCDIC is available as an option.

CIRCLE NO. 359

Video display divides into separate areas

Human Designed Systems, 3700 Market St., Philadelphia, PA 19104. (215) 382-5000. $1260 (50 qty).

The Concept 100 CRT terminal handles several different functions simultaneously by allowing the user to divide the display memory into any number of separate rectangular "windows," which can be treated as separate displays. The terminal handles forms control, text editing, line-drawing graphics, multiple pages of display memory and multiple character sets. Up to 19 user-programmable function keys are provided.

CIRCLE NO. 360

Video terminal displays 1920 char/page

Datamedia, 7300 N. Crescent Blvd., Pennsauken, NJ 08110. Bob Sullivan (609) 665-2382. $1520 (100 qty).

The Elite 3025A is a buffered TTY-compatible CRT terminal with a single-page video memory that displays 1920 alphanumeric characters in a 24-line, 80-char format. Operating modes include local edit, batch, batch modified and transparent. The terminal is asynchronous and compatible with 103 and 202-type modems. Fifteen baud rates, up to 9600, are keyboard selectable.

CIRCLE NO. 361

Small plasma display mounts on desk

Pichler Associates, 410 Great Rd., Littleton, MA 01460. Pete Martin (617) 486-8948. $1450; stock to 12 wks.

The DPA64 alphanumeric plasma display is a small desk-mountable, PROM-operated unit that is easy to read in high ambient light over a 120° viewing angle. Plug-compatible with most minicomputers and modems through a 20-mA current-loop or RS232C interface, the UL-listed unit handles up to 9600 baud. A self-refreshing RAM buffers up to 128 char. Changing the PROM produces code and character-font changes. The unit displays up to four 16-char lines of 0.3-in. high 5 × 7 dot matrix characters. The DPA64 measures 6.5 × 7.5 × 8.5 in.

CIRCLE NO. 362

Rack-mounting supplies adjust over wide range

Acopian, Easton, PA 18042. Tom Skopal (215) 258-5441. $300 to $370; 1 wk.

Rack-mounting power supplies provide output-voltage ranges between 0 to 6 and 0 to 50 V dc and output current to 16 A. The output voltage and current limit-point adjusts continuously from zero to maximum ratings, either by means of the built-in controls or with external programming resistances. Options include metering, overvoltage protection and 210 to 250-V-ac input. Line and load regulations are ±0.005% or 2 mV and ripple is 0.25 mV rms. Height of the units are 3.5 and 5.25-in.

CIRCLE NO. 363

UL-recognized switchers have one to seven outputs

LH Research, 1821 Langley Ave., Irvine, CA 92714. Wally Nusslock (714) 546-5279. $0.65/W.

Eight single and multiple-output switching-power-supply models in the MM Series are recognized under UL 478. The number of outputs produced by various units ranges from one through seven. Total power for all outputs is either 375 or 750-W, depending on the model.

CIRCLE NO. 364

Switcher models get UL recognition

ACDC Electronics, 401 Jones Rd., Oceanside, CA 92054. (714) 757-1880. $620 to $720; stock.

The JF Series of fan-cooled switching-regulated power supplies boast UL component recognition under standard 478 for electronic data-processing equipment. The switchers generate almost 2 W per in^3. Three versions are available: JF120 (5 V, 120 A); JF150 (5 V, 150 A); JF102 (either 5.2 V, 16 to 80 A or 2.2 V, 0 to 50 A). Regulation of all models is 0.1% ±5 mV for either a no-load to full-load change or for a ±10% input-voltage change. Ripple is 10-mV rms max or 50-mV pk-pk max. Output voltage returns to within 1% in less than 100 μs following a 50% load step. The package for all three units is 5 × 8 × 10½ in.

