JUNE 23, 1977

ONE-CHIP CPU MAKES QUICK WORK OF MINICOMPUTER DESIGN/113

16-bit microcomputer bites off big chunk of controller jobs/118

How you cut software costs with analog I/O chips/130

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Electronics

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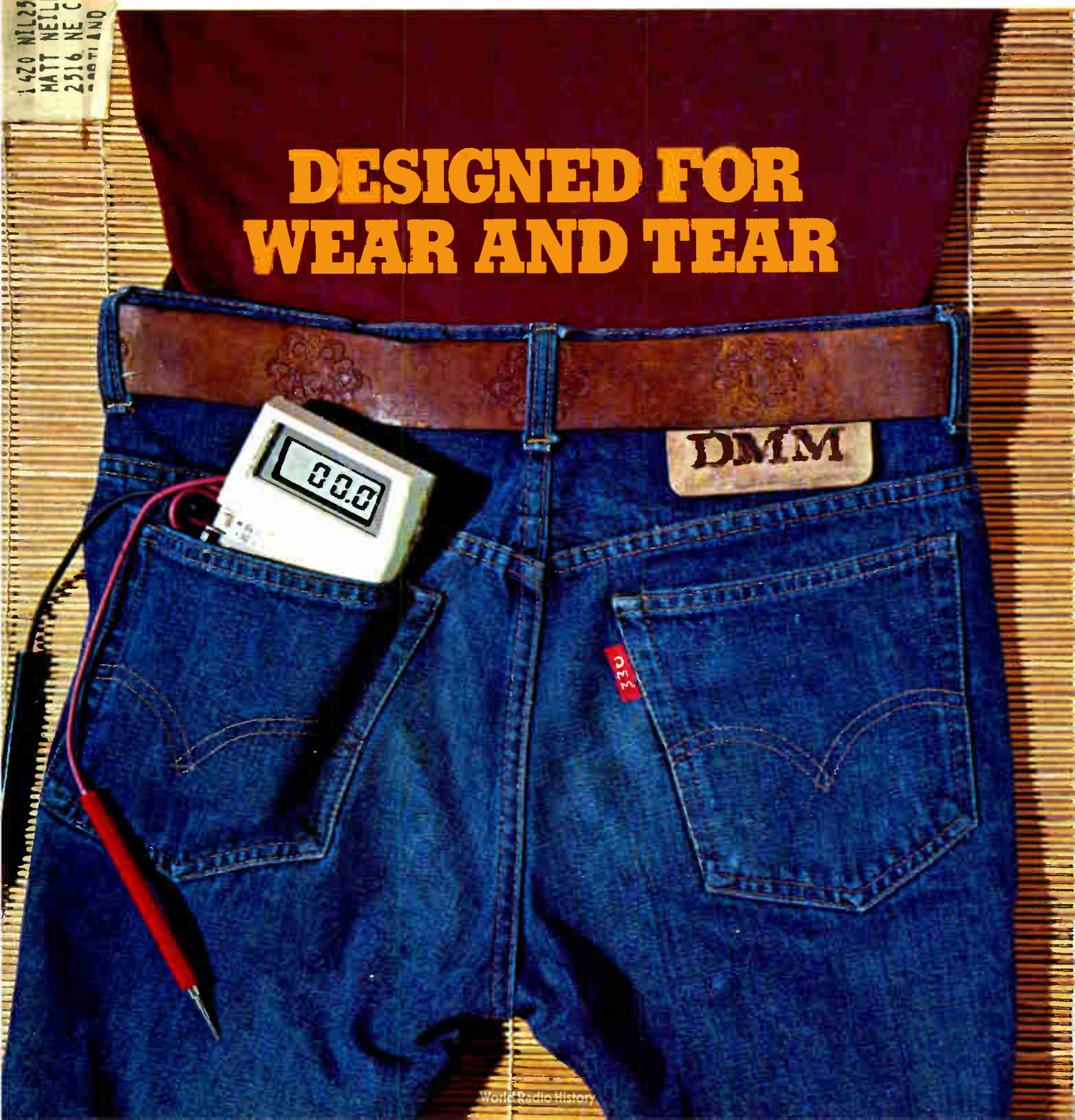

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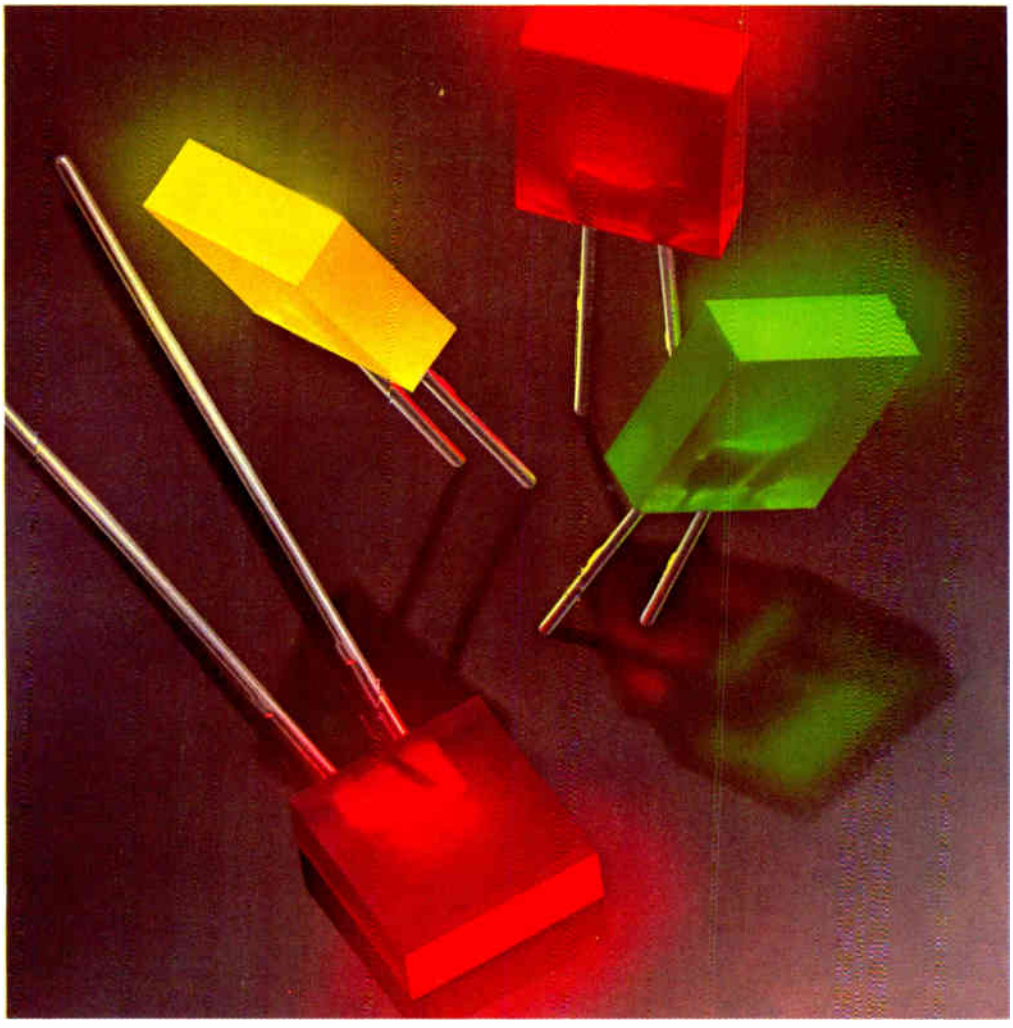

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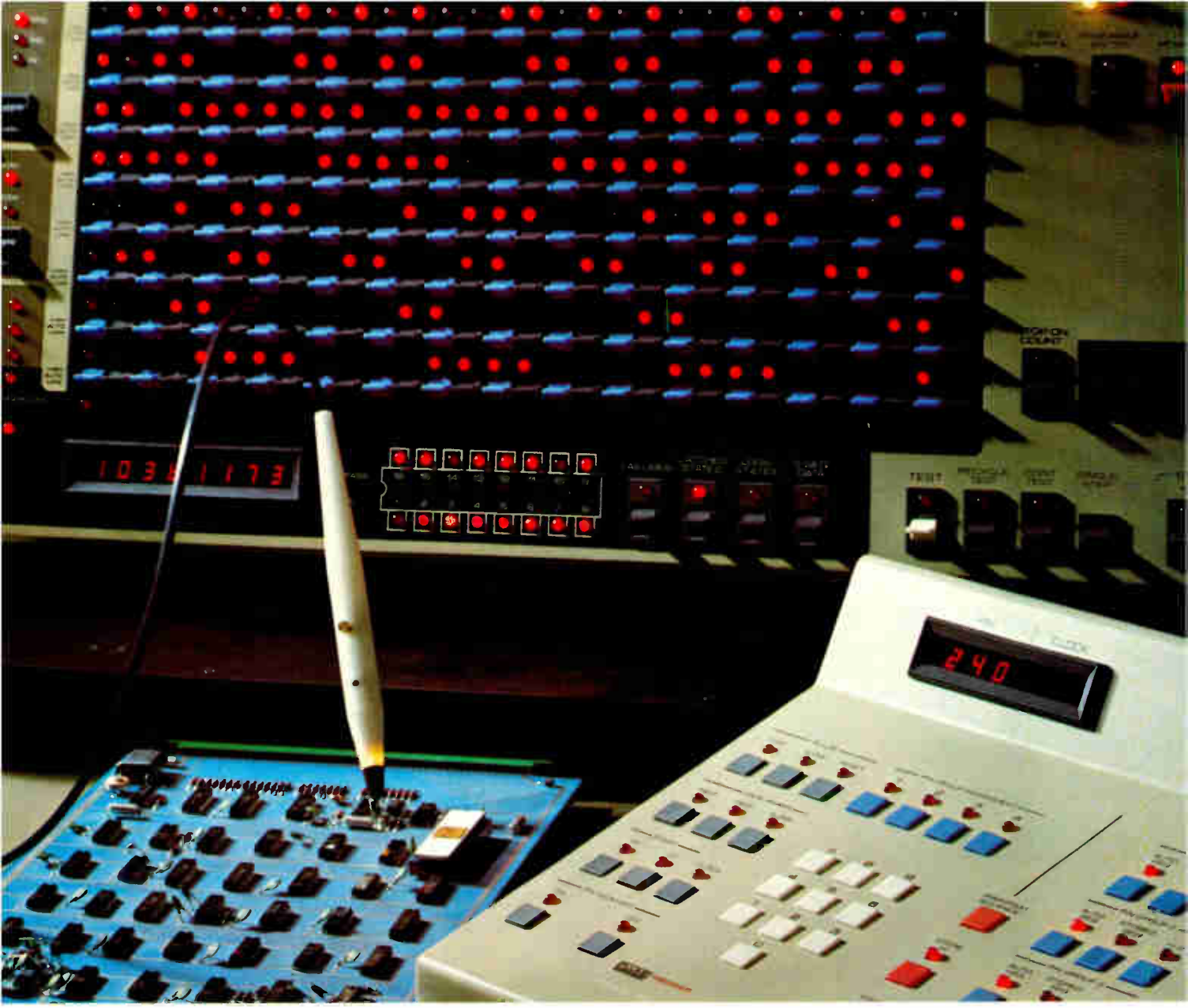

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Electronics
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Highlights

Cover: A tough DMM for tough demands, 107
A liquid-crystal display driven by a custom analog-to-digital converter chip keeps power demand low in a new portable digital multimeter. The complementary-metal-oxide-semiconductor chip simplifies external circuitry and incorporates additional features that make the meter more useful. This article is the latest in the continuing series of product development profiles.

Cover photographed by John Ashworth.

Digital television is on its way, 94
By the mid-1980s, digital video processing will be found in many broadcast studios, although the switchover to analog home receivers will certainly take decades. The technology is already here, and various companies are producing different pieces of the necessary equipment.

Two chips extend range of 16-bit design, 113 & 118
A high-performance minicomputer central processing unit on a chip and an n-channel metal-oxide-semiconductor single-chip minicomputer break new ground in 16-bit technology. The CPU (p. 113) will complement general-purpose single-board minicomputers. The microcomputer (p. 118) will serve low-cost control applications.

And in the next issue . . .
A special report on displays . . . the first of a three-part examination of electronics engineers, their careers, and their future.

Electronics

Reflecting the international nature of electronics, the careers of two of our authors started on separate continents and finally crossed to a third. Until they joined Fairchild Semiconductor, about all Dan Wilnai and Peter W. J. Verhofstadt, who coauthored the article about Fairchild's 9440 microprocessor that starts on page 113, had in common was the fact that they both earned their engineering degrees in 1963.

Wilnai was born in Tel Aviv, Israel, and received his degree from the Technion-Israel Institute of Technology, while Verhofstadt, who hails from Heyen, the Netherlands, gained his degree from the Technische Hogeschool, Eindhoven. Wilnai served as a technical officer in the Israeli Air Force and then joined Elta Electronics in Ashdod, Israel, as a project leader. In September 1974, he moved to Fairchild Semiconductor, where he is now manager of the processor development group.

Verhofstadt was associated with Siemens AG in Munich, Eurocontrol in Brussels, and Transitron Corp. in Wakefield, Mass., working on the design and development of digital computer systems and digital integrated circuits. He joined Fairchild in 1970 and has been responsible for the development of most of the company's new digital product lines. He is now manager of Advanced Products Operations.

To achieve the rather ambitious goals of the 9440 project, a multidisciplinary task force was created, headed by Verhofstadt. The company's I^3L technology development was handled by the R&D organization under Thomas Longo, James Early, and Madhu Vora. System architecture and logic design were provided by Chuck Erickson and Bob Moeckel under Wilnai. The circuit was designed by Hemraj Hingarh of the I^3L circuit design group headed by Dick Crippen. Support was provided by the software engineering group directed by Ashok Suri.

As it happened, the first assignment in microprocessors for John Bryant, the principal designer of Texas Instruments' 9940 one-chip microcomputer and co-author of the article about it on page 118, was designing TI's version of Intel's 8080 microprocessor. But once TI planners decided that their 9900 16-bit microcomputer family was the way to go, Bryant became a systems engineer responsible for defining peripherals in support of the big 9900 CPU. That role served him well as program manager of one-chip, low-cost 9940 member of the family.

"It wasn't easy to define a one-chip architecture to handle the complex instruction repertory of a powerful general-purpose CPU like the 9900 and still make the chip cost-competitive with lower-performance competition," says Bryant. "It required several logic innovations to do the job," he recalls.

Like most TI-ers, he has been at the company all his professional life. He started at the Houston IC facility in 1972, after getting his EE degree from the University of Arkansas. He also has an MSEE from Texas A&M and is close to an MBA from the University of Houston.

June 23, 1977 Volume 50, Number 13 96,968 copies of this issue printed

Published every other Thursday by McGraw-Hill, Inc. Founder: James H. McGraw 1860-1948. Publication office 1221 Avenue of the Americas, N.Y., N.Y. 10020; second class postage paid at New York, N.Y. and additional mailing offices.

Executive, editorial, circulation and advertising addresses: Electronics, McGraw-Hill Building, 1221 Avenue of the Americas, New York, N.Y. 10020. Telephone (212) 997-1221. Teletype 12-7960 TWX 710-581-4879. Cable address: MCGRAWHILLNEWYORK.

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Readers' comments

Recalculate those figures

To the Editor: In your story about the blockbuster calculators Texas Instruments Inc. just announced [May 26, p. 42], in the text and again over the picture you refer to 240 steps of program memory in Texas Instruments' SR 52. In fact, it has only 224 steps.

In the fourth line from the end, you refer to two levels of subprograms available in Hewlett-Packard Co.'s HP 67 and 97. They both have three levels, not counting the stack. And five lines above there, there is a typographical error: the $750 unit is the HP 97.

John R. McGinley Jr.
Van Cleef, Jordan, and Wood Inc.
New York, N. Y.

Revise that report

To the Editor: Your report [June 9, pp. 36–8] on the recent microelectronics workshop held at John Hopkins University's Applied Physics Laboratory contains two errors. First, I chair the research and development technology committee of the Computer Science Research and Development Council, not the council itself, which is chaired by a senior individual from the Naval Material Command. Second, it was not the council but members of the V/Stol advanced development team that indicated a technical preference for the SPL-1 language.

B.A. Zempolich
Assistant Technology
Administrator, Air 360B
Naval Air Systems Command

Correction

Those readers who have been experiencing difficulty in getting their trapezoidal-waveform generators for an electronic music synthesizer to work [March 17, p. 97]: take heart. A 10-microfarad input capacitor was inadvertently omitted from the input lead to Q_1. This device is part of the RC network that differentiates the input signal.

Also, transistors Q_1, Q_2, and Q_3 may be general-purpose devices. A few readers in Europe have experienced difficulty in acquiring the devices originally specified.

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News update

■ Owning a household pet often winds up costing more than one might first expect. So it is with the personal electronic transactor, or PET, a cassette-programmable personal computer from Commodore Business Machines Inc. of San Francisco.

Really an intelligent, interactive visual-display unit, PET contains an 8-bit microprocessor, 9-inch black-and-white cathode-ray-tube terminal, 73-key keyboard, and 4,096 bits of random-access memory and was to be distributed through retail stores for $495 [*Electronics*, March 31, p. 89, and May 12, p. 36]. However, when Commodore took the wraps off its PET model 2001 at the Consumer Electronics Show in Chicago earlier this month, the personal computer was sporting a $595 price tag, and reports were circulating around McCormick Place, the site of the big show, that it may soon go to $700 or higher.

"The firm price is $595, instead of $495, because we finally have a product," explains Arnold Karush, Commodore's assistant sales manager. The $495 figure, he continues, "was never a price we were selling at but was an estimated price. It wasn't until the CES that the unit was for sale. And," he adds, "we never took an order at $495."

Karush says Commodore officials, after examining the cost of producing PET, decided the firm could not sell the personal computer at $495 and make a decent profit. This may be especially so, since distributors generally receive a heavy discount. But will PET soon be selling for $700 or higher, as reported? "At $595, we're comfortable, at least for the foreseeable future," states Karush.

Although Karush declines to explain why the targeted price of $495 could not be reached, reports are that some of the firms supplying component parts of the system could not meet early cost projections. PET is based on the 8-bit 6502 metal-oxide-semiconductor microprocessor made by MOS Technology of Norristown, Pa., which Commodore acquired last year.

Bruce LeBoss

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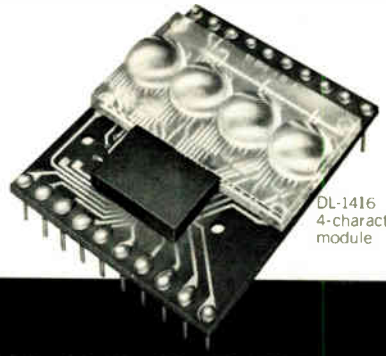

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Engineering jobs and the tax laws

At a time when the U. S. is moving into new world telecommunications markets, particularly in the Middle East, there has been an outflow of American engineers and administrators from the area as a result of new tax rulings. The long-term consequences for American engineering employment—already at a disadvantage compared with other countries—could be extremely serious.