CIRCLE NO. 365

New literature

1/20 and 1/10 hp motors

Specifications and schematics on a series of motors and gear motors with input horsepower ranging from 1/50 to 1/10 are shown in a brochure. Molon Motor & Coil, Rolling Meadows, IL

CIRCLE NO. 366

Circuit breakers

Photographs, dimensional drawings, delay curves, specifications of a snap-action magnetic circuit breaker are given in a four-page bulletin. Airpax Electronics, Cambridge, MD

CIRCLE NO. 367

Industrial control μC

The IP300 industrial-control-microcomputer system is described in a brochure. The publication discusses operational advantages, hardware features and system software of the IP300. The pamphlet contains a configuration summary listing standard systems, options, and both digital and analog I/O modules. Digital Equipment Corp., Communication Services, Northboro, MA

CIRCLE NO. 368

Silicon photodetectors

A 24-page electro-optic-components catalog reviews the physical and electrical properties of silicon photodetectors, providing basic information on structure, response, sensitivity limits, temperature effects and equivalent operating circuits. Centronic, Mountainside, NJ

CIRCLE NO. 369

PC board laminates

Copper-clad laminates for printed-circuit boards are described in a fold-out brochure. The illustrated six-page brochure contains a comprehensive, easy-to-read table that lists applications and technical specifications for each of the many laminate grades and compositions available. Westinghouse Electric, Micarta Div., Hampton, SC

CIRCLE NO. 370

Op amps

Data sheets on 18 operational amplifiers and 22 fast analog-function modules plus a microcomputer are included in a 92-page catalog. A selection guide indexes op-amp modules by slewing rate, by gain-bandwidth at ×100, and by settling time to 0.1%. Optical Electronics, Tucson, AZ

CIRCLE NO. 371

Pressure transducers

Two bulletins describe 0 to 5-V-dc isolated-output signal, bonded strain-gauge pressure transducers. Teledyne Taber, North Tonawanda, NY

CIRCLE NO. 372

UL standards

"Catalog of Standards for Safety" is an easy and quick reference guide to UL's 396 published standards. Underwriters Laboratories, Northbrook, IL

CIRCLE NO. 373

Magnetics

The use of custom magnetics in modern circuits and application information on wideband, rectifier, and pulse transformers and inductors are discussed in a 14-page booklet. Polyphase Instrument, Bridgeport, PA

CIRCLE NO. 374

GP and power relays

Specifications, characteristics, wiring diagrams and dimensional drawings for more than 1200 stock and special relays are included, as well as socket information, in a 56-page catalog. A relay selection chart guides the user to the proper relay class which fits his particular requirements. Magnecraft, Chicago, IL

CIRCLE NO. 375

Signal processors

A brochure describing the new SPS-61 and SPS-81 programmable digital signal processors features a unique set of comparisons that clearly explain the difference between array processing and real-time signal processing. Signal Processing Systems, Waltham MA

CIRCLE NO. 376

Semiconductors

"Integrated Circuits Reference Book 1978," Vol. 1: Analog Circuits ($29.50) and Vol. 2: Digital Circuits ($29.50) lists details of all ICs, with a PRO ELECTRON type number, which are available on the market. It is an up-to-date reference source of ICs made in Western Europe. "Semiconductor Reference Book 1978" ($35.00) is a revised and updated Fifth Edition listing the technical characteristics of every semiconductor device made in Western Europe with a PRO ELECTRON type number, which is on the market. Both books include an explanation of the PRO ELECTRON code, a list of the symbols used and a glossary in English, French and German. Scholium International, Flushing, NY

CIRCLE NO. 377

Rf coaxial connectors

A 36-page catalog features the SMA series of rf coaxial connectors. ITT Cannon Electric, Santa Ana, CA

CIRCLE NO. 378

Digital cassette recorders

Descriptions, specifications and application information on low-power recorders for data logging, data loggers with crystal-controlled clocks, universal readers, incremental and continuous read/write cassette systems, OEM incremental transports and ANSI-compatible high-speed continuous recorders are covered in 16 illustrated pages. Block diagrams, outline drawings and timing sequences are also included. Memodyne, Newton Upper Falls, MA

CIRCLE NO. 379

Connectors

Cinch Nu-Lok environment-resistant coaxial cable connectors that meet MIL-C-25516 are fully described in a 16-page catalog. TRW Cinch Connectors, Elk Grove Village, IL

CIRCLE NO. 380

Bulletin board

Raytheon Data Systems Co. has doubled the main memory of its **PTS-100 programmable terminal systems** and increased the number of operator stations those systems can support.