That there is far more to the Middle East market for electronics than military systems is good news. But the fact that much of the new growth is in national telecommunications systems—to be followed later by television and other consumer products that rely on telecommunications—will make it tougher for American companies to compete with their European and Japanese counterparts.

Unlike American leadership in military systems, national telecommunications technology around the world is not far behind that of the U. S. Moreover, foreign exporters have the added advantage of being able to work hand in glove with their own governments to gain entry into new markets—sometimes the aid extends to low-cost government loans to buying nations for the purchase of engineering services and hardware.

It is heartening that the Western Electric Co.—whose parent American Telephone & Telegraph Co. seems to conduct most of its business with the Government these days in court—is undertaking a major move back into the international marketplace. Yet some people, such as Continental Telephone Companies' chairman Charles Wohlstetter, see a distinct handicap to U. S. telecommunications manufacturers who must send engineers abroad if they are to succeed in overseas markets. That handicap is the Tax Reform Act of 1976, which cut the earned-income exclusion for U. S. engineers and other citizens working abroad to $15,000 from the former level of $20,000 or $25,000.

Under the new rules, the cost of moving an engineer and his family abroad, educating his children in private schools, paid vacation time, and other cost-of-living benefits are now all taxable. The result, Wohlstetter charges, is that "an American employee in the Middle East occupying a $25,000 job can actually cost his company up to three times that amount; and because of all this, an American firm can hire approximately two and a half British engineers for the price of one American." Compounding this are the tax law changes that recapture the previously deductible U. S. tax credit for foreign losses and eliminate benefits to U. S. companies operating in developing nations.

Wohlstetter may be right when he calls the "crazy quilt" of complex and conflicting laws and regulations a dangerous threat to promising new employment opportunities. Engineers and other technology-oriented workers tend to give less thought to the peculiarities of tax and trade laws than they do their own developed specialties unless they move into a management role where they are obliged to consider the impact of such peripheral issues on their jobs. Yet these are precisely the issues that determine whether or not they will have a job in the years to come.

While it is true that not all the side effects of new Government regulations can be foreseen, there is no reason to ignore them once they are spotted. The Congress still has tax reform very much on the agenda. During its work on a new tax law, it should take a hard look at whether what seemed to be revenue-draining loop hole may not have been a relatively low-cost incentive to increased international trade and higher technological employment.

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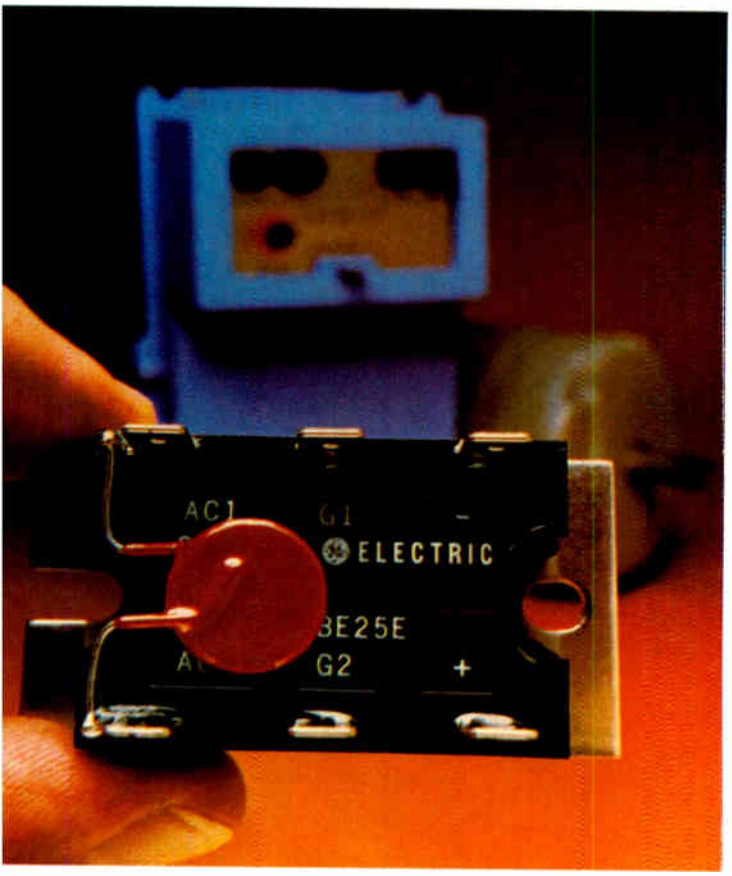

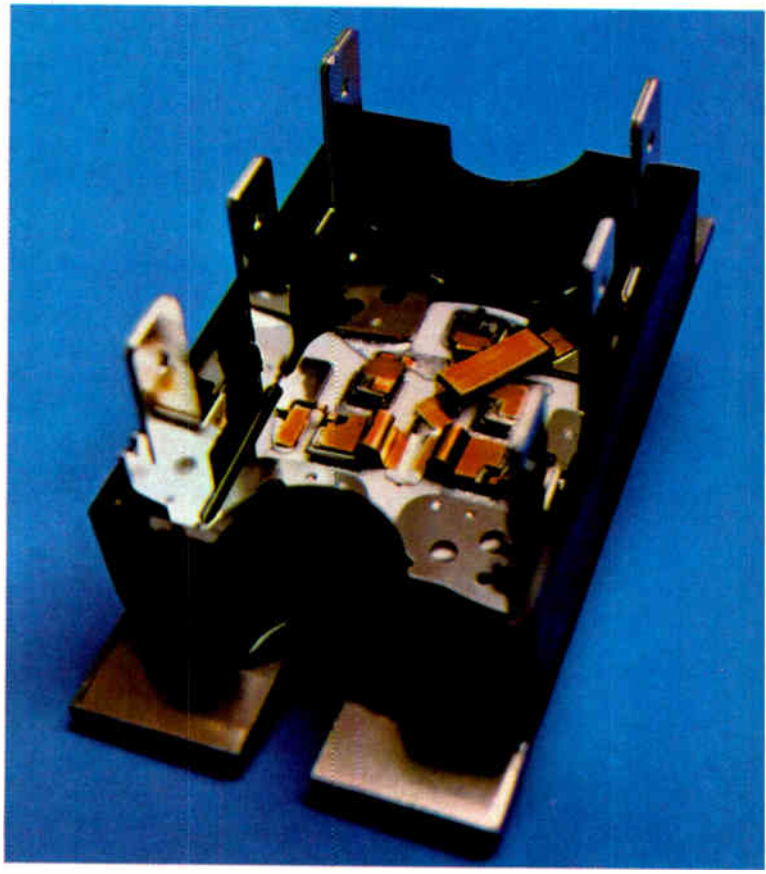

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People

DEC's Brick helps the LSI-11 sail away

Robert Brick is delighted about his part in this year's America's Cup race as the new account manager for the LSI-11 microcomputer at Digital Equipment Corp.'s Components group, Marlboro, Mass. He is acting as project manager for the LSI-11, which is being used by the Independence syndicate in its two sailing vessels competing for the U. S. spot in the prestigious race off Newport, R. I. (see related story, p. 34). Both the *Independence* and the *Courageous* are using the DEC microcomputer to compute such critical racing factors as the boat's position, true wind speed, and wind direction.

"I think I'll be able to look back at this assignment with a lot of satisfaction," observes the 35-year-old Brick, himself an avid sailor and eight-year DEC veteran. "It's something like the guy who builds a color TV set from a kit and then never stops talking about it."

But the modly dressed Brick is quick to point out that he is one member of a DEC team that also includes David Schanin, LSI-11 applications engineer, and programmer Scott Gerren. All three have spent recent weekends—mostly at Marblehead, Mass., where the two boats are in preliminary trials—working with the boats' navigators, Peter Lawson of *Independence* and William Gorch of *Courageous*.

The navigators and the DEC team first met March 5, when Lawson and Gorch spelled out what they wanted from a microcomputer—the first to be used in such a race. It boiled down to faster throughput, greater accuracy, and more memory than was possible with the desk-top scientific calculator the navigators had previously used to derive critical data during a race.

"In just about two months, we had the system up and running," Brick says. Lawson wrote the programs for the calculator, and Gerren worked with him to translate them into the Focal language. Brick, who worked his way up from sales engineer in branch offices to the LSI-11 marketing spot, helped with the cabling layout and also designed the aluminum box that protects the system from saltwater. Schanin has been overall systems integrator.

Sailor's aide. Robert Brick supplies America's Cup yachtsmen with faster answers.

By early June, the program was debugged. DEC is helping fine-tune the system during the trials. Brick hopes the *Independence* or the *Courageous* will be the U. S. cup defender, but no matter how things turn out, he says, "we've all thoroughly enjoyed the whole experience."

TI's Shelly looks to widen digital-watch market

Lubbock, Texas, may not be the time capital of the world yet, but Ronald W. Shelly is doing his best to make it that. The 33-year-old Shelly moved there from Dallas early this month to head up Texas Instruments Inc.'s Time Products division. He was named to the post two months ago, just days after the division slashed its plastic-cased digital watch prices to a minimum of $9.95.

Shelly says his firm will be the first watch company ever to sell through supermarkets. The under-$10 watch family—now limited to models with light-emitting-diode displays—is key to TI's attempts to open the digital-watch market to

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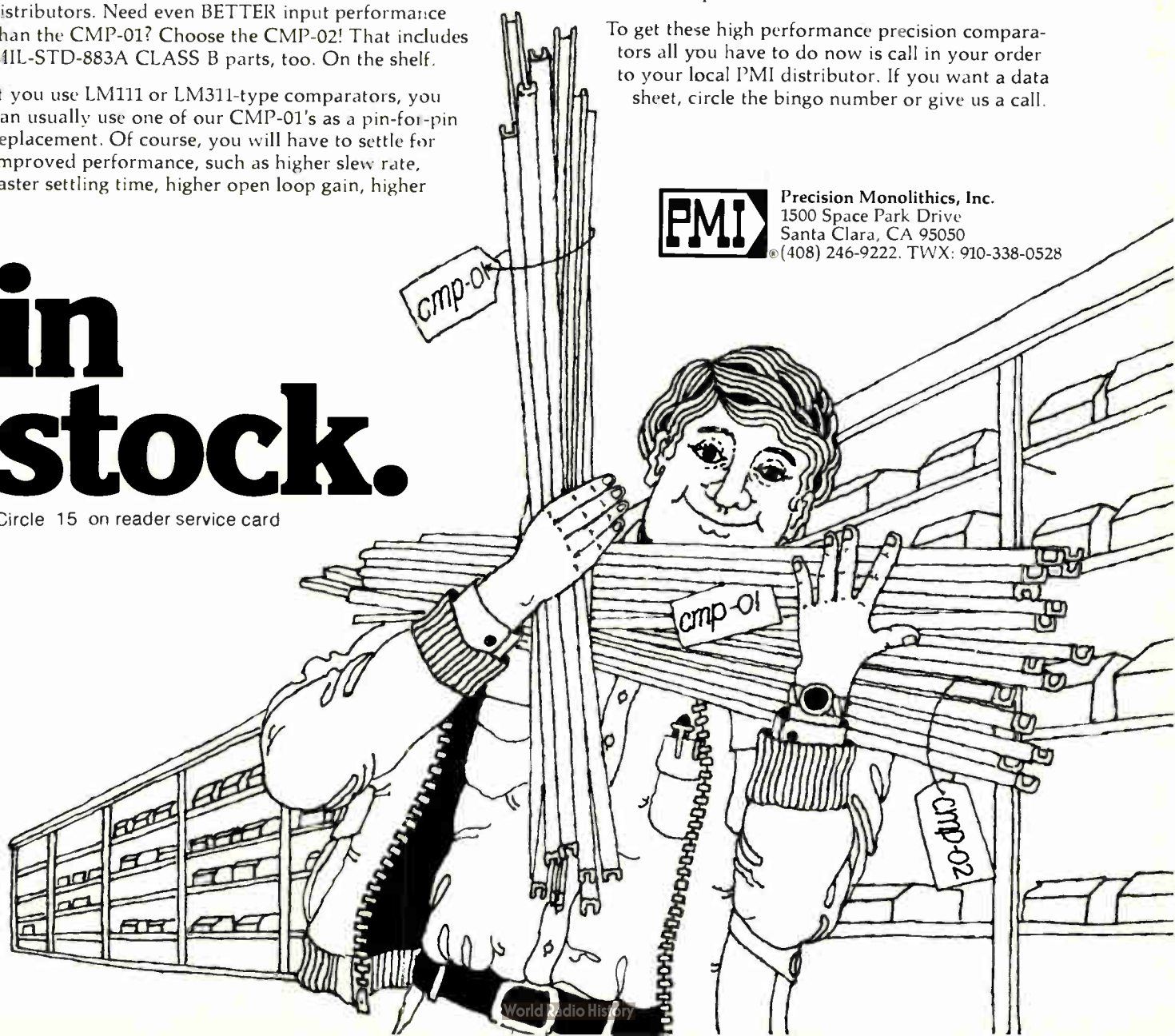

People

First. Robert Shelly expects watches in supermarkets will spur impulse buys.

ever-increasing volumes, particularly through nontraditional distribution channels. "We've test-marketed watches in supermarkets in the Northeast, and now we're setting up an extensive food broker network," he says. The watch will be sold in the common blister pack, but the customer will be able to open it in order to try on the watch and see whether it works.

Market increasing. Shelly, a seven-year TI veteran, expects the watch to sell: "We figure that the $9.95 watch will increase the size of the market by maybe 10% or 15%. At that price, a watch can be considered an impulse buy, and so it can't help but increase the total market."

The firm estimates that 15 million digital watches were sold in the U. S. last year and 18 million worldwide. This year's worldwide total could climb to 25 or 30 million if manufacturers keep up with demand.

Besides shaving prices, watchmakers can help expand the market by adding options and putting "a lot of different functions on a customer's wrist," Shelly says. "Liquid-crystal watches bring us the opportunity to keep coming up with innovations." Unlike LED models, the LCD watches open up multifunction markets with such features as elapsed-time, time-zone, and alarm functions. While Shelly refuses to discuss future watch products, he hints that the firm's LCD line—introduced last month and now limited to classical timekeeping—is the one to watch.

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Meetings

International Conference on Nuclear and Space Radiation Effects, IEEE, College of William and Mary, Williamsburg, Va., July 12 – 15.

IEEE Power Engineering Society Summer Meeting, IEEE, Maria Isabel Sheraton and Camino Real Hotels, Mexico City, Mexico, July 17 – 22.

Summer Computer Simulation Conference, ISA, IEEE, *et al.*, Hyatt Regency O'Hare Hotel, Chicago, July 18 – 20.

1977 International Conference on Crime Countermeasure Science and Engineering, IEEE *et al.*, Oxford University, Oxford, England, July 26 – 29.

ACM-Pacific 77 – Exploring the Small Computer, ACM, LeBaron Hotel, San Jose, Calif., July 28 – 29.

Electromagnetic Compatibility Symposium, IEEE, Olympic Hotel, Seattle, Wash., Aug. 2 – 4.

IFIP Congress 77, International Federation for Information Processing (Toronto, Ont., Canada), Royal York Hotel, Toronto, Aug. 8 – 12.

Medinfo 77 – World Conference on Medical Informatics, International Federation for Information Processing, Harbour Castle Hotel, Toronto, Ont., Aug. 8 – 12.

Conference on Active Microwave Semiconductor Devices and Circuits, Cornell University, Ithaca, N. Y., Aug. 16 – 18.

NBS Seminar on Time and Frequency: Standards, Measurements, and Usage, National Bureau of Standards, Boulder, Colo., Aug. 22 – 26.

Product Liability Prevention Conference, IEEE, New Jersey Institute of Technology, Newark, N. J., Aug. 24 – 26.

Intrasociety Energy Conversion Engineering Conference, IEEE, Sheraton Park Hotel, Washington, D. C., Aug. 28 – Sept. 3.

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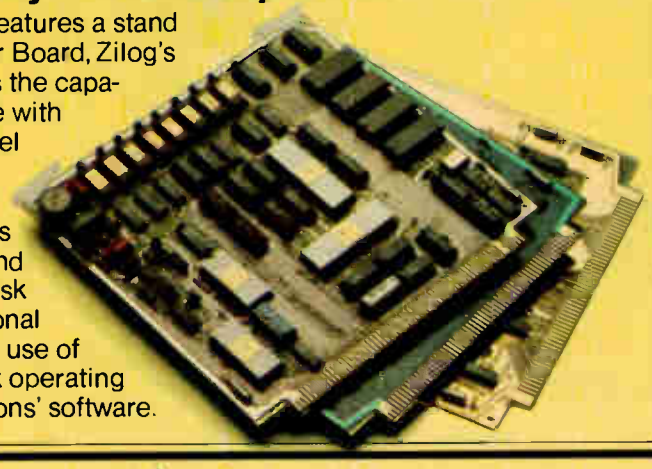

Announcing the Z80-MCB. An assault against big board computers.

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- Z80-CTC for programmable baud rate generation or other user functions such as real time clock.
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- One-half K-byte monitor software has terminal handler, load and punch routines as well as set and display memory commands. A GoTo command begins execution of user programs. The 1K-byte version adds more debug aids such as set and display registers and breakpoints. The 2K and 4K-byte versions include a floppy disk controller and even more debug capability.

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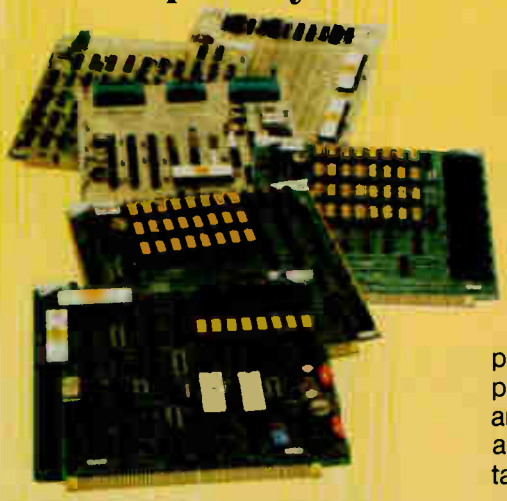
Additional boards give you expansion capability.



- Z80-RMB Memory Board: Contains 16K bytes of dynamic random access memory along with sockets for up to 8K bytes of ROM.
- Z80-IOB Input/Output Board: Allows the MCB to be expanded via the backplane bus to allow additional I/O interface channels. 64 programmable I/O lines per board.
- Z80-PMB PROM Memory Board: Contains sockets for up to 32K bytes of EPROM or PROM and additional programmable I/O channels.

Circle 23 on reader service card

- Z80-PPB PROM Programmer Board: Allows the user to program PROM's or EPROM's electrically.
- Z80-SIB Serial I/O Board: Provides additional four (4) serial duplex channels.
- Z80-VDB Video Display Board: Interfaces the MCB to a standard video monitor. This board contains 256 bytes of memory and also interfaces to a ASCII standard keyboard.