CIRCLE NO. 381

Longer shelf life, high reliability, and no degradation in power output over operating life are among the advantages of a new hard seal construction technique now being offered on **Hughes Aircraft Co.'s line of helium-neon lasers.**

CIRCLE NO. 382

Intel's Microcomputer Components Div.'s 6-MHz 8748 single-chip microcomputer, which was priced at $275 in single-unit quantity and $150 in 100-unit quantity, is now priced at $75 and $48, respectively.

CIRCLE NO. 383

Blank cards for programming Hewlett-Packard's HP-67 and 97 calculators are now available at a reduced price—$195 (1000 qty).

CIRCLE NO. 384

Data General has added comprehensive **data communications capabilities to its microNOVA family,** giving users the ability to implement asynchronous and synchronous protocols and run Data General's RJE80 (IBM 2780/3780) and IBM HASP II emulation packages on a microcomputer system.

CIRCLE NO. 385

Elco's Series 6307, 6064, 6007 and 6308 **card-edge connectors** are now U.L. approved.

CIRCLE NO. 386

Opcoa's OP 004 series stud-mount GaP LED panel lamps come with 6-in. insulated leads and provide a variety of indicator functions in equipment requiring LEDs with long lead lengths. The typical luminous intensity at a forward current of 15 mA is 2 mcd with viewing angles of 60° and 120°. These units come in red, green, and yellow.

CIRCLE NO. 387

Application notes

Power supplies

Power-supply decoupling, preloading and input-transient-suppression methods are treated tutorially in the latest issue of *WATTS UP.* The 12-page journal includes descriptions of significant new ac/dc and dc/dc power supplies, plus recent technical literature. Semiconductor Circuits, Haverhill, MA

CIRCLE NO. 388

Capacitance-type switching

A capacitance-switching technique that employs standard microcircuits is described in a 16-page designer's guide. Included are curves and nomographs. American Microsystems, Santa Clara, CA

CIRCLE NO. 389

Spectrum analyzers

The advantages and potential that can be obtained by interfacing a spectrum analyzer to the computational power and analysis of a computer are discussed in a four-page application note. Marconi Instruments, Northvale, NJ

CIRCLE NO. 390

Soldering problems

"Common Production Soldering Problems: Causes and Cures" details the problems encountered in hand, dip or wave soldering. For each problem a complete visual description is provided for quick identification. Multicore Solders, Westbury, NY

CIRCLE NO. 391

V/f and f/v converters

Twenty-five applications on both v/f and f/v converters are given in an application note. Teledyne Semiconductor, Mountain View, CA

CIRCLE NO. 392

Microcircuit packaging

An "Encyclopedia of Hybrid Microcircuit Packaging," a 74-page booklet, contains nearly 300 subjects, from "A.I.D." to "zymurgy," and 170 illustrations. Qualified persons in the hybrid-microcircuit industry may obtain complimentary copies of the encyclopedia. Isotronics, New Bedford, MA

CIRCLE NO. 393

X-Y recorder

The most important features required in a full-capability X-Y recorder are described in a 4-page data sheet. Using the Model 7015B X-Y recorder as an example, the brochure discusses the importance of the internal time base, matched input filters, remote pen lift, TTL-level remote control, autogrip chart hold and paper-alignment guides as well as construction features and product support. Hewlett-Packard, Palo Alto, CA