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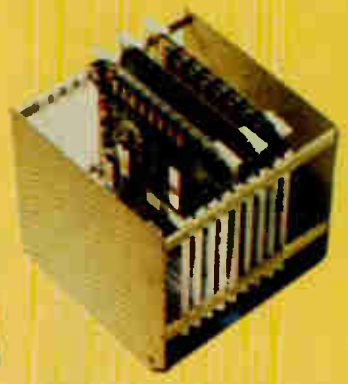

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Electronics newsletter

AMD to make Intel's 8085 micro family

Intel Corp.'s three-chip 8085 microcomputer family—a minimum-parts enhanced-version of the 8080 system—will get a big boost in the general-purpose 8-bit marketplace. The big Santa Clara, Calif., microcomputer manufacturer has lined up its neighbor, Advanced Micro Devices Inc., as a second source for the new MCS-85. AMD, now a principal alternate source for the 8080, will begin offering the 8085 central processing unit this fall and the other parts of the basic set by year's end.

To overcome AMD's initial resistance to spending the funds required to copy the 5-volt MCS-85 family, **Intel agreed to a product-and-technology package:** AMD gets the 85 family mask sets and test tapes in exchange for a commitment to supply Intel with unspecified 8-bit-compatible peripheral-chip designs. (Intel is already well along in designing a wide range of 8-bit peripherals.) Meanwhile, a second-source agreement, including some technology exchanges, has been arranged with Siemens AG for marketing the MCS-85 family. Japan's Nippon Electric Corp. will also be an MCS-85 supplier, but without a technology exchange agreement. First shipments of the CPU are due in 1978.

Circuit from TI could drop price of games to $10

Look for video games to go the route of digital watches and calculators, with low-end retail prices dipping under $10 by Christmas, thanks to a new ball-and-paddle circuit that Texas Instruments Inc. will put into production next month. **At least six games makers plan to use the TI chip in high volume,** including Venture Electronics, Micro Electronic Systems Inc., and Interstate Industries Inc., which showed their versions on the floor of this month's Consumer Electronics Show in Chicago.

Called "Super-Spin" for the wicked arc the ball cuts as its horizontal speed decays, the TI circuit is the first of a family of single-chip parts that next year will include strategy and action games, possibly with on-chip color and digital scoring. The firm is trying to get the total system cost down to $5 by next year.

National chip supplants horizontal, vertical TV controls

National Semiconductor Corp. has come up with a technique that should make both horizontal- and vertical-hold controls, as well as factory presets, obsolete. It is a simple linear integrated-injection-logic countdown chip that for less than $1 delivers a phase-locked horizontal scanning frequency and counts down from it to get an injection-locked vertical output pulse.

The key to the synchronization system **is a new 503-kilohertz ceramic resonator,** made by MuRata Corp. of America, Rockmart, Ga., that gives a more accurate initial frequency reference than the LC and RC voltage-controlled oscillators now used. Also, it does not require shielding from the set's yoke, as LC circuits do, and it exhibits more stability over temperature changes, including warmup, than RC oscillators.

HP prepares to issue products using SOS circuits

Hewlett-Packard Co. will introduce "a series of major products" over the next nine months that will use complementary-MOS circuits built with the silicon-on-sapphire process, says executive vice president John A. Young. HP is already producing SOS read-only memories and substituting them for other ROMs in its 2640, 2644, and 2645 general-purpose display terminals to gain firm field-reliability data on the SOS parts. Thus far, says Young, the devices "are meeting our yield estimates and **exceeding the performance results we anticipated."**

Meanwhile, HP Laboratories in Palo Alto is pursuing bubble memory technology. "The bubble memory will first show up in a terminal product, where small, high-speed memories are required," possibly within the next 12 months, says Young.

TI, National rush to market National's op amp

National Semiconductor's half-dollar LM351 bi-FET op amp [*Electronics*, March 3, p. 26] will have company in the market: Texas Instruments also will have parts next month. The TI version, called the TL076, will be screened from a new TL070 low-noise op amp family. But besides second-sourcing the National device, TI will have a proprietary dual version and two quads, one of which will be pin-for-pin compatible with Raytheon's RC4136, popular in audio systems. Coming in August for its original TL080 series: a low-power unit that pushes power dissipation down to 280 microamperes, a tenth of the figure for earlier parts.

Intech converter balances accuracy, speed, and price

Intech/Function Modules Inc. of Santa Clara, Calif., will soon be offering a 16-bit analog-to-digital converter module with what **promises to be the best compromise among accuracy, speed, and low price** in the business. Designated the A-858-16, the unit typically yields ±½ least significant bit at 16 bits with ±¾ LSB linearity guaranteed and conversion time of 40 microseconds maximum. Priced at $425 per single unit, it will offer a range of sample and hold amplifiers.

National to offer easy-to-use, $1 transducer chips

Continuing to pioneer in monolithic transducers, National Semiconductor Corp. of Santa Clara, Calif., will shortly go into production with a pair of low-cost bipolar chips that maintain a tight linearity over a broad range of temperatures. **They are easier to use and cost less than rival devices.** Programmed by an external resistor, one device, the LM134, develops a current that is directly proportional to temperature. The other device, the LM135, behaves like a zener diode, producing a voltage that varies linearly with temperature. Once calibrated at one temperature, military versions of the sensors hold linearity error to within 1°C over the range of −55°C to +125°C, whereas commercial versions maintain linearity to within 2°C from −25°C to +100°C. The price of the commercial versions will be under $1 apiece for 100 or more.

Addenda

Scientists at Sandia Laboratories report that they have used **electron beams to induce the experimental production of fusion neutrons.** The feat, accomplished for the first time in the U. S., is considered an important preliminary step toward the long-range goal of generating energy by controlled thermonuclear fusion. . . . Ultratech of Santa Clara, Calif., has become **the first mask maker to purchase an electron-beam lithographic system** to make low-defect semiconductor master masks. Previous purchasers have all been semiconductor manufacturers. . . . TRW Inc.'s large-scale-integrated products operation has reduced the power consumption of its 130-nanosecond 8-by-8-bit multiplier to 1.2 watts from 1.8 W.

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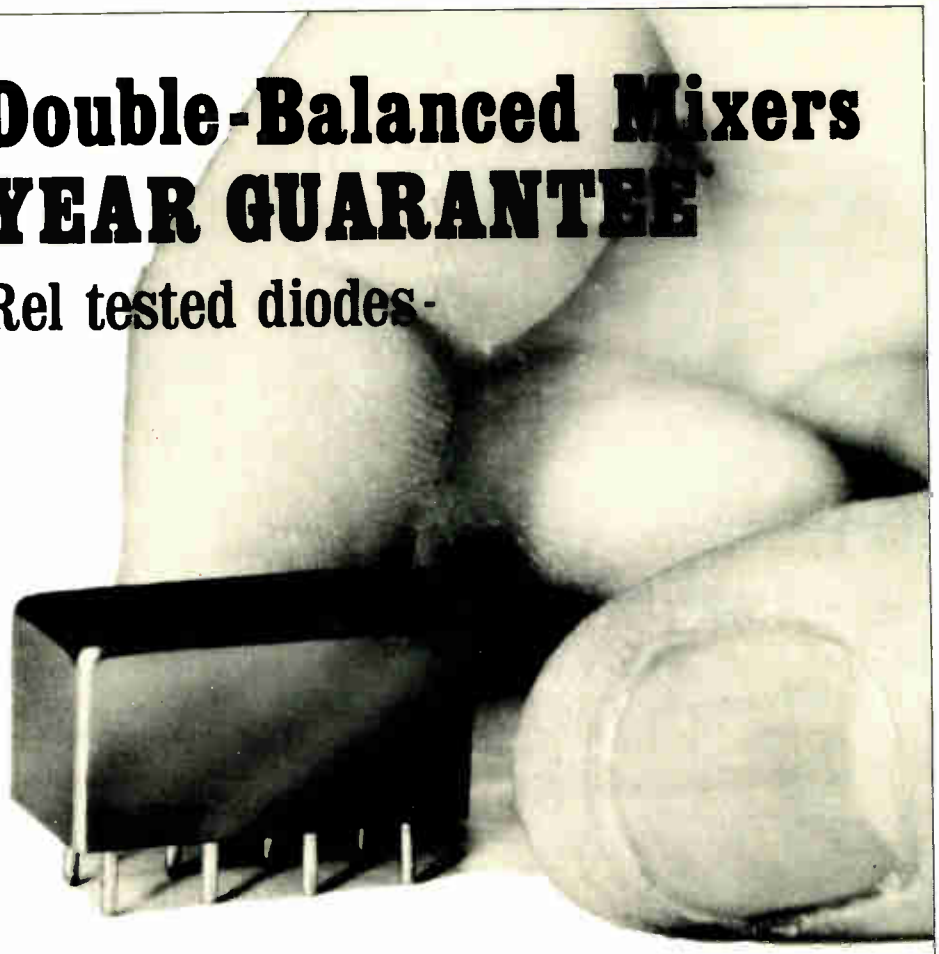

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For other Mini Circuit Lab Products See ADS on pgs.1, 45, 50, 51.

MICROWAVES is published monthly except two issues in June, by Hayden Publishing Co., Inc., 50 Essex Street, Rochelle Park, NJ 07662. Controlled circulation postage paid at Waseca, MN, New York, N.Y. and Hammond, IN, postage pending at Easton, PA.

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V-MOS process gets first test in new memories

Coming in July is 45-ns 1-k static RAM, to be followed soon by 4-k part with access time of under 100 ns

American Microsystems Inc.'s $10 million investment in V-MOS is about to be tested with a wide range of memory products. With its V-groove metal-oxide-semiconductor process, AMI hopes to be at the cutting edge of semiconductor product design and alter its somewhat disappointing performance in standard digital products over the last two years.

The timetable for the new devices has them coming hot and heavy. Next month, the Santa Clara, Calif., manufacturer will sample a $6.20 (in quantities of 100 and up) 45-nanosecond, 1,024-bit static random-access memory. This will soon be followed by an under-100-ns, 4,096-bit static RAM. Application for these high-speed statics will be in the big mainframe buffer and cache memory designs now served by bipolars.

In read-only memories, a 16,384-bit ROM is now being sampled, with higher-density 32,768- and 65,536-bit versions in development. Coming also is an 8,192-bit static RAM; a 16-k electronically programmable ROM using a proprietary V-MOS–related, floating-gate design; and a series of very-high-speed, high-density, and low-power dynamic RAMs.

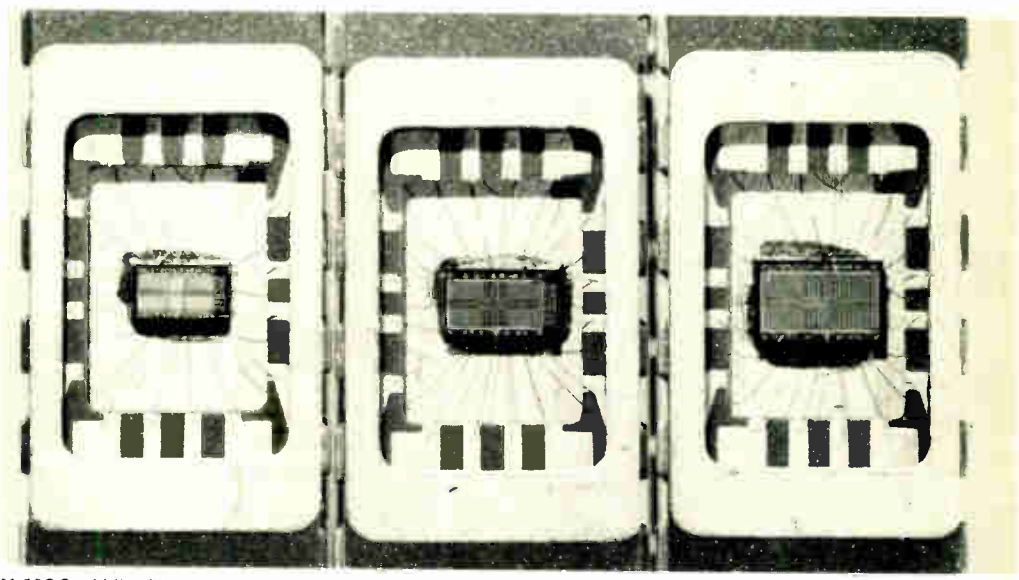
Impressive. What is particularly impressive about the V-MOS parts is that even AMI's first-generation devices, built with relaxed 5- and 10-micrometer photolithographic techniques, offer significantly higher performance than production second- and third-generation designs done in more conventional n-channel MOS. For example, the fastest 1-k and 4-k n-MOS statics typically operate with an access time of about 150 ns.

But perhaps even more important, AMI's V-MOS process will quickly undergo next-generation iterations using 4-μm fabrication rules that will increase the performance by 50% while reducing chip sizes and therefore costs by the same amount [*Electronics*, March 3, p. 32].

Key to the high performance of the new family of devices, says Robert Yu, memory engineering design manager, is the vertical n-channel MOS transistors with gates formed on the face of V-shaped grooves etched in the silicon. The advantage, says Yu, comes from the fact that the V-MOS transistor has a short (about 1-μm) channel length that is achieved by diffusion and not by stretching lithography. Moreover, the structure lays out efficiently; a typical transistor has a 25-μm channel width, though the surface V-groove gate area is only 10 by 10 μm.

Very little scaling is being used in the first generation of devices. For example, the 4-k static RAMs now being sampled measure about 89 by 155 mils. In the improved versions, chip size will be reduced to about 89 by 117 mils. "And this is with very little tweaking and scaling," says Yu. "Where present n-MOS techniques are starting to run out of gas, V-MOS is just gathering steam."

Comparison. Terry Holt, department manager for memory engineering at AMI, says, "With V-MOS we expect this year and next to be where our competition will be, in terms of performance, two and four



V-MOS. AMI will supply samples of its 1-k S4015-3 static RAM with 45-ns access time, shown unpackaged at right. RAMs to come have access times of 35 ns, middle, 28 ns, left.

How AMI does it

Although at first glance V-metal-oxide-semiconductor circuit devices may appear more complex than ordinary silicon-gate devices, the critical processing steps in V-MOS, after the initial wafer processing, are really no harder than the critical steps in high-performance n-channel processing.

Easiest to build are V-MOS read-only memories, where the cell is basically an array of V grooves at the intersection of narrow interconnection lines. One set of interconnections are the diffused bit lines, which are also the drains for the V-MOS transistors, and the other set are the polysilicon gates. A seven-mask grounded-source V-MOS process features selective oxidation; it needs one more mask than ROMs made with depletion-load MOS processing.

For dynamic random-access memory, cells are built with a six-mask metal-gate process that relies on floating-gate structures to get around the grounded-source limitation of V-MOS ROMs. It is done by adding diffused buried layers, which then double as dynamic RAM storage capacitors. For static RAMs, American Microsystems Inc. uses a conventional six-transistor cell in which ion-implanted n-MOS devices serve as pass gates for unselected cells, two V-MOS transistors are cross-coupled with polysilicon-to-diffusion contacts for storage control, and n-MOS loads and resistor-aligned n-MOS devices are used as pass gates for transferring data to the bit lines.

To fabricate V-MOS erasable programmable ROMs, an extra layer of polysilicon is added to the grounded-source process. Like conventional double-polysilicon erasable PROMs, the chip is programmed by injecting hot electrons from the channel of the selection device, through a gate oxide, into a floating gate. But whereas the standard process requires a 27-volt programming voltage, V-MOS erasable PROMs require only a 15-V pulse.

years from now. Nevertheless, AMI can expect intense competition in these new high-performance markets. For example, Intel Corp., with an extension of silicon-gate n-channel processing, which the company calls H-MOS for high-performance MOS, is already sampling a 4-k static RAM that operates at 45 ns typically and at 70 ns maximum. It has also introduced a 16-k erasable, programmable ROM that requires only a single 5-volt supply.

Meanwhile, Fairchild Camera and Instrument Corp., Mountain View, Calif., booster buffer memory performance with new 93470 and 93471 4-k static transistor-transistor-logic parts that have typical access times of 30 to 35 ns. And for fast mainframe designs, Fairchild has its 4-k and 16-k dynamic RAMs sporting access times well below 100 ns built with its Isoplanar process. □

Microwaves

Gallium-arsenide field-effect transistors are reaching new highs in power, frequency

Compact and versatile solid-state phased-array radar systems are exactly what the U. S. Air Force and Navy want for frequencies up through X band (8 to 12 gigahertz). But the missing link for such systems has been a source that meets power and bandwidth requirements with reasonable efficiency. Enter the gallium-arsenide field-effect transistor, which, military spokesmen say, "looks like it will be that source."

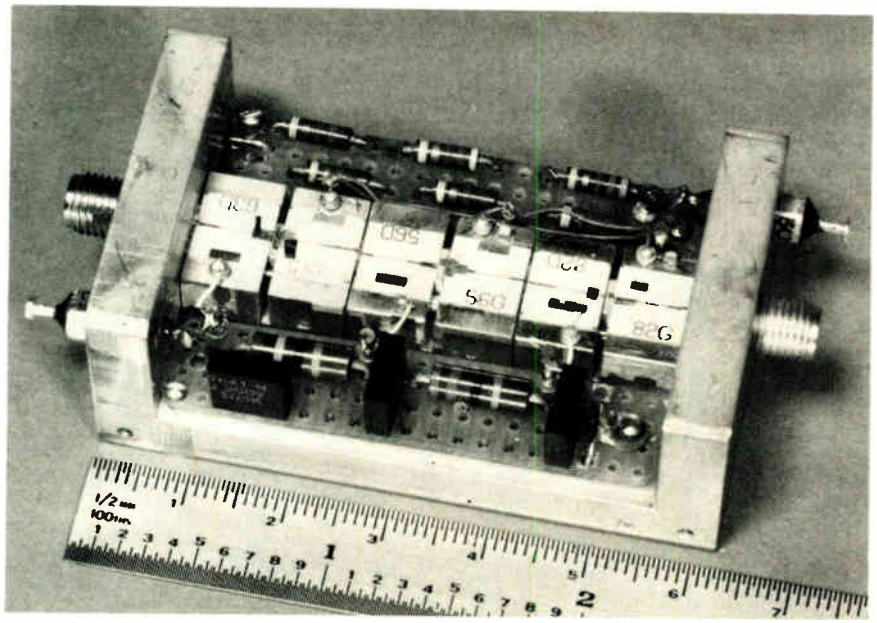
The services' optimism is based largely on work at Texas Instruments Inc.'s Central Research Laboratories in Dallas. William Wisseman, manager of the labs' advanced microwave components branch, claims: "GaAs power FETs make active elemen' phased-array radars feasible at X band." What's more, he says, the devices "will be a primary source of microwave power at frequencies from 4 to 30 GHz."

Wisseman's conviction that the gallium-arsenide devices will replace Gunn and Impatt diodes in many systems operating at X band is based on the performance they recently achieved under a pair of Air Force and Navy contracts. As part of a $650,000 Air Force-funded effort, TI's GaAs power FETs delivered 3.2 watts at 10 GHz with 6-decibel gain and 22% efficiency. "We're getting 5.1 W out of a single device at 8 GHz with 5-dB gain and 35% efficiency," Wisseman says.

Under a $158,000 Navy contract, TI has obtained 1.3 W with 20% efficiency and 19.2-dB gain over a 9-to-10-GHz range from a breadboarded three-stage driver portion of a four-stage amplifier. The goal is 5 W at X band with 25-dB gain and 20% efficiency. The five-year program, begun last October, ultimately calls for "building a 100-element-or-so phased-array radar," states Eliot Cohen, the project manager of the first phase of the program at Naval Research Laboratories in Washington, D. C. RCA Laboratories, Princeton, N.J., is working in parallel with a similar award.

Until the GaAs FETs came along, "the only way to get a phased-array radar at X band was with vacuum tubes—but these are much narrower-band systems," continues Cohen. Earlier solid-state attempts included the use of lower-frequency S-band transistor amplifiers with frequency multipliers to reach X band. But these "didn't give us the efficiencies or bandwidth we wanted. GaAs FETs are particularly attractive because they combine the power, efficiency, and bandwidth we want in one device."

According to Cohen, TI is presently achieving higher device power levels than RCA at 8 GHz and above, but things could change. "We're concentrating our efforts now on designs that are reproducible, reliable and, eventually, low in cost," says Fred Sterzer, director of RCA Laboratories' microwave technology center. Thus far, RCA has achieved over 1 W at 10 GHz with a 16-gate



Breadboard. TI's three-stage GaAs FET driver amplifier yields 1.3 W cw, 19.2-dB gain at 9 to 10 GHz. White areas are alumina microstrip impedance-matching networks.

device and 4 W at 4 GHz with a 48-gate device. The more gates, the greater the power-handling capability of the device.

TI still has 10 months to go on its two-year Air Force program. According to Chern Huang, project engineer at the Air Force Avionics Laboratory at Wright-Patterson Air Force Base, Ohio, TI will demonstrate the power capability of GaAs FETs by producing lab devices that deliver 4 W continuously and 6 W pulsed at X band with 25% efficiency. It will also try to establish the ability to build some numbers of GaAs FETs that deliver 1 W cw and 2 W pulsed at 10 GHz with 20% efficiency and 6-dB gain. Also, Huang points out, TI will apply the GaAs FETs in subsystems, including in addition to amplifiers for phased-array radar, broad-band amplifiers for driving higher-power traveling-wave tubes for electronic countermeasures, and a voltage-controlled oscillator for detector systems now using Gunn oscillators.

Price cut. Perhaps indicating what can happen to the cost of the GaAs FETs, TI plans to reduce prices this summer by more than 75% on its optically defined line of commercial devices. (The new, higher-power devices are made with 0.5-to-1.0-micrometer-wide gates defined with electron-beam techniques; self-aligning optical techniques could also meet the dimensions but are more complex, according to Wisseman.)

The price of TI's MSX803, which delivers 1 W at 8 GHz, will be slashed from $1,000 to $250 in lots of 1 to 9, with similar reductions for lower-power GaAs FETs. "I would anticipate that TI will offer a 2-W-at-8-GHz electron-beam-defined GaAs power FET before the year is out," Wisseman says. "While the price is not set, it likely will be between two and three times that of the 1-W devices," or about $500 to $750. □

Consumer

TI makes noise in games, toys

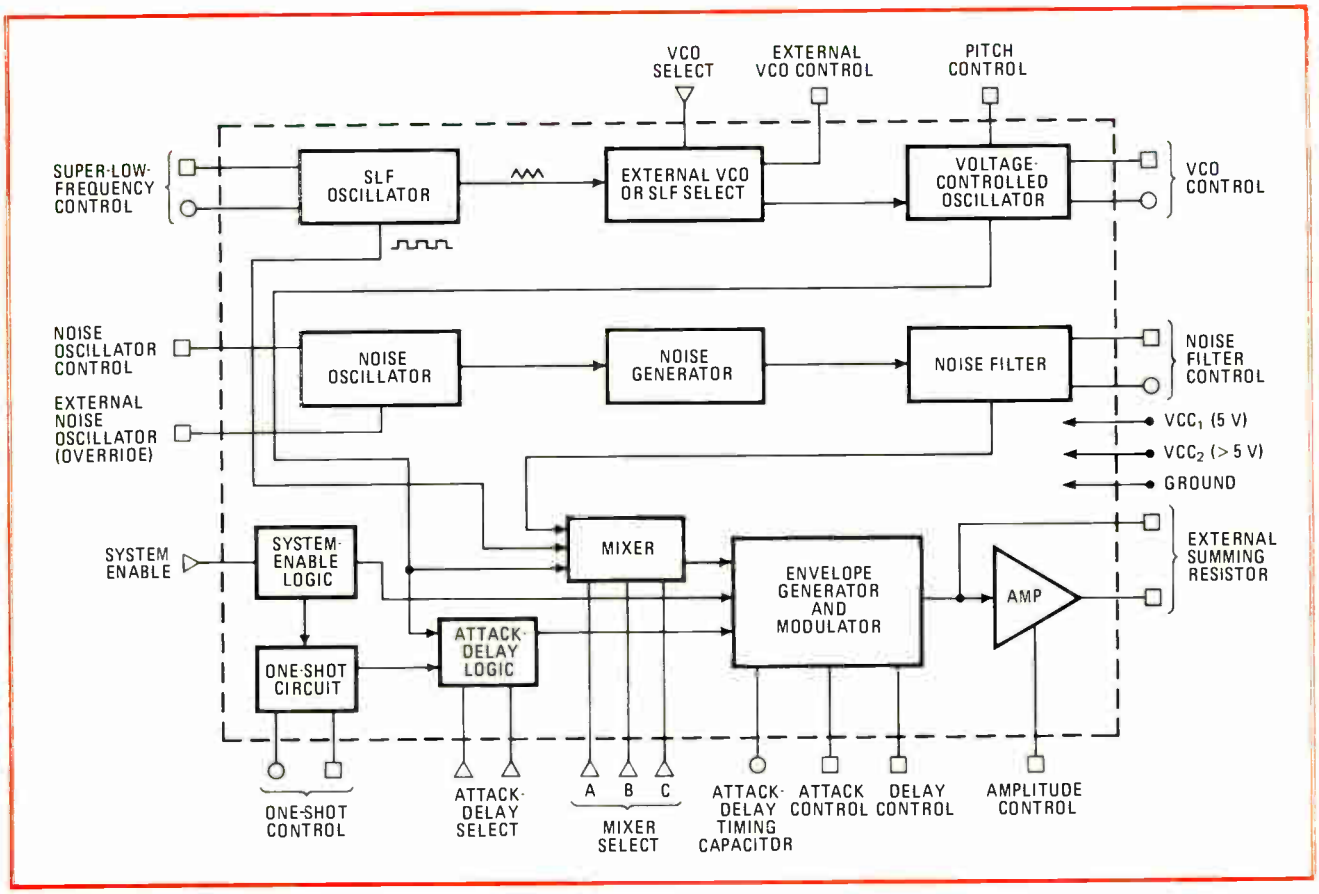
Texas Instruments Inc. has come up with a cheap way to add bells and whistles to consumer products. It is a complex-sound generator, and the firm is using a combination of bipolar linear and integrated-injection-logic techniques to yield a single chip that the user can program—with external resistors and capacitors—to deliver almost any sound.

The circuit, which will be available later this month, was designed for the video-game market, but it is tagged at $1 in production volumes—inexpensive enough, TI hopes, for the price-conscious toy market as well. "It will be affordable not only for games, but for toy cars, helicopters, organs, dolls, horses, or anything, in fact, that makes a noise," says Ron Johns, manager of the company's consumer circuits department in Lubbock, Texas. It can be used in any application that requires audio feedback to the operator, he stresses, adding that he has already pocketed an order from an appliance manufacturer. Uses in consumer and industrial equipment could include alarms on timers and controls, he says.

Tailoring. By varying the values of adjustable external components, toy and equipment makers can get the custom sounds that distinguish their products from others on the market. Adding logic to switch in different sets of components produces different sounds for the same product. For example, a video-game manufacturer can generate the pulsating sound of an airplane engine, followed by the shrill wail of a bomb dropping, followed by an explosion. This switching logic must now be implemented by the manufacturer, although TI is designing a programming chip that, when mated with the sound generator, will give a series of about eight standard sounds.

TI provides three different on-chip sound-generation circuits—a super-low-frequency oscillator, a voltage-controlled oscillator, and a noise-generation system that consists of a noise oscillator to supply random frequencies to a noise generator and a noise filter to round off the square-wave output of the noise generator. These are shown in the block diagram on page 32. All three are fed to the chip's I^2L mixer, which selects either one or any combination of the three inputs and feeds it to the circuit's envelope generator and modulator.

The voltage-controlled oscillator circuitry, for example, produces a tone that is dependent on the voltage



Noisemaker. Sounds produced by Texas Instruments' one-chip sound generator depend on input voltages set on resistors (squares), capacitors (circles), and logic levels (triangles). The hope is that the chip's $1 tag will make it attractive for both toy and game markets.

fed to its input: the higher the voltage, the lower the frequency. By using the triangular-wave output of the super-low-frequency oscillator at the VCO input, the circuit will produce an oscillating frequency for, say, a siren. The 28-pin device also has an external VCO control pin to which a dc voltage can be applied to give a single tone, or any type of waveform can be used to get a frequency-modulated output.

The chip also contains one-shot logic for producing sounds that last less than two seconds, such as bells, gunshots, or explosions, rather than the continuous sound of, for example, a train or car engine or a siren. Logic on the chip determines the envelope, or amplitude-time relationship, of the mixer's output, and circuitry within the chip's envelope generator section tailors the rise and fall time of the envelope to produce the desired sound.

The resulting sound is fed to the chip's output amplifier, which is designed to interface with sound modulators, or additional amplifier stages. Though the chip has input pins for control resistors and capacitors, the user would only rarely use all of them to generate his sounds, Johns points out. And where the user needs the chip for a single, dedicated sound, the seven logic input pins can be hardwired for either high or low logic levels. □

Home VTR offense kicks off in fall

This fall when the new television programming season gets under way, a growing number of home videotape record and play units will be on the receiving end. Almost all of the TV set makers, U. S. and Japanese, have now made commitments to market one of the Japanese-developed, ½-inch VTR formats, and at the recent Consumer Electronics Show in Chicago, home VTR makers agreed that demand will outstrip supply.

This year, probably about 225,000 units will be sold, but the figure should jump to 750,000 or more units by 1978 and climb into the million-plus neighborhood by 1979 as prices drop. So far, only Sony Corp., with its $1,300 Betamax, and Quasar Electronics, with its $995 VX-2000, have had any experience selling systems in the home VTR market.

Others plunging. That is going to change rapidly as the others plunge in between now and Christmas. Prices for VTRs will probably stay around $1,000 while the VTR firms get a foothold. "The magic number—the price at which these products will really begin to take off—is around $700," points out Richard F. O'Brion, vice president

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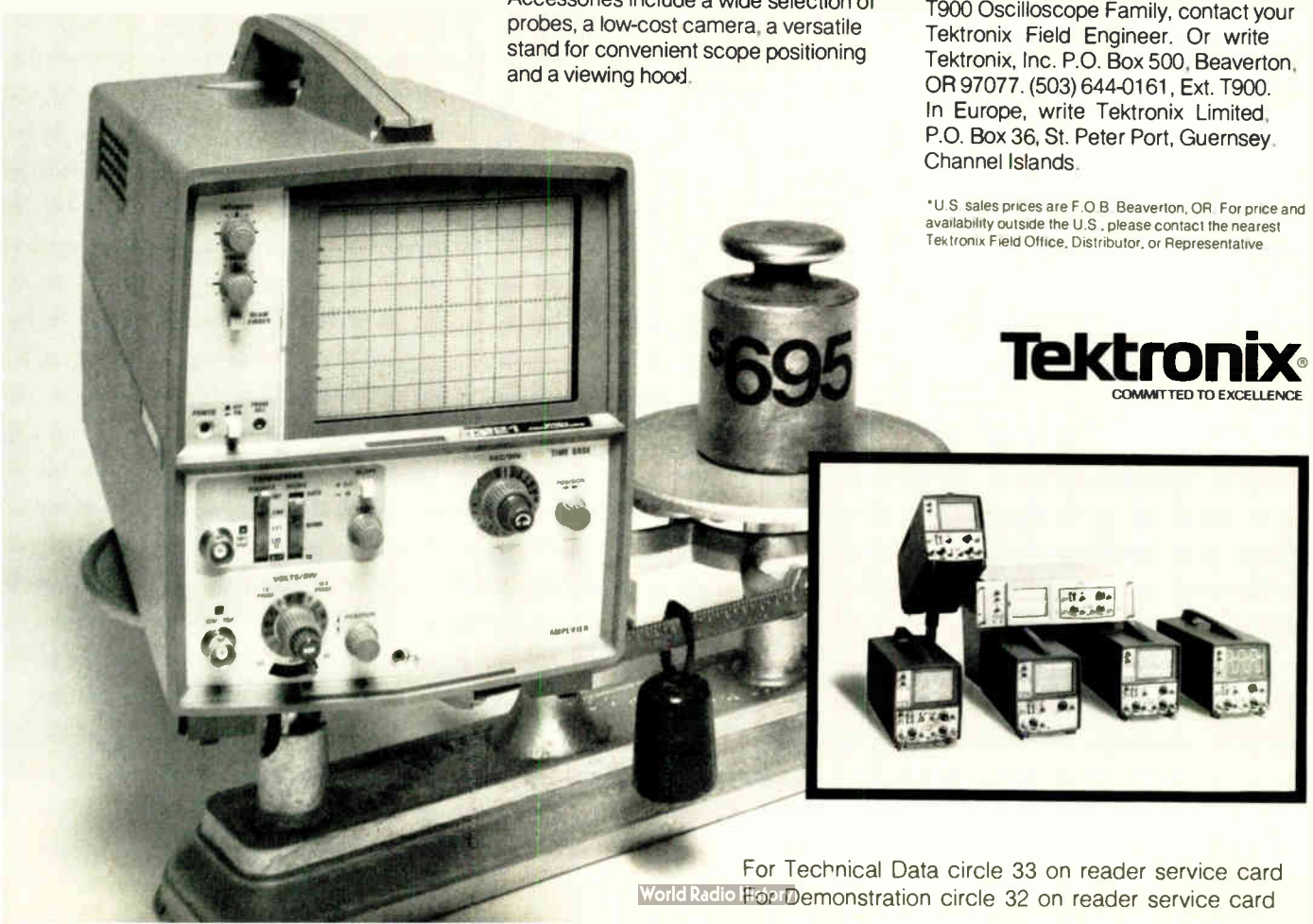

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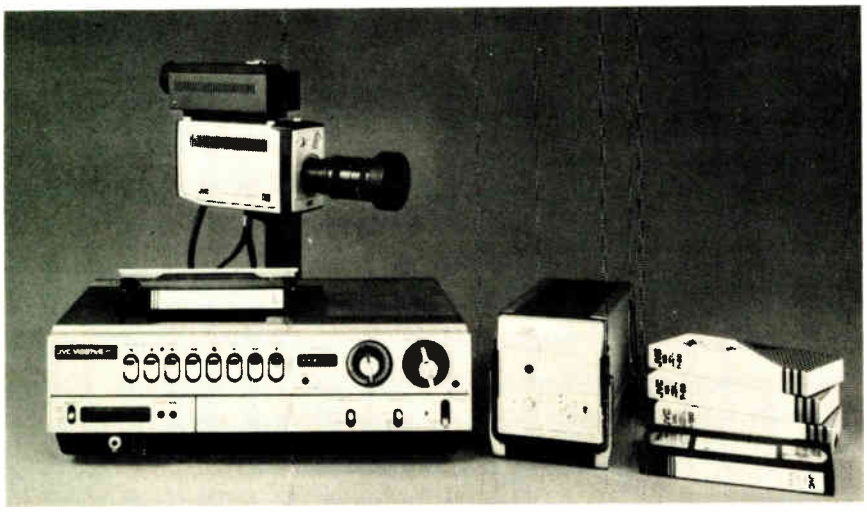

Home VTR. JVC Industries will market two-hour Vidstar VHS video-tape recorder for $1,280, as well as a single-tube color television camera and blank tape cassettes.

for marketing of JVC Industries Co., Maspeth, N. Y., a subsidiary of Victor Company of Japan Ltd. "But I don't think it's going to be easy to get that price down very quickly unless some maker decides to start selling at a loss."

Incompatible designs. In the meantime, the competitors will be jockeying to establish favorable market positions, hoping that the lack of a standard design does not confuse consumers. The differences are largely on the mechanical side, with the systems each feeding the tape in and out of the cassette differently. There are also variations in tape speed. The one-hour JVC tape runs, for example, at 33.35 millimeters per second, Sony's Betamax at 40 mm/s, and Matsushita Electric Industrial Co.'s VX-2000 at 52.1 mm/s. Moreover, the Sony format has a more complicated read-head mechanism than Matsushita's.

Opposite sides. The two biggies in color TV, RCA Corp. and Zenith Radio Corp., are on opposite sides. Starting in August, RCA will market the video home system in a two- and four-hour format made for it by Matsushita. The unit has a slowed-down tape speed to accomplish the four-hour play. Zenith is committed to market one- and two-hour Beta-format units made to its specifications by Sony. Zenith's VCR system will also have a black-and-white camera and sound attachment. Neither Zenith nor RCA has announced prices yet.

Both GTE-Sylvania and Magnavox have opted for Matsushita's four-hour VHS equipment to be marketed late this fall. Admiral and General Electric have made no announcements yet.

Of course, the Japanese producers will also be selling VTRs with their own brand names in the U. S. Besides Sony, Sanyo, Toshiba, and Pioneer will be using the two-hour Beta format. JVC plans to have 4,500 to 5,000 units available in this country by October. Price for the two-hour Vidstar VHS deck is $1,280. Cassettes will be $19.95 for two hours, $15.95 for one hour, and $11.95 for a half hour.

Panasonic, Hitachi, Sharp, and Mitsubishi will sell four-hour units made by Matsushita. Meanwhile, Quasar, which is part of Matsushita, will continue to market the single-videohead VX 2000 originally developed in Japan by Matsushita as an under-$1,000 alternative.

What about video disks? Says Jack Sauter, marketing manager for RCA's Consumer Electronics division, "There's no reason why the VTR and the disk cannot stand together in the market. The disk will be a low-cost means of playback, and the tape will offer record and play." RCA, he states, will continue to develop its capacitive video disk, to be introduced sometime next year. □

Navigation

LSI-11 to help steer America's Cup boats

Microcomputers will probably be plotting courses in this year's America's Cup yacht race, scheduled for September off Newport, R. I. Out of the six sailing vessels already competing in trials to determine the two finalists, three are using Digital Equipment Corp.'s LSI-11 to help the navigator determine such things as the boat's position and the true wind speed and direction.

Usually, the navigator is too busy figuring these critical race factors on a scientific calculator to offer much of his sweat and muscle in actually helping sail the 12-meter-class sloop. Peter Lawson, however, is looking forward to being a more useful crew member. Lawson is navigator of *Independence*, one of three U. S. sloops competing for the honor of defending the America's Cup.