CIRCLE NO. 394

quick ads

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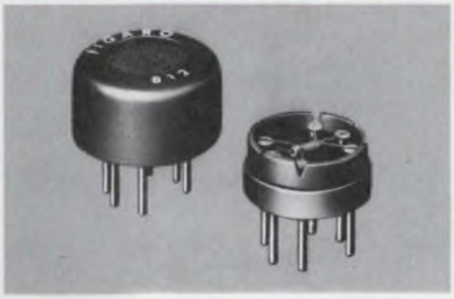
MINIATURE CERAMIC TRIMMER CAPACITORS 9371 series of ceramic trimmer capacitors are compact, economical and rugged. They are 50% smaller than other trimmers of this type yet provide high capacitance values. Available in 4 capacitance ranges, 1.5 to 4, 3.0 to 10, 3.5 to 18 and 5.0 to 25 pf with Q's > 300 at 10 MHz. They have an overall diameter of .225" with .215" above board height. JOHANSON MANUFACTURING CORPORATION, Rockaway Valley Road, Boonton, N.J. 07005 201-334-2676

TRIMMER CAPACITORS **181**



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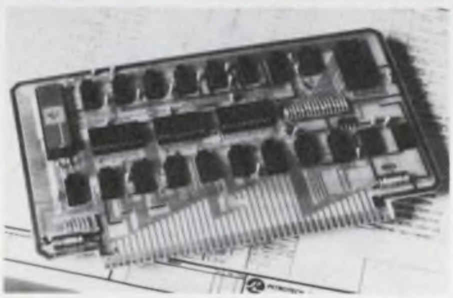
YOU'LL GET IT THE DAY BEFORE YOU ORDER IT as soon as we perfect a time-travel machine. Meanwhile 3 working days is typical turn-around for rack-mounting chassis units, card cages, desk-top & floor-standing cabinets, mini-consoles, subassembly housings. Circle our number or phone Techmar, 213-478-0046, and stand away from the door!

ENCLOSURES **182**



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Synchro to Linear DC Converter: Infinite Resolution. Full (±180°) or Limited Angle DC Output (±90°), ±6 or ±15 minute accuracy at input rates up to 1440°/sec., 60 or 400 Hz input. Custom Output scaling available. Module 2.6" x 3.1" x .82" H. Price from $350 in quantity. Other CCC Products are Synchro to Digital, Digital or DC to Synchro, Solid State C.T.'s or CDX's, and Absolute Encoders. Send for Free Catalog & Application Notes. Computer Conversions Corp., East Northport, N.Y. 11731—(516-261-3300).

SYNCHRO TO LINEAR DC **183**

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ULTRASONIC PULSE MODULES **186**

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quick ads

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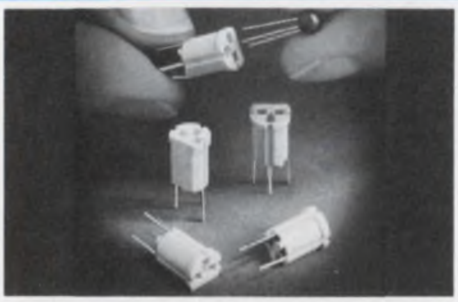
POWER SUPPLIES 187

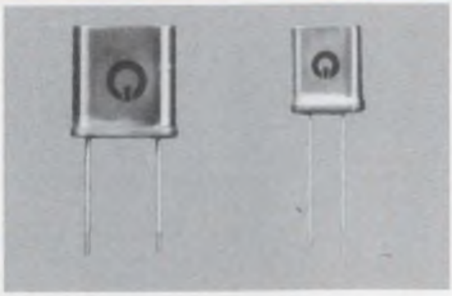
Paladin Corporation introduces the first truly easy-to-use, efficient, coaxial wire stripper. The Paladin Coaxial Stripper will strip every coax wire with an O.D. between .14 & .30 inches. Its compact body (3.5 in.) and light weight (1 Oz.) allow for use in areas which previously prevented post-stripping coax wires. The tool has removable cassette blades which are rated for up to 10,000 strips. PALADIN CORP., 2680 Valencia Circle, Thousand Oaks, CA 91360, (805) 492-2853

COAXIAL WIRE STRIPPER 188



NEW 3-LEAD TRANSISTOR SOCKETS from Methode have an extended funnel-shaped lead-in which eliminates the need for transistor lead preforming or trimming. Also, ideally suited for automatic insertion of transistors into the socket. Contacts are reliable dual leaf cantilever type of phosphor bronze with tin plating. Insulation is flame retardant polyester rated 94VO. Methode Electronics, Inc., 1700 Hicks Rd., Rolling Meadows, IL 60008. (312) 392-3500.