Automatic. "I like to sail, and the computer will allow me to do more of that," Lawson says. Data from the boat's sensors are digitized and fed into the 16-bit LSI-11 automatically. Previously, Lawson had to feed data to his desk-top calculator by hand. The computer gives him information faster, providing solutions to problems that will influence his skipper's tactics. Such problems might include how to turn, or "tack," and in which direction, and what sail combination might be best.

Lawson's *Independence* has been dueling with *Courageous*, 1974's successful U. S. defender, in match races off Marblehead, Mass. *Courageous* carried a Data General Nova minicomputer in 1974. This time out, *Courageous* is using the LSI-11. So is *Sverige*, the Swedish entry.

The microcomputers are protected against salt water by specially designed aluminum boxes, points out Robert Brick, new account manager for the LSI-11 at DEC in Marlboro, Mass. Military-type connectors funnel cable in and out of the under-15-pound boxes. Sensors and instru-

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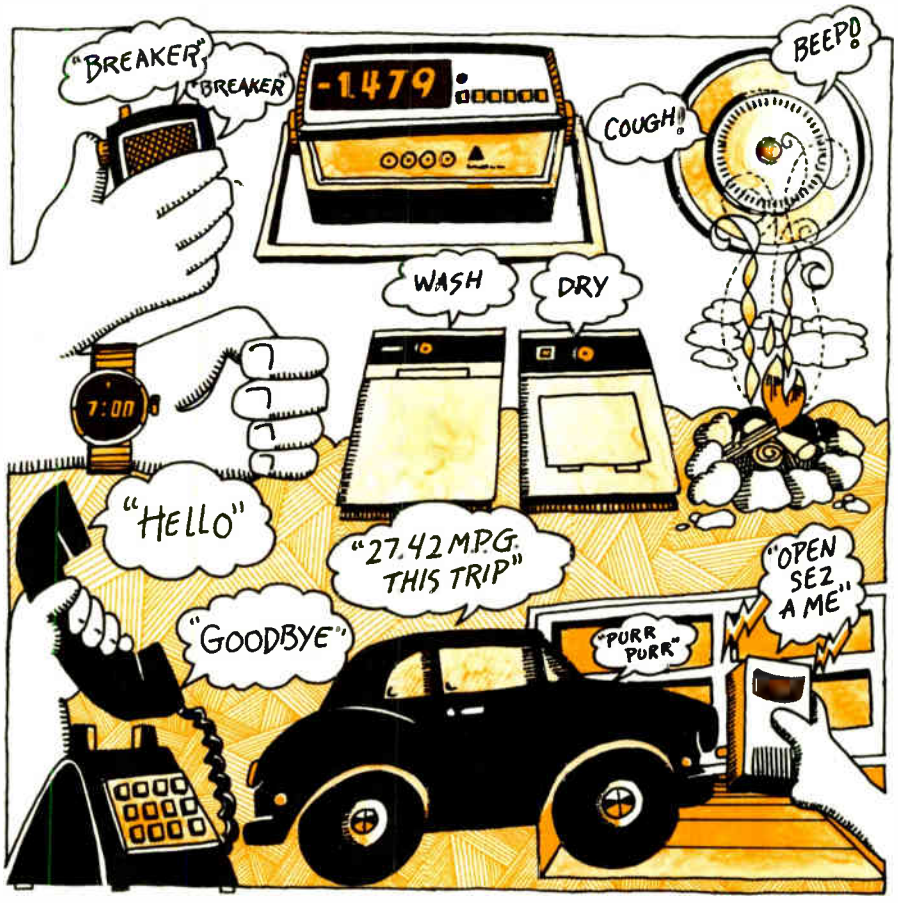

So it goes for things like garage door openers, in-dash and underhood automotive systems, and appliance controls. And, there's more just around the corner: internally programmed watch chips to keep your product current, an internally programmable processor, or one-chip microcomputer, to shorten design cycle times in many applications, and one kilobit RAMs for battery backup systems. You name it.

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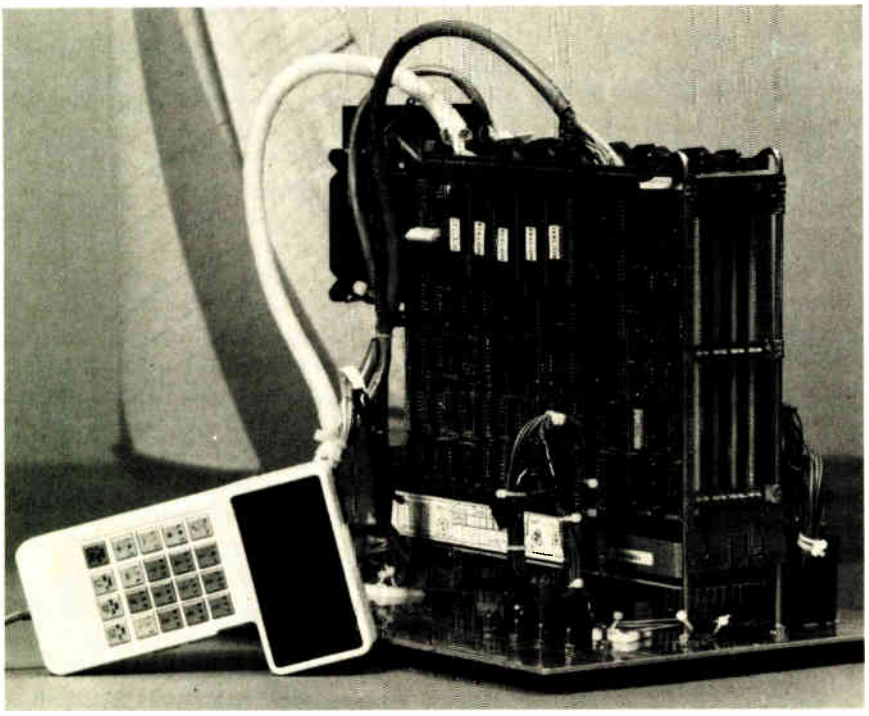

Aide. Hand-held terminal from Termiflex is used to call up programs and display on light-emitting diodes sailing data stored and processed in Digital Equipment's LSI-11.

ments for the system, including the analog-to-digital conversion, are provided by Signet Scientific Co., Burbank, Calif. Data is read out on the light-emitting-diode display of a hand-held terminal from Termiflex Corp., Nashua, N.H.

Input. The sensors consist of a cup anemometer and wind vane on the sloop's mast that derive analog signals representing apparent wind speed and direction, a knotmeter that indicates speed through the water, and an electronic compass that gives digital indication of the boat's heading. The LSI-11 samples the digital signals several times a second and converts apparent wind speed and direction to the true wind speed and direction. It also precisely computes the boat's relative position—in both time and distance—to marks along the race course.

Another important LSI-11 function, Brick points out, is computing "velocity made good" to a mark. This is the rate at which the boat is closing on a mark, even though it may not be sailing directly toward it. It is important to know this, Brick says, because the skipper may, for example, want to alter tack to obtain the optimum direction and speed for that part of the race.

In all, a navigator can call up 24 different programs, loaded into 16,384 words of metal-oxide-semiconductor random-access memory before the race begins. Programs include ones for calculating velocity made good and true wind speed and direction for competing boats. Two 12-volt batteries power the system. □

Military

Belgians ordering operational RPVs

This year, while the United States military is still debating the need for remotely piloted vehicles, Belgium will field the first of two squadrons of 20 jet-powered RPVs for battlefield surveillance.

At the Washington meeting of the National Association of RPVs earlier this month, Belgium's contractor, Manufacture Belge de Lampes et de Material Electroniques of Brussels, described its latest step. With the aid of Teledyne Brown Engineering Co., Huntsville, Ala., it is adding low-light-level television reconnaissance as an option to its Epervier system, which now operates with either still cameras or an infrared line scanner. The goal: an upgraded system—called Asmodée—that can be sold to other countries in Europe and the Middle East.

Limbo. American programs are moving slowly, on the other hand, with current interest centered on developing recoverable mini-RPVs for reconnaissance. Still in limbo are larger vehicles like Boeing's Compass Cope for high-flying reconnaissance and the competitive Northrop Corp. and Beech Aircraft efforts to develop TEDS (for tactical expend able drone system) mounted with a warhead for defense suppression. Production prospects are dim by industry estimates.

The Army, now the lead RPV developer, is concentrating its efforts on the mini XMQM-105 known as Aquila, but it is not scheduled for engineering development before October 1978. The Naval Air Systems Command will have no more than $8 million next fiscal year to begin conceptual development of an over-the-horizon reconnaissance RPV for shipboard launch. The Air Force is off to an even later start on small RPVs. Its expendable Harassment vehicle program has uncertain internal support and is in funding difficulty with a Congress that argues the military RPV case has not been proved. All three services contend that lack of strong interest from field commands has slowed progress.

The Army's Aviation Systems Command, St. Louis, is developing the Aquila, which is a 146-pound radio-controlled, recoverable drone with a 22-lb payload. Lockheed Missiles & Space Co. has received close to $16 million over two and a half years for building 23 Aquilas. They have been used for testing battlefield reconnaissance 20 to 30 kilometers behind enemy lines by television and still cameras, as well as for testing laser range-finding and target designation.

Shaped like a "flying wing," Aquila is 6 feet long with a 12-foot

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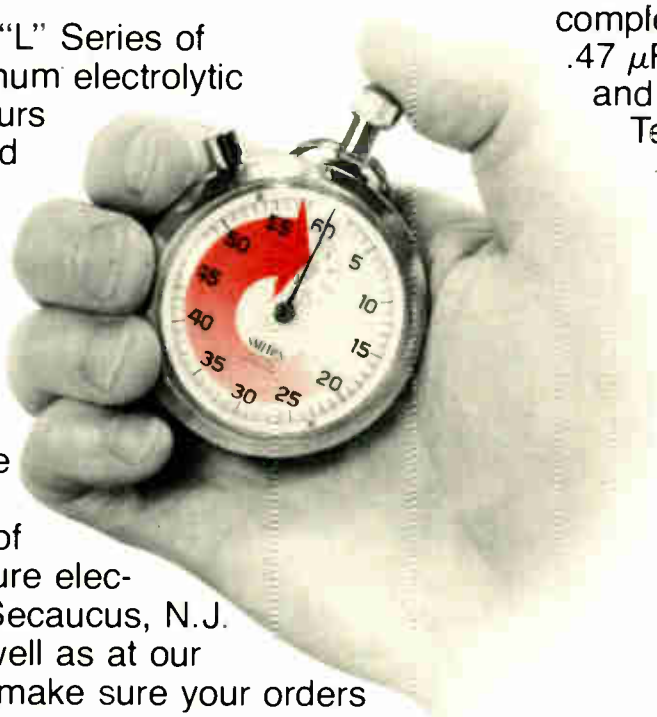

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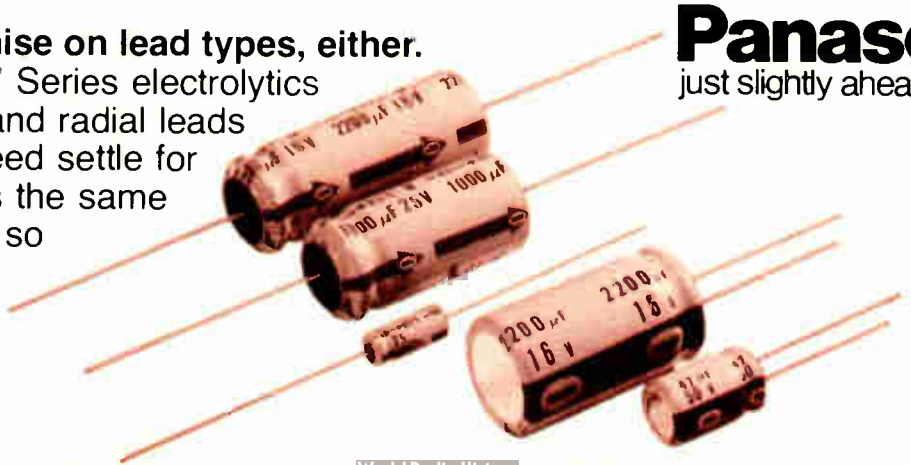


Circle 37 on reader service card

wingspan and is powered by a 112-horsepower engine that drives a propeller at the rear. Maximum flight time is 3 hours, top speed is 120 miles per hour. Tests with a classified Honeywell laser rangefinder on board should be completed this year. The Army expects to request engineering development proposals by next spring.

Navy ship commanders remain to be convinced of the ability to recover RPVs safely and make their components safe for shipboard handling, says Rear Adm. Carl J. Seiberlich, assistant deputy chief of naval operations for air warfare. He explains that the Navy had a disastrous experience with multiple crashes of the Drone Antisubmarine Helicopter, 60 of which are in storage "presumably awaiting the Resurrection." Apparently the helicopters themselves were reliable—the problems were chiefly in the electronic controls, which were subject to interference from shipboard electronic systems. Sieberlich suggests the Navy might be more inclined toward expendable, single-shot systems if proved cost-effective. This would eliminate problems of recovery, maintenance, and storage at sea, he says.

Epervier. Belgium's 342-lb Epervier, developed for $15 million, is not pushing the state of the electronics art, but is built from solid-state equipment "that works," points out MBLE's Albert Dellicour, RPV program manager. While the drone is larger, heavier, and costlier than Aquila—$150,000 each vs an Army goal of $10,000 to $15,000—its 44-lb payload is double Aquila's. So is its maximum turbojet speed of 310 mph. While Epervier missions average only 20 minutes, its 40-to-50-mile range matches Aquila's, Dellicour points out. Moreover, it can fly automatically, controlled by a memory pre-programmed before flight, or it can accept program changes in flight by pulse-coded radio signals. Most of the on-board electronics, including the planned low-light-level TV adapted from a Hughes Aircraft military satellite, and its S- and L-band transmitters, is considered classified by the Belgians. □

News briefs

RCA improves bipotential picture-tube gun

RCA Corp.'s Picture Tube division claims "very substantial progress" in obtaining improved focus performance in both high-focus-voltage bipotential, in-line gun and tripotential in-line gun color picture tube designs. The significant advantage of the high-focus bipotential gun, says Joseph Colgrove, division vice president and general manager, is that it uses only one focus voltage (9 kilovolts) as compared with two focus voltages (7 and 13 kV) in the tripotential gun, which should reduce receiver and tube manufacturing costs and increase reliability. In addition, RCA claims that the high focus bipotential gun has better edge and corner sharpness than the tripotential types. The new tube will be available next year in 25-inch, 100° deflection and 19-in., 90° deflection tubes. The company will also market a 25-in., 100° tube with a tripotential gun. Both Zenith and GTE-Sylvania are now marketing tripotential gun tubes.

Sprague and GE put a-m/fm radio on single chip

A single bipolar integrated circuit from Sprague Electric Co., Worcester, Mass., performs all the functions of a low-cost a-m/fm radio except for vhf tuning. Housed in a 16-pin dual in-line package, the ULN-2204A was developed for General Electric Co., which has begun radio production using it. The device is now available commercially to other radio makers. In the a-m mode, it is a complete superheterodyne broadcast or shortwave receiver, including automatic gain control. In fm operation, it acts as a high-gain intermediate-frequency amplifier/limiter and phase-shift detector.

EIA names counsel Ray Johnson acting general manager

The Electronic Industries Association's Raymond E. Johnson, general counsel, will become EIA acting general manager on June 15 pending the selection of a new president to succeed V. J. Adduci, who has resigned [*Electronics*, May 26, p. 75]. Johnson will have all the authority of the executive office until the appointment of a new president, by Sept. 1.

GenRad unveils fast board tester

GenRad Inc., Concord, Mass., has taken the wraps off the successor to its model 1792D printed-circuit board tester. It is called the 1796 and can mix analog and digital statements so that both kinds of pins can be tested under software control. The price, comparable with that of the 1792, will range from $125,000 to $300,000, with $200,000 for a typical system.

Computers

Single-board units hit price low

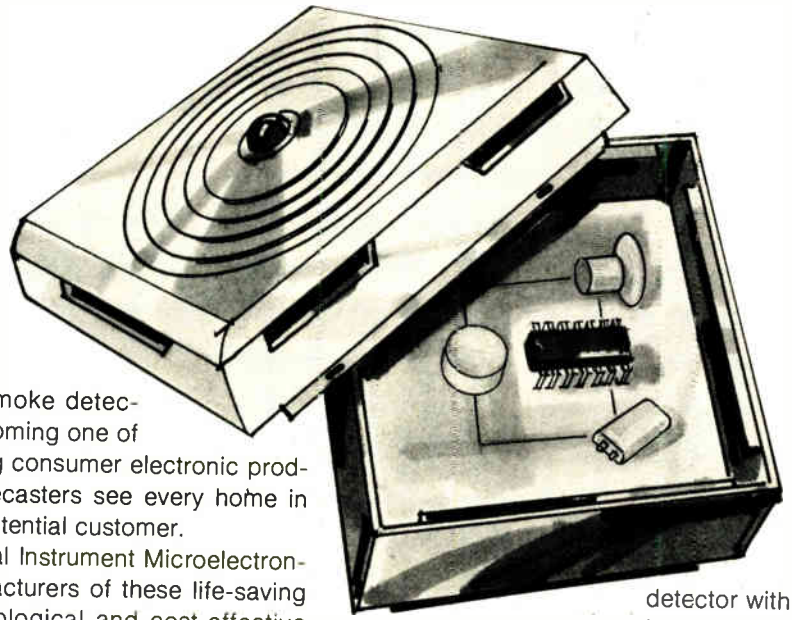
Two single-board microcomputers quietly introduced by Intel Corp. at the National Computer Conference last week could become one of the industry's hottest OEM items, especially among manufacturers of high-volume microcomputer-controlled equipment.

One board costs less than $100, the other less than $200, making them the lowest-priced computer boards in their performance bracket. Yet both are full computers, completely assembled and tested and ready for software development.

The under-$100 board, designated the SBC 80/04, is designed specifically for stand-alone use in dedicated applications. The other, the SBC 80/05, features the bus structure made popular by its more powerful predecessor, the SBC 80/20 [*Electronics*, March 17, p. 121]. This structure allows it to act not only as a stand-alone computer but as part of a low-cost distributed processing system or in a multiprocessor system as a remote slave to one or several 80/20 master boards.

Key to the substantially lower cost of the 80/04 and the 80/05 is the

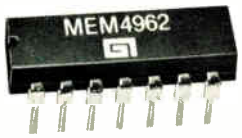
The chip with the sensitive nose.



Early warning smoke detectors are fast becoming one of the hottest selling consumer electronic products. Market forecasters see every home in the world as a potential customer.

Now, General Instrument Microelectronics offers manufacturers of these life-saving devices a technological and cost-effective breakthrough that can help to develop the full market potential of the smoke alarm market. It's the new MEM 4962.

A single-chip LSI package, the MEM 4962 includes a FET input, detector, voltage comparator, oscillator, trigger, horn driver and C/MOS output. That's all the circuitry you need for a "sensitive nose" to detect combustion.



GI's new MEM 4962 replaces more than 30 discrete components now being used in conventional ionization smoke alarms. You know what that can do for your inventory costs and assembly time.

Switch your product to GI microcircuit technology and you can offer your customers a competitive priced smoke detector with super-sensitive reliability, long battery life, and audible reminder when battery power is too low for safety. All this from a single-chip package.

Whatever you manufacture — smoke detectors, microwave ovens, TV or stereo sets, TV games, calculators, organs, pianos, data and telecommunications equipment — chances are GI has the circuitry to help you be more competitive. Write today or call the leader in microcircuit technology — General Instrument Microelectronics, 600 West John Street, Hicksville, New York 11802, Telephone: (516) 733-3107.

We help you compete.

GENERAL INSTRUMENT CORPORATION
MICROELECTRONICS

higher level of integration made possible through the use of the new MCS-85 family of microcomputer components, in which a three-chip system replaces up to 10 or more 8080 system components. In addition, the three power supplies formerly required for 8080 systems are replaced by a 5-volt supply.

The SBC 80/04 board contains 256 bytes of random-access memory, and the SBC 80/05 512 bytes of RAM. Moreover, each of the 6.75-by-12-inch boards contains sockets for up to 4 kilobytes of reprogrammable or masked read-only memory. But because it is designed for distributed and multiprocessing applications, the SBC 80/05 also contains the same bus-control logic for determining input priorities used in the SBC 80/20. This control logic allows up to four SBC 80/05 boards or any high-speed controller to share the system bus in serial or daisy-chain priority fashion. Once bus control is achieved, a bus bandwidth of up to 5 megabytes per second is possible. □

Communications

AT&T to build network for Iran

American Telephone & Telegraph Co.'s Iranian subsidiary will begin work July 1 under a contract worth about $100 million for the first year of a 10-year program to engineer a $10 billion public and military communications system for Iran. And Western Electric Co., AT&T's manufacturing arm, is expected to be a major competitor for the remaining $900 million of Iran's $1 billion annual outlay for installing telecommunications hardware.

This was revealed by American Bell International Inc.'s John A. McCarthy, engineering plans vice president, in an interview in Washington during a two-day mid-June seminar on "Future Directions in International Telecommunications" sponsored by Arthur D. Little Inc., Cambridge, Mass. His disclosure came on the heels of another by Western Electric's James S. Herbert, executive vice president, that his company plans to move vigorously into supplying telecommunications systems "to meet the needs of developing nations." Herbert told the ADL forum that Western Electric "is just getting organized" to move back into the international market, one it pulled out of in the 1920s.

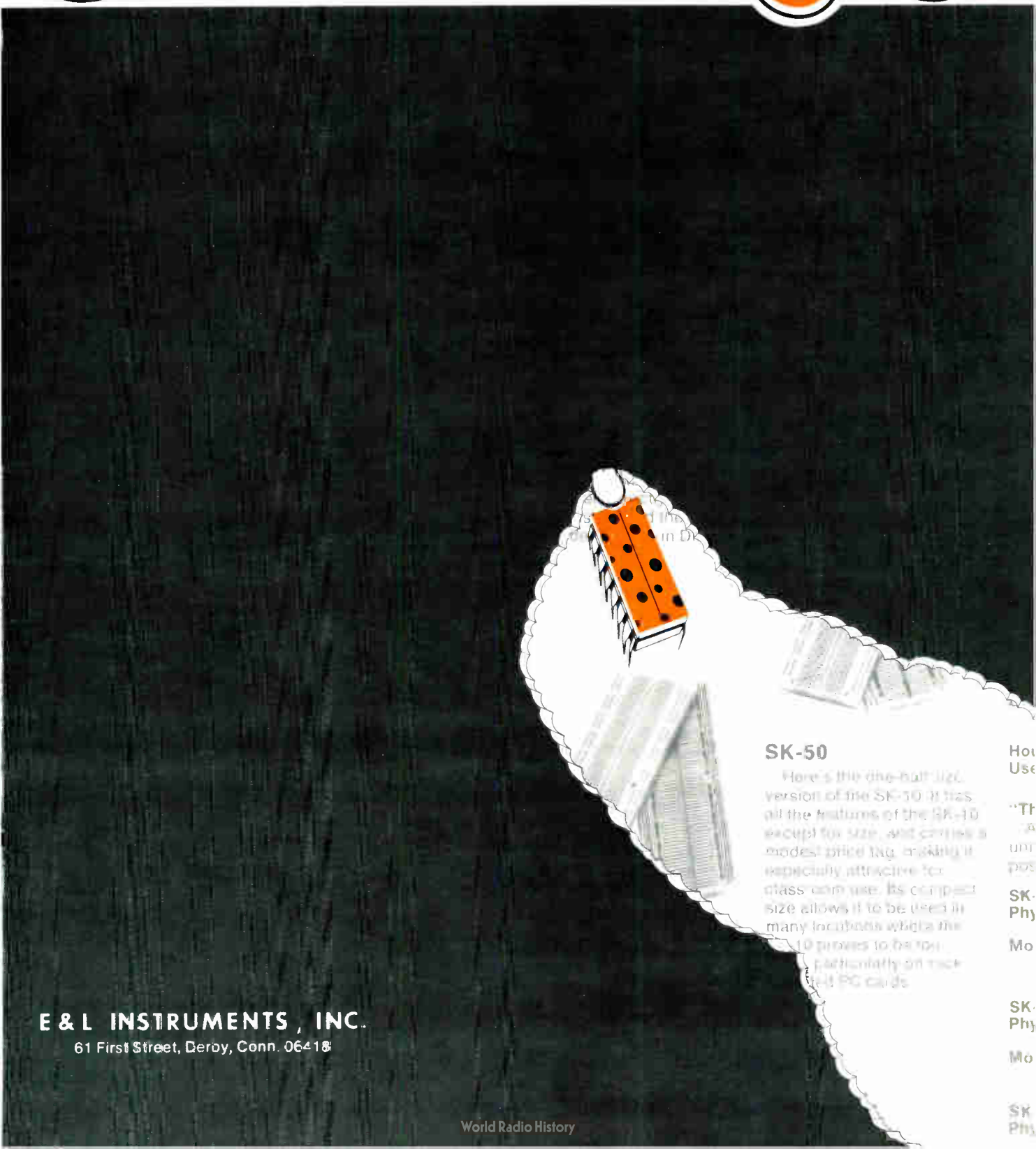
As for Iran, the Shah has approved the communications program, McCarthy said, and funding of the new ABII contract will begin July 1. AT&T established the subsidiary in August 1975 when it received its first contract to study Iran's telecommunications system and its needs [*Electronics*, Aug. 21, 1975, p. 49]. ABII will now provide Iran with systems engineering, maintenance, personnel training, and billing systems. That Iran expects hardware vendors to establish production facilities in the country was made clear at the time of the original 1975 agreement, when the Shah indicated Iran's policy was to develop a "modern technological capability and increased manufacture of communications equipment."

Western Electric. In its international role, Western Electric will offer its products and engineer, furnish, install, and maintain large networks, Herbert says. To do this it will "obtain resources from the Bell System and/or other companies.

Herbert cites WE's first major international marketing success—a $408 million contract he negotiated with Saudi Arabia in early June to supply and install a new microwave communications network with the support of subcontractor Collins Systems International Inc. Collins will provide the bulk of the Intra-Kingdom Microwave Project's radios, and Western Electric will provide the transmission microwave carrier and multiplexing equipment.

While Western Electric "has not decided yet" whether it will enter into joint ventures overseas with other companies, Herbert added that his company will consider licensing overseas companies in contracting countries to manufacture hardware "on a case-by-case basis." □

The COMPLETE BUGWORKS



SK-50

Here's the one-half size version of the SK-10. It has all the features of the SK-10 except for size, and carries a modest price tag, making it especially attractive for class use. Its compact size allows it to be used in many locations where the SK-10 proves to be too [illegible] particularly on rack [illegible] PC cards.

E & L INSTRUMENTS, INC.
61 First Street, Derby, Conn. 06418

Solderless

If you are involved in any aspect of circuit design, experimental construction of electronics or are merely interested in learning about analog or digital techniques, then you should take a good look at the full line of E&L products that are featured in this brochure. They represent the least expensive, quickest and most direct route to mastering the world of electronics.

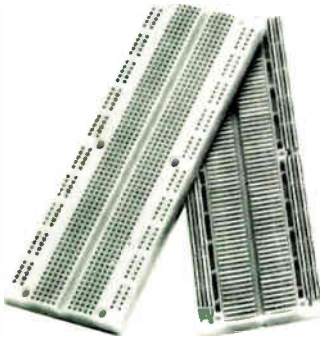
From simple solderless breadboards to complete design stations, E&L has the products, the instruments and the educational material that will enable you to design and build your own system.

After browsing through the next 22 pages of products, check the back cover for all ordering information including OEM, Educational and Industrial discounts.

SK SERIES.

SOCKETS FOR CIRCUIT DESIGN . . . SIMPLE BUT VERSATILE.

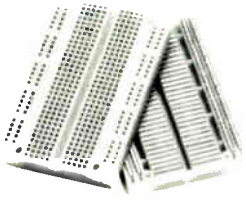
Start your circuit designing with E&L's SK series. These solderless breadboards enable you to insert all your electronic components directly into a spring matrix, without adapters, for instant circuit construction. All components of 20 to 26 gage insert directly. From ½ watt resistors and the smallest diodes to plug-in DIP packages from 8 to 40 pins. Spread the leads when TO-5 package is desired. All interconnects are made with solid 22 gage wire, stripped ¼" (6,35 mm) on each end, eliminating the need for special jumper sets. Combine the solderless sockets with E&L's sophisticated instruments and you have great design systems.



SUGGESTED RESALE PRICE **$16.50**

SK-10

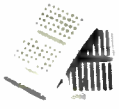
The SK-10's unique matrix configuration is embedded in a high temperature plastic molding. It gives you 64 pairs of 5 common spring contacts for principle circuit construction and a series of common buss strips (8) of 25 connections each.



SUGGESTED RESALE PRICE **$8.50**

SK-50

Here's the one-half size version of the SK-10. It has all the features of the SK-10, except for size, and carries a modest price tag, making it especially attractive for classroom use. Its compact size allows it to be used in many locations where the SK-10 proves to be too large, particularly on rack mounted PC cards.



SUGGESTED RESALE PRICE **$2.25**

SK-20

The SK-20 is a miniature breadboarding socket that is an excellent replacement for standard DIP sockets in custom breadboarding, particularly in the interfacing version. The SK-20 is perfect for permanent installation where the 5 common contact points are of prime importance for fan-in/fan-out.

SK SERIES SPECIFICATIONS

Contacts: Nickel Silver

Typical Insertion Life: Based on 22 gage components, a minimum of 10,000 insertions.

Average Contact Resistance: 5 milliohms

Lead Size Accommodations: 20 to 26 gage (½ watt resistor to small diodes)

Housing: Acetal Co-polymer

Useable Temperature Limit: 105°C

"The Lifetime Guarantee"

All of E&L's SK sockets now carry a lifetime guarantee. If a unit ever fails to meet your requirements, return it to E&L, postpaid. for a free replacement. No questions asked.

SK-10

Physical: .33" H (8,4 mm) x 2.2" W (5,6 cm) x 6.5" L (16,5 cm)

Mounting Holes: (Designed for # 4 flat head screws) 1.46" (3,71 cm) across width x 3.08" (7,82 cm) across center line to each end.

SK-50

Physical: .33" H (8,4 mm) x 2.2" W (5,6 cm) x 3.4" L (8,6 cm)

Mounting Holes: (Designed for # 4 flat head screws) 1.46" (3,71 cm) across width x 3.08" (7,82 cm) across center line to each end.

SK-20

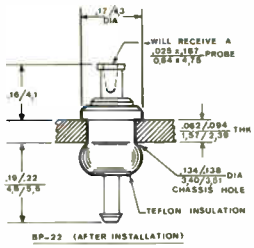
Physical: .33" H (8,4 mm) x 1" W (2,54 cm) x 1.75" L (4,45 cm)

Mounting Holes: 1.56" (3,96 cm) center to center

Breadboarding

BP SERIES

QUALITY BREADBOARDING JACKS AND PINS

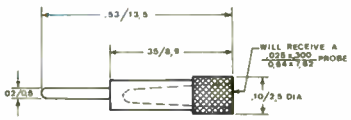


BP-22 (AFTER INSTALLATION)

BP-22

The BP-22's are Teflon® insulated breadboarding jacks for use in metal panels of 1/16" (1,57 mm) to 3/32" (2,36 mm) thickness. Solderless interconnections are made with 22 gage solid wire. The BP-22 mounts in a .136" (3,45 mm) hole without soldering.

SUGGESTED RESALE PRICE **$9.30** (pkg. of 25)

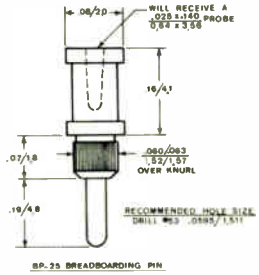


BP-24 ADAPTER PIN

BP-24

A reusable adapter pin that allows up to 16 gage wires to be inserted in the BP-22, 25 or any of the SK-10/SK-20 Sockets. Large electrolytics can thus be breadboarded as simply as a DIP IC.

SUGGESTED RESALE PRICE **$11.50** (pkg. of 100), **$3.25** (pkg. of 25)



BP-25 BREADBOARDING PIN

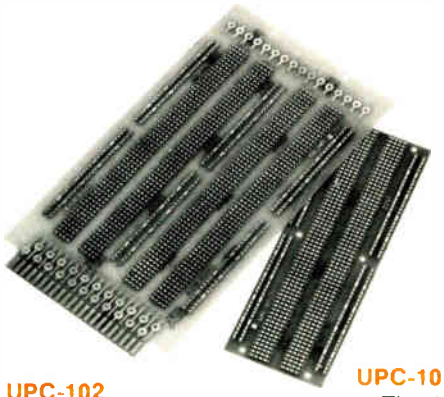
BP-25

A breadboarding pin where spacing on .100" (2,54 mm) centers is desired. .0595" (1,50 mm) hole size. A protruding metal tip that will engage the opening in the top of another pin allows "stacking."

SUGGESTED RESALE PRICE **$8.50** (pkg. of 25)

UPC-101, UPC-102

SPECIAL PURPOSE PRINTED CIRCUIT BOARDS



UPC-102

The 102 circuit board features dual SK-10 circuit patterns and adds a card edge connector for plug-in use. .156" (3,96 mm) centers; 22 connections.

SUGGESTED RESALE PRICE **$15.00**

UPC-101

The 101 is an exact duplication of the SK-10 circuit pattern. A drilled hole pattern and circuit pattern identical to the SK-10 allows the designer to go directly from his breadboard to final soldered unit without laying out the circuit again.

SUGGESTED RESALE PRICE **$6.50**

THE INTERFACE SOCKET

FOR PERMANENT CONNECTION TO PRINTED CIRCUIT BOARDS

A variation on the original solderless breadboarding socket gives you another inexpensive way to construct instrument/computer interfaces. In addition to the normal 5 parallel contacts on top, a tab is punched out at the bottom of the contact pin. Interfacing is made simple by quick and permanent connection of the contact pin to the printed circuit board.

SPECIFICATIONS

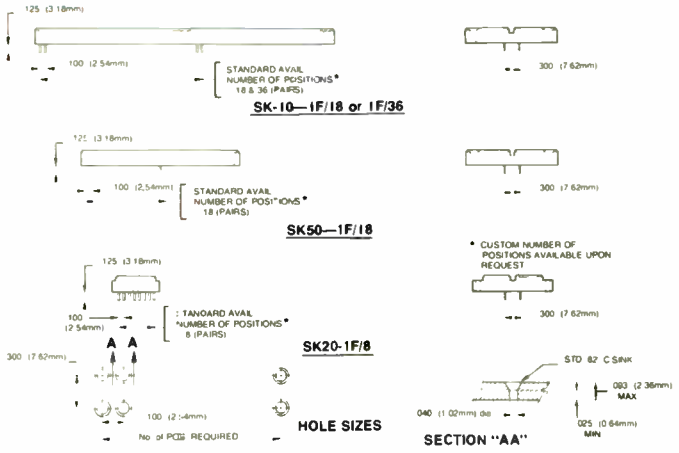
SK-10-1F18 — 18 pairs of rear solder tabbed connectors/46 pairs of standard connectors.
SUGGESTED RESALE PRICE **$18.75**

SK-10-1F36 — 36 pairs of rear solder tabbed connectors/28 pairs of standard connectors.
SUGGESTED RESALE PRICE **$19.75**

SK-20-1F8 — 8 pairs of rear solder tabbed connectors.
SUGGESTED RESALE PRICE **$3.25**

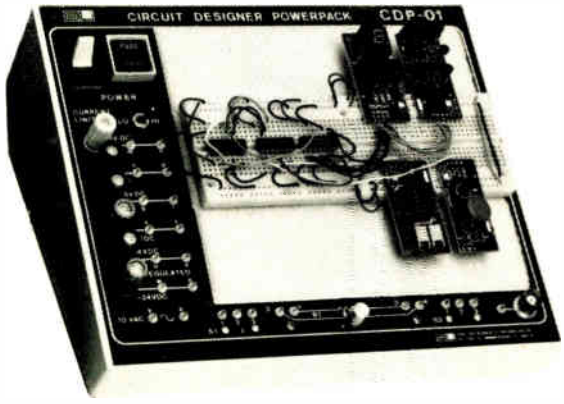
SK-50-1F18 — 18 pairs of rear solder tabbed connectors/15 pairs of standard connectors.
SUGGESTED RESALE PRICE **$10.50**

MOUNTING DETAILS



Universal

E&L has designed a series of compact, inexpensive, reliable and rugged units to meet the needs of small labs, educational institutions and hobbyists. These units are available either in kit or assembled form.



CDP-01

THE ALL-PURPOSE GENERAL DESIGNER

Here is all you need for a wide variety of circuit work. From CMOS Logic, TTL, Linear IC's to simple R/C design. A central work area covered by Velcro® Loop Material gives you complete freedom in attaching different units to the instrument. Terminals are labeled for easy identification and the unique dual current limiting concept saves precious IC's from burn-out. The power supplies have the capacity (.75A and .25A) to do any reasonably sized job that fits on the working surface. Each CDP-01 comes with a hard backed SK-10 Socket. Available in kit (CDP-01K) or assembled (CDP-01A) form at either 115V or 230V.

SPECIFICATIONS

POWER SUPPLIES	SUPPLY A	SUPPLY B
Voltage (DC)	5V	+15/−15V
Type	Trimmer adjustable	fixed, tracking
Tolerance (volts)	N/A	14.15/15.75
Output Current		
Low Setting	100 ma	50 ma
High Setting	750 ma	250 ma
Current Limiting	Yes	Yes
Noise and Ripple	Less than 10MV	Less than 20MV
Overload Indicator	LED Indicator	LED Indicator

In addition to the above supplies, the CDP-01 provides +24/−24V dc (unregulated) fused internally at ¼ amp. Also available on the front panel are two connections to one of the low voltage secondary windings — nominally 10V ac. The primary fuse will blow in the event of a short.