3-LEAD TRANSISTOR SOCKETS 189



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CRYSTAL 190

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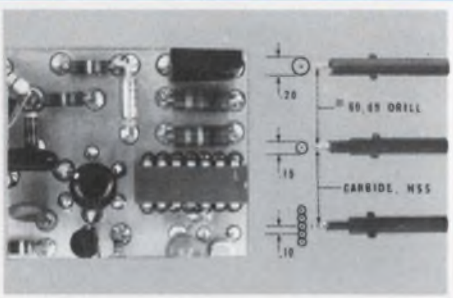
MAGNETIC SHIELDING 191



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NO ETCH BREADBOARDS 192

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BUS BARS 193

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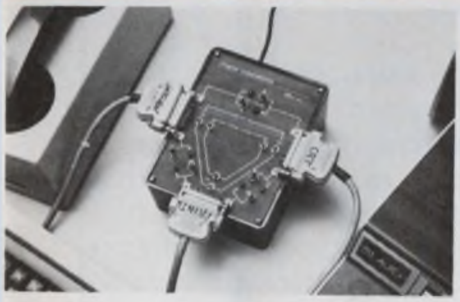

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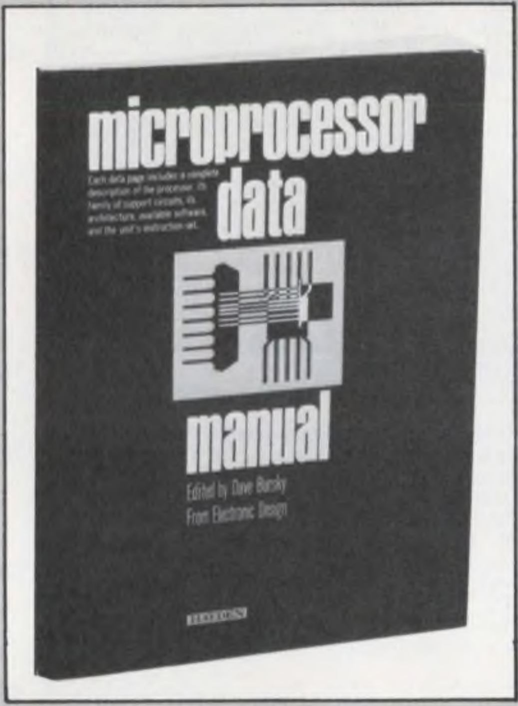

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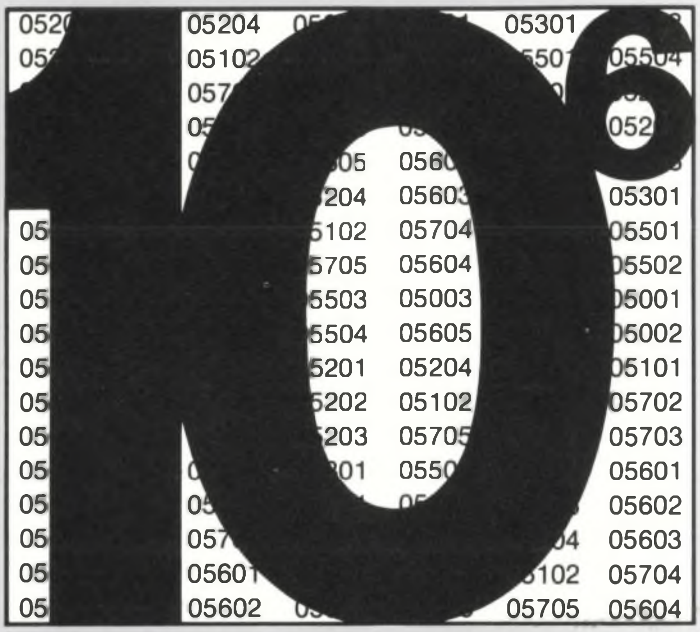

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