CONTROLS:

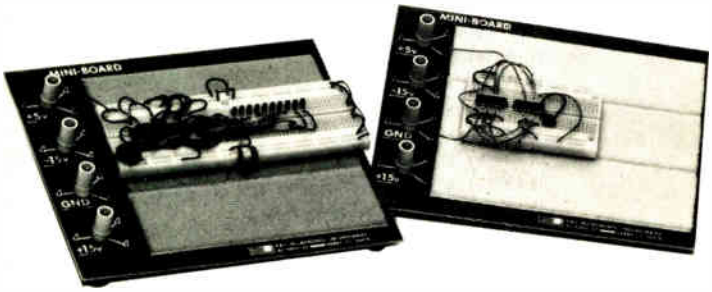
(1)—Off/On Switch (with integral light)
(1)—Low/High current limiting switch.
(1)—Uncommitted linear 10K slide pot with center tap (detent)
(2)—Uncommitted slide switches — SPDT (½ amp @ 125 V dc)

Connectors: (25) BP-22 — Insulated solderless breadboarding pins.
(1) SK-10 with permanent backing.
(1)—BNC Connector
(6)—5 Way Binding Posts

Miscellaneous: Center portions of panel covered with Velcro® Loop Material for attachment of external components.
(3) Fuses — (2) ¼A and (1) ¾A Slo-Blo.
(For additional Velcro to attach custom components, use V-04.)

Physical: 3.5" H (8,9 cm) x 7.6" W (19,3 cm) x 9" L (22.9 cm)
Sloped Approx. — 17°
Weight — 5 lbs. (2,27 Kg)

SUGGESTED RESALE PRICE ASSEMBLED — **$150.00**, KIT — **$110.00**



SPECIFICATIONS

Base: 1/16" (1,57 mm) G-10-Approx. 7" (17,8 cm) x 8" (20,3 cm)
Connectors: (4) Binding Posts, (12) Breadboarding Pins
Sockets: (1) SK-10 with Velcro® Hook Material Backing (SK-50 with the MB-101)
Mounting Area: 6" (15,2 cm) sq. Velcro Loop Material

MB-100

MINIMUM COST BREADBOARDING PACKAGES

MB-100 is an exceptionally flexible circuit design aid. A simple mounting board with binding posts and solderless breadboarding pins and a detachable SK-10 socket. In addition to the socket, you can mount any kind of electronic components, relays, meters, transformers, etc., with Velcro®. E&L supplies a hard backing for the rear of the socket.

SUGGESTED RESALE PRICE **$29.10**

MB-101

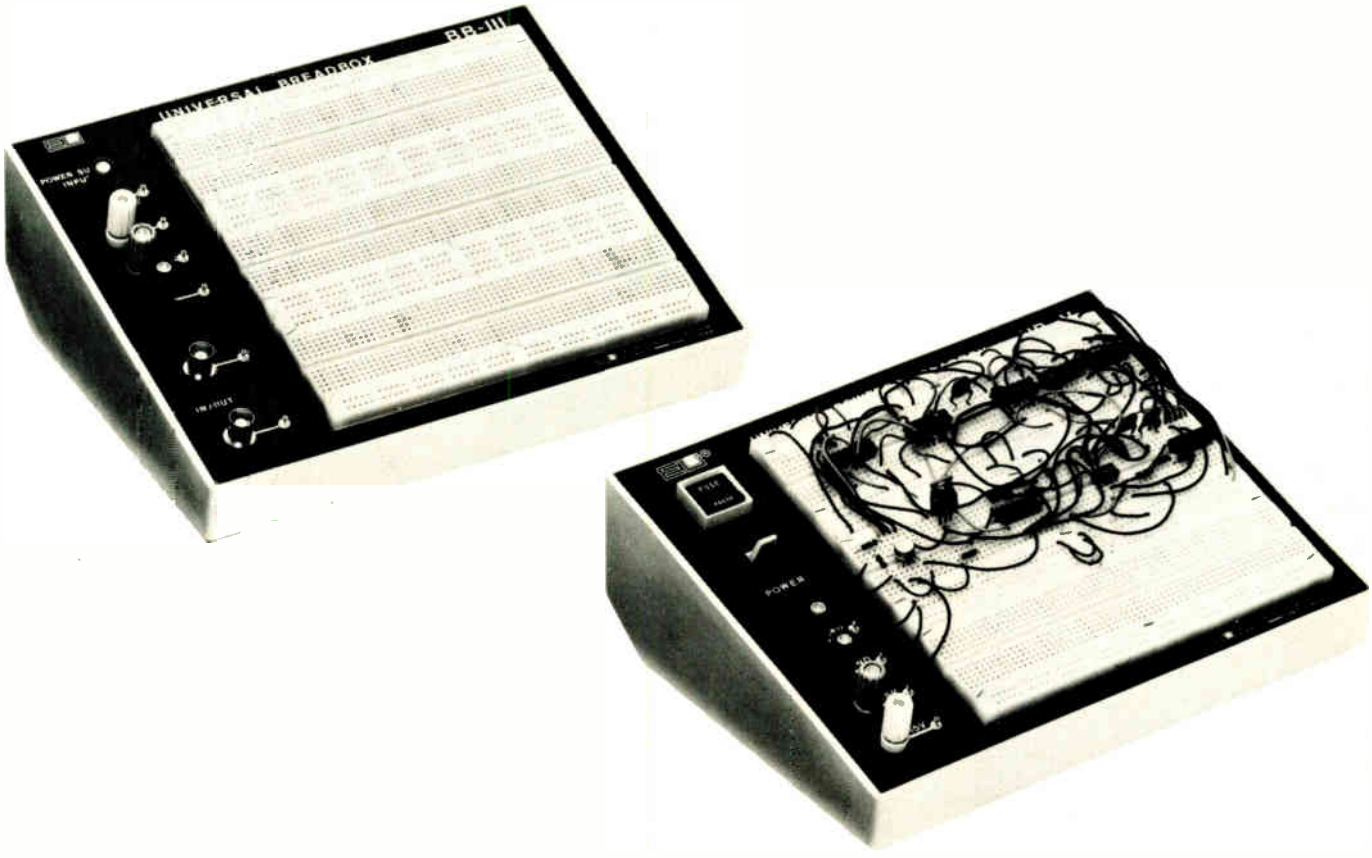
The same base and capabilities as the 100 with an SK-50 replacing the SK-10.

SUGGESTED RESALE PRICE **$21.10**

Designers

BREADBOX III

BREADBOX IV
UNIVERSAL POWERED BREADBOX



FOR ANALOG OR DIGITAL WORK, THE MOST BREADBOARDING CAPABILITY FOR THE LEAST MONEY.

The Breadbox III is the most economical approach to either digital or analog work. Simply plug in your own components on 3 SK-10 sockets and you're ready to build your own circuits. With 4 binding posts for external power and BNC's for scope probe connections and other instrumentation as well. The Breadbox III may be ordered as Option 1 with the sockets detachable and held by Velcro®.

A LOW PRICED, COMPLETELY SELF POWERED DESIGNER.

Two husky power supplies, +5V and +/−15V, plus a breadboarding area of 3 SK-10 sockets large enough to handle almost any design. That's the Breadbox IV. For both digital and analog designs, the Breadbox IV is the most reasonably priced instrument in the field. Available in kit (BB-IVK) or assembled (BB-IVA) form at either 115V or 230V.

SPECIFICATIONS

Connectors:	(4) 5 Way Binding Posts (2) BNC Connectors (6) BP-22 Solderless Breadboarding Pins
Sockets:	(3) SK-10 Sockets
Miscellaneous:	Molded Plastic Box Painted and Screened Metal Panel
Physical:	3.5″ H (8,9 cm) x 7.6″ W. (19,3 cm) x 9″ L (22,9 cm) Sloped Approx. 17° Weight — 3 lbs. (1.12 kg.)

SUGGESTED RESALE PRICE
STANDARD — $72.25, OPTION 1 — $77.75

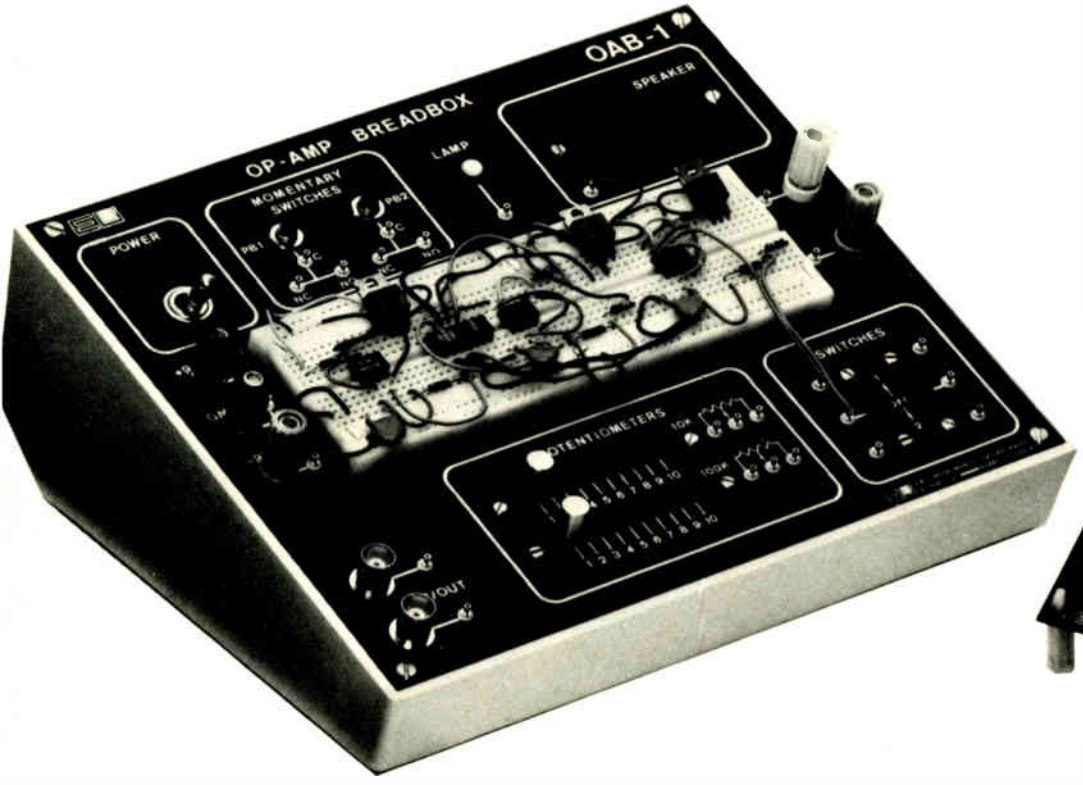
SPECIFICATIONS

Power Supplies:	+5V @ ¾ AMP ±15V @ ¼ AMP
Line & Load Regulation:	Less than 5%
Noise & Ripple:	Less than 5 mv on +5V Less than 10 mv on ±15V
Connectors:	4-five way binding posts 4-BP-22 Solderless Breadboarding Pins 3-SK-10 Sockets
Miscellaneous:	Molded, high-impact, plastic case. Painted and screened metal panel. Internally lighted, on-off switch. Fused @ ¾ AMP
Physical:	3.5″ H (9 cm) x 7.6″ W (19,3 cm) x 9″ L (22,9 cm) Sloped Approx. — 17° Weight — 7 lbs. (3,18 kg.)

SUGGESTED RESALE PRICE
ASSEMBLED — $135.00, KIT — $94.50

Linear/Analog

OAB-1
THE COMPLETE, PORTABLE AND INEXPENSIVE, OP-AMP BREADBOX



An instrument package for linear design work. For testing op-amps or actual circuit design, the battery powered OAB-1 gives you the SK-10 breadboard and BP-22 jacks for complete solderless design. Available either in kit (OAB-1K) or assembled (OAB-1A) form. The OM-1 manual works well with the OAB-1.

SPECIFICATIONS

Power Supply:	(2) 9 volt cells (not supplied)
Controls:	(2) SPST Pushbuttons
	(2) 3-position slide switches
	(2) Slide Pots — 10K and 100K
Connectors:	(1) SK-10 Breadboarding Socket
	(5) 5-way binding posts
	(30) BP-22 Solderless Breadboarding Pins
	(2) BNC Connectors
Miscellaneous:	LED indicator light
	Incandescent Lamp (load)
	Miniature speaker
Physical:	3.5″ H. (8,9 cm) x 7.6″ W. (19,3 cm) x 9″ L. (22,9 cm)
	Sloped Approx. 17°
	Weight — 5 lbs. (2,27 kg.)

SUGGESTED RESALE PRICE
ASSEMBLED — **$90.00**, KIT — **$60.00**

STS-01
A STARTER KIT FOR A MODEST BUDGET

Here's a kit fit for even the most modest budgets. An SK-20 Socket combined with speaker, breadboarding pins, battery clips, mounting spacers and a test switch. The result is a simple but flexible means of building and testing op-amp circuits. Use the learning manual OM-1 for a comprehensive introduction to op-amp work.

SUGGESTED RESALE PRICE **$14.00**

Designers

OA-2
THE COMPREHENSIVE APPROACH TO DESIGNING OP-AMP CIRCUITRY

Fixed +5V and +/−15V power supplies with large current capacity, a sensitive null detector and a full function generator with external frequency adjustment are all the tools you need for linear work and interfacing to TTL Logic. The circuit is assembled on the SK-10 and externally connected by BP-22 breadboarding pins. Available in kit (OA-2K) or assembled (OA-2A) form at either 115V or 230V.

SPECIFICATIONS

Power Supplies:	**Supply A**	**Supply B**
Type	± 15V	+ 5V
Volt. tol.	Fixed, tracking 14.25/15.75	Fixed, regulator 4.7/5.3
Output current	200 ma. each supply	500 ma.
Current limiting	Yes	Yes
Noise/Ripple	Less than 20 mv	Less than 10 mv

Function Generator:
- Waveforms — Sine, square and triangle
- Frequency — Internal 500Hz or externally adjustable from 1Hz to 100KHz
- Distortion — < 3% all waveforms
- Amplitude — Better than 5V peak to peak — all waveforms

Null Indicator: 2 LED's
- Input amplitude w/o overload — 15V maximum
- Sensitivity — detects less than 10/100 mv difference (switchable)
- Indicator — low, null, high (both off at null)

Controls:
- Off/On switch (Integral Light)
- Null sensitivity switch
- Internal/External frequency selector on function generator
- (2) uncommitted SPDT slide switches
- (2) Slide Pots — 10K and 100K

Connectors:
- (1) SK-10 Solderless breadboarding socket
- (4) 5-way binding posts
- (29) BP-22 Solderless Breadboarding Pins

Physical:
- 3.5" H (8.9 cm) x 7.6" W (19,3 cm) x 9" L (22,9 cm)
- Sloped approx. — 17°
- Weight — 7 lbs. (3.18 kg)

SUGGESTED RESALE PRICE
ASSEMBLED — **$175.00**, KIT — **$120.00**

OA-3
TWO FLOATING POWER SUPPLIES FOR OPEN-ENDED DESIGNING

The OA-3 features fully floating variable power supplies that form an exceptionally flexible unit. The highly regulated power supplies make the OA-3 most practical for unusual voltage requirements. The variable power and the fixed 5V supply open up the full range of linear circuit work. The OM-1, OA-2M and the BRS-1, 2 educational materials are perfect for class or home study of linear circuits. Available in kit (OA-3K) or assembled (OA-3A) form at either 115V or 230V.

SPECIFICATIONS

Power Supplies:	**Supplies A&B**	**Supply-C**
Type:	0 to plus 15 VDC 0 to minus 15 VDC Front Panel Adjustable	5 VDC Trimmer Adjustable
Volt. Tol:	± 10% of Scale (or 1 volt)	—
Output Current: (Max)	50 ma	100 ma
Noise/Ripple:	Less than 20 mv	Less than 10 mv

Controls —
- Off/On switch (Integral light)
- (2) Uncommitted SPDT Slide Switches
- (2) Slide Pots — 10K and 100K
- (2) Slide Pots For Variable Supplies

Connectors —
- (1) SK-10 Solderless Breadboarding Socket
- (2) 5 Way Binding Posts
- (22) BP-22 Solderless Breadboarding Pins
- (2) BNC Connectors

Physical —
- 3.5" H (8,9 cm) x 7.6" W (19,3 cm) x 9" L (22,9 cm)
- Sloped Approx — 17°
- Weight — 7 lbs. (3,18 kg)

SUGGESTED RESALE PRICE
ASSEMBLED — **$155.00**, KIT — **$102.50**

Analog / Digital

DD-1
THE ORIGINAL DIGI-DESIGNER

The least expensive entry into digital circuits, the most dynamic area of circuit design. The DD-1 comes complete with a stable internal power supply, pulsers, status switches, I/O connectors, a 6 frequency clock, 4 LED indicators and the SK-10. This complete package meets all of your requirements. At this price the DD-1 is a must for every student, technician or engineer doing digital circuit design. Available in kit (DD-1K) or assembled (DD-1A) form; at either 115V or 230V.

DC-2, an IC package with the appropriate integrated circuits (IC-1) and DD-1 form the DC-3 package. **($126.75)**

"Digital Electronics and Laboratory Computer Experiments," published by Plenum Press is an excellent reference tool for DD-1 self-instruction.

SPECIFICATIONS

Power Supply:
Output:
5 volt DC (user adjustable from 4.0 to 7.0V)
400 ma (5% regulation)
Clock:
Six Frequencies: nominal outputs, 1, 10, 100, 1K, 10K and 100KHz.
Outputs: normal and inverted
Amplitude: nominally 5v peak to peak
Switches:
(2) debounced pushbuttons (logic 0/logic 1)
(4) SPDT Slide Switches to apply ground or 5 volts to circuit
Logic Lamps: (4 LED type)
ON—greater than 2.5V
OFF—less than .5V
Input Impedance—22K Ω
Connectors:
(1) SK-10 Socket
(4) 5-way binding posts
(22) BP-22 Solderless Breadboarding Pins
(2) BNC Conductors
Physical:
3.5" H (8,9cm) × 7.6" W (19,3cm) × 9" L (22,9 cm)
Sloped Approx.—17°
Weight—5 lbs. (2,27 Kg)

SUGGESTED RESALE PRICE
ASSEMBLED — $127.75, KIT — $77.75

CD-1 CMOS/TTL DESIGNER
A NEW GENERATION OF DIGITAL DESIGNING

The new CMOS designer, CD-1, is the most advanced trainer available. It has a fully variable output voltage that allows the user to work with CMOS logic directly as if it were normal TTL circuitry. TTL circuit work is possible by setting the mode selector to TTL position. In fact, with the CD-1 there are virtually no restrictions on designs. Associated educational materials are available for use in formal teaching situations.

Available in kit (CD-1K) or assembled (CD-1A) form at either 115V or 230V.

The CMOS-M and the associated IC's (CMK-1) plus the CD-1K form the CMC-3 package. **($123.50)**

SPECIFICATIONS

D.C. Power Supplies:
Fixed: +5 Volt +/−5%
2% load regulation
1 Amp, short circuit protected
Variable: +3 to +15 Volt
Adjustable from front panel slide switch 100 ma for external use
Clock: 6 frequencies — nominal outputs 1, 10, 100, 1K, 10K, 100KHz
Complementary Outputs: TTL/CMOS Compatible
Switches:
1 — TTL/CMOS Selector switch: places entire unit in either mode
2 — debounced pushbuttons with complementary outputs
4 — logic level slide switches
4 Logic Lamps:
TTL/CMOS compatible logic indicators (L.E.D. type)
Connectors:
(1) SK-10 breadboarding socket (will accept up to 8-14 pin DIP IC's)
(2) uncommitted BNC connectors, case grounded to panel
(2) five-way binding posts
(22) BP-22 Solderless Breadboarding Pins
Physical:
3.5" H (8,9cm) x 7.6" W (19,3cm) x 9" L (22,9cm)
5 pounds (2,27 Kg)
Sloped Approx. −17°

SUGGESTED RESALE PRICE
ASSEMBLED — $145.00, KIT — $97.50

Designers

ADD-8000

MALMSTADT AND ENKE'S DESIGN FOR THE CLASSROOM

The Premiere Breadboarding System. The ADD-8000 is designed with unparalleled flexibility to form a unique aggregation capable of use as a digital voltmeter, a frequency counter and an analytical instrument.

Dr. Howard Malmstadt and Dr. Chris Enke have designed a mainframe complete with every basic function capable of sophisticated unitized circuitry: voltages, waveform generator, 7 segment displays and LED indicators, BCD source and all the necessary switches. V/F, A/D conversions, counter/timer and analog switches are only the beginning.

The ADD-8000 is totally flexible and expandable. It is supported by an experimental workbook, the ADDbook One, and can be used in conjunction with Electronic Measurements for Scientists. Published by W. A. Benjamin, Co., available at your local bookstores.

In addition, Drs. Malmstadt and Enke have designed a complete set of adapter boards and plug-ins, that can easily be installed in older models, such as the EU801A or EU801C, updating them to today's technology.

See separate brochure No. 803-0148.

SUGGESTED RESALE PRICE $995.00
(Complete System)

ADD-8000 SPECIFICATIONS

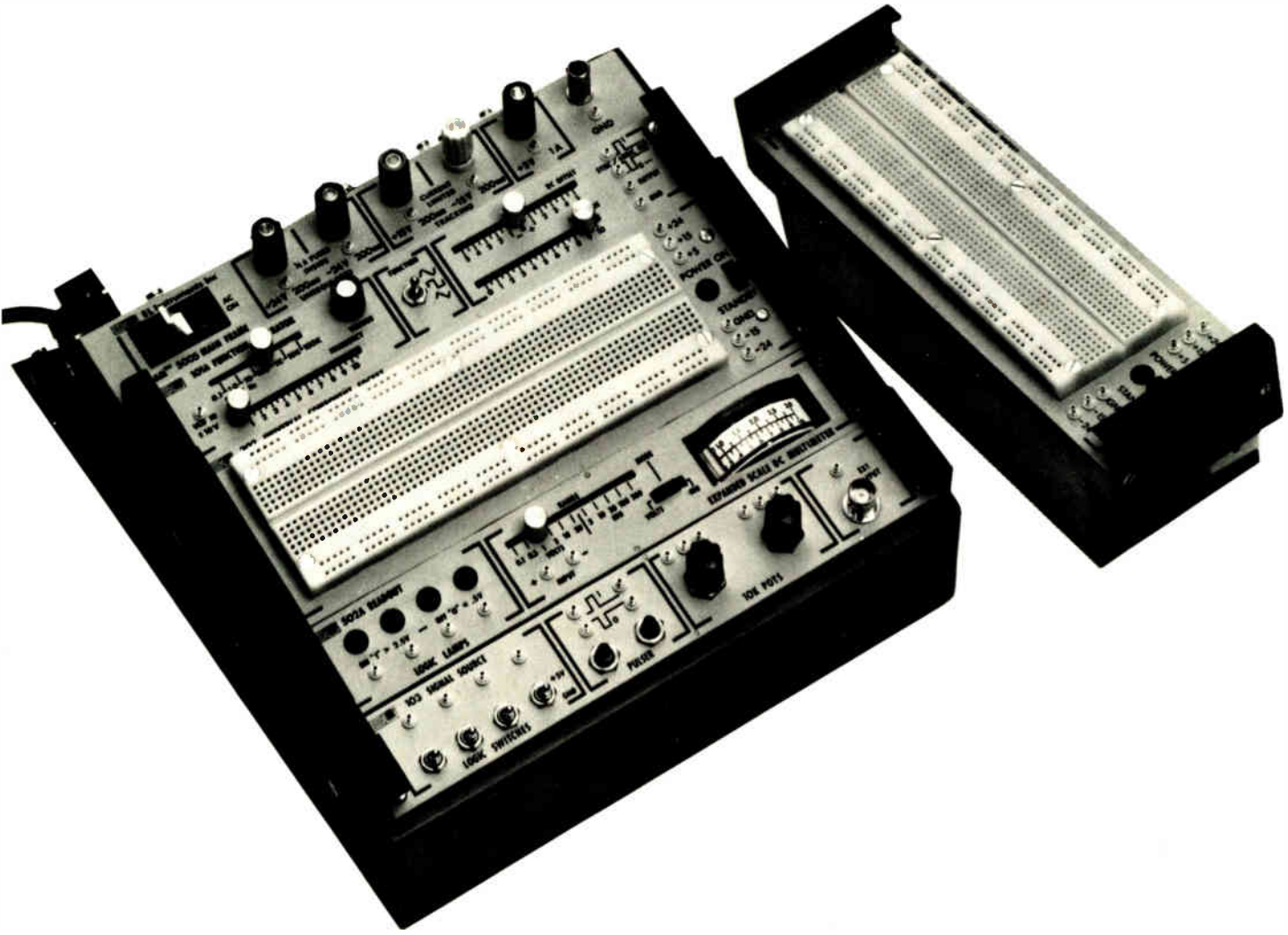
Entire System includes:
1 — ADD-8000 Mainframe
1 — ME-T/ADD — Terminal Block (2 BNC's and 4 five-way binding posts)
1 — ME-C/QOA — Quad Op-Amp Card
1 — ME-C/BBD — Breadboarding Card
1 — ME-C/PAS — Programmable Analog Switch Card
1 — ME-C/DVM — Voltage-to-Frequency Card
1 — ME-C/CTF — Counter-Timer-Frequency Meter Card
1 — Resistor Array — allows the PAS card to become a D/A Converter
1 — ME-M/1 — ADDbook One
1 — ME-J/RO — Readout Jumper Set
1 — ME-J/CW — Pre-cut wire package

MAINFRAME DESCRIPTION

- Function Generator — sine, square and triangle
- Precise adjustable voltage reference source
- BCD encoded source
- Two 4-digit decimal readouts
- LED Status Indicators
- Binary Switch Register
- LED Binary Readout
- Regulated, Current-Limiting Power Supply — 5V @ 3A and ±15V @ 250 ma
- 21 Slot Card Bin
- Velcro* surfaces to attach 2 uncommitted SK-10's
- SK-50 interface socket — to patch front panel functions

Analog / Digital

ADAM



THE MODULAR BREADBOARDING SYSTEM

Custom design your own instrumentation/breadboard package. Take your basic ADAM, use the 5005 powered mainframe and a wide range of individual plug-in modules to meet your own requirement for a specific job or custom circuitry.

The basic 5005 Mainframe contains all power supplies necessary to operate the separate modules plus power for the circuit being designed on the panel-mounted SK-10 universal component socket.

The basic ADAM System includes:

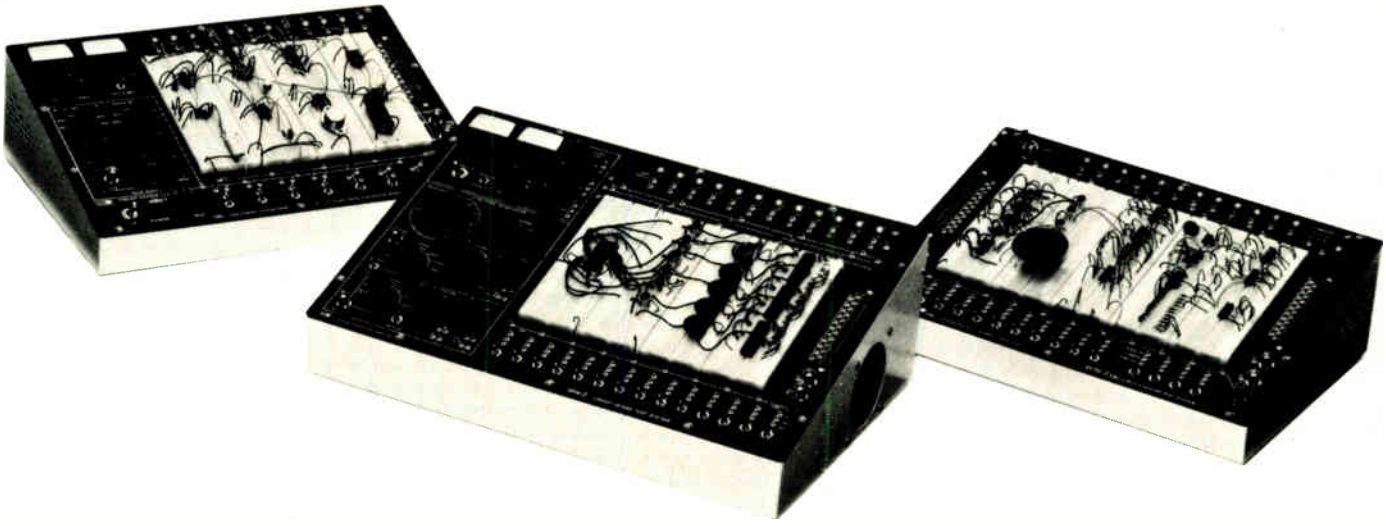
- 5005 Mainframe and power supplies
- 103 Signal Source Module
- 101 Function/Pulse Generator
- 302 Universal Component Socket Module (2)
- 502 Readout and DC Multimeter Module

Individual circuits may be saved and you can continue using the balance of the instrument. Plus, you can expand the entire system simply by adding a blank mainframe (5000) and drawing power from the main unit. See separate brochure 803-0122.

SUGGESTED RESALE PRICE **$510**
(Complete System)

Design Systems

ELITE SERIES



ELITE 1
A COST EFFECTIVE, FLEXIBLE, LARGE SCALE DESIGNER

ELITE 1 is a fully operational breadboarding system, compatible with CMOS logic work. A fully metered (current/voltage) variable stable supply (from 2-10V @ 2 amps), ideal for CMOS or TTL, is complemented by a wide range pulse generator (1Hz to 1MHz) with variable pulse width and amplitude. ELITE 1 also has 4 SK-10's and status monitors, switches and I/O connections.

SUGGESTED RESALE PRICE
STANDARD — **$725.00**
OPTION 1 — **$750.00**
OPTION 2 — **$790.00**

ELITE 2
THE TOP OF THE LINE

All the ELITE 2 needs is an oscilloscope and you have a complete development system. Intermix analog and digital, discrete and integrated logic and work with all of the logic families. ELITE 2 has the capabilities to accomplish almost anything in electronics. Three floating, regulated meter supplies, a full function/pulse generator (1Hz-1MHz), buffered logic lamps (+/− input), a complete array of switches, and I/O connectors and 4 SK-10 sockets. ELITE 2 is the top of the line in circuit design.

SUGGESTED RESALE PRICE
STANDARD — **$1435.00**
OPTION 1 — **$1460.00**
OPTION 2 — **$1500.00**

ELITE 3
THE PACKAGED DESIGNER FOR TTL WORK

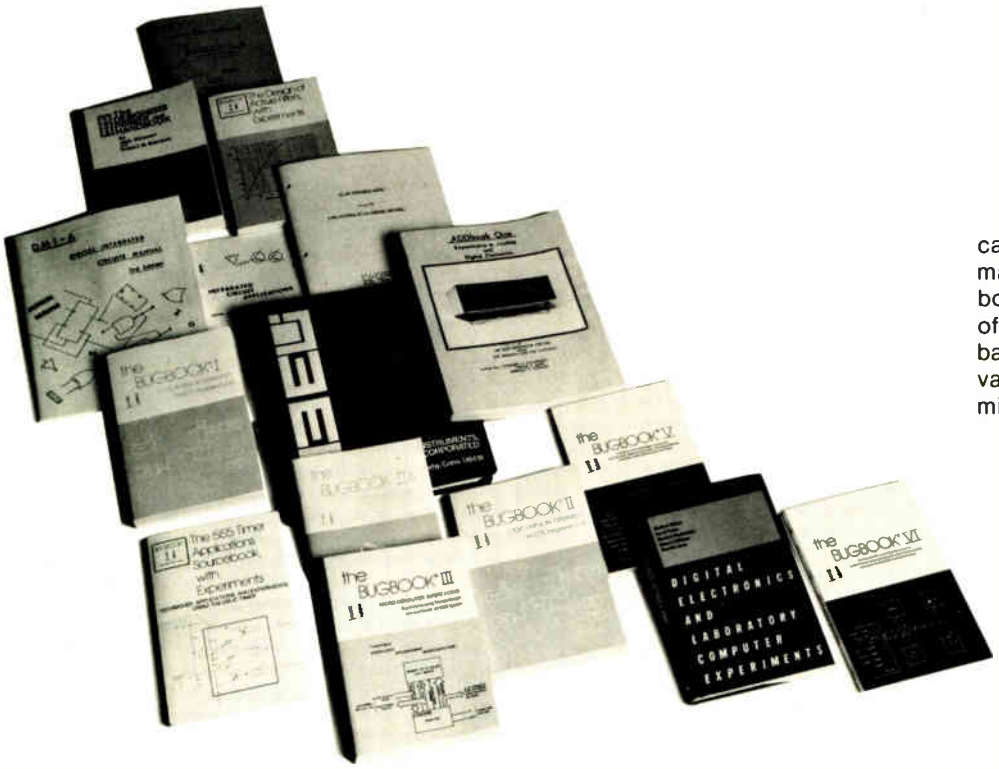
Save time, save money. ELITE 3 is all you need for your TTL applications. It carries a large power supply (2. amps @ 5V), ample switches (that can be ordered as pulsers or bounce free), and I/O connectors that make it a natural for designing a custom interface on a cost-effective basis.

A new option allows the 5 SK-10 sockets to be mounted on a $\frac{1}{8}$" (3,18mm) thick piece of plexiglass, permitting removal of the whole socket area. Please indicate your preference.

See separate brochure No. 803-0103.

SUGGESTED RESALE PRICE
STANDARD — **$410.00**
OPTION 1 — **$435.00**
OPTION 2 — **$475.00**

Educational



E&L offers a group of carefully selected texts, manuals, and reference books that relate to the area of circuit design concepts, basic digital electronics, advanced techniques and microcomputers.

Bugbooks I and II — 750 pages of a well-illustrated and comprehensive text with integral experiments to carry the user from basic digital electronics, such as gates and codes (digital), to sophisticated circuits employing random access memories, sequencers, 4 decade counters and dot matrix displays. Thanks to the unique structure of each Bugbook, users can pick and choose appropriate experiments and questions and proceed at their own pace and depth of interest. Each book is soft bound.

SUGGESTED RESALE PRICE **$17.00**

Bugbook IIA — Interfacing and Scientific Data Communications. A supplement to Bugbooks I & II covering more advance topics in Digital Electronics; in particular, transmission of data with asynchronous techniques using the ASC II code; how to use RS 232/20ma current loops in combinations with the universal asynchronous receiver/transmitter. Soft bound.

SUGGESTED RESALE PRICE **$5.00**

IS — Instructor's Manual This supplementary manual to the Bugbooks I & II is necessary for instructor use in the classroom and laboratory or for individual use in home-study situations. The Manual provides supplemental information including answers to the questions at the end of each experiment, suggestions for further reading, a discussion of the philosophy of the authors in their approach to digital electronics, and organizational suggestions for a lecture/laboratory course. This material is a must for individuals who are taking the course on a self-teaching basis; the answers to the experimental questions provide important feedback concerning the extent to which the material has been learned.

SUGGESTED RESALE PRICE **$3.00**

Bugbook III — Micro Computer Interfacing. Experiments using 8080 Microprocessor system. Soft bound, 597 pages. This is unique text written in a self teaching style with experiments that thoroughly explain how to use, interface and program microcomputers. It focuses on a microprocessor system that uses the 8080 microprocessor and describes both in a general and specific manner. How to interface, how to program, how to work with the I/O busses, working with timing loops and more. The Bugbook III has been used successfully by individuals who are just experimenters or all the way through direct integration into formal classroom studies in universities. The book contains over 60 experiments, over 200 definitions.

SUGGESTED RESALE PRICE **$15.00**

Bugbook V. Introductory Experiments in Digital Electronics, 8080A Microcomputer Programming, and 8080A Microcomputer Interfacing. 493 pages.

The Bugbook V is the first book in an integrated approach to self-instructed basic digital electronics, breadboarding, and 8080A microcomputer interfacing/programming. Detailed laboratory experiments cover the 7440-series of TTL integrated-circuit chips, including the concepts of signal gating; AND, OR, NAND, and NOR gates, truth tables, decoders, demultiplexers, counters, flip-flops, latches, monostable multivibrators, and the 555 timer. The accompanying text provides background information on these subjects. Answers to all tests and laboratory experiment questions are provided in the text.

SUGGESTED RESALE PRICE **$9.50**

Materials

Bugbook VI. Introductory Experiments in Digital Electronics, 8080A Microcomputer Programming, and 8080A Microcomputer Interfacing. 490 pages, May, 1977.

The second book in an integrated approach to basic digital electronics, breadboarding, and 8080A microcomputer interfacing/programming. Also written for self-instruction, Bugbook VI integrates the digital concepts discussed in Bugbook V into a treatment of 8080A microcomputer interfacing and programming. Detailed laboratory experiments in Bugbook VI cover device select pulse and memory address pulse generation; accumulator input/output; memory mapped input/output; three-state bussing; the 8080A instruction set; advanced input/output concepts and experiments; interrupt servicing; and the design of a modest 8080A-based microcomputer. Answers to all tests and laboratory experiment questions are provided in the text.

SUGGESTED RESALE PRICE **$9.50**

BRS-1 — The first of the Bugbook Applications Lines is the 555 Timer Applications Sourcebook. E&L proudly introduces this new addition to the Bugbook Series, the Bugbook Reference Series. The BRS-1 is a laboratory workbook and reference textbook that provides theory and applications of the versatile 555 timer chip. The organization and electrical characteristics of the 555 are discussed and then followed by applications, including monostable multivibrators, astable square wave generators, regulated power supplies, measurement circuits, switching regulators, games, telephone, music and automotive circuits, circuits for the ham, photographer and CB buff. Like the original Bugbooks, the BRS-1 is self-instructional and has sixteen experiments included. The parts to do *all* the experiments come as a separate package, known as the BK-1.

SUGGESTED RESALE PRICE **$6.95**

BRS-2 — The second of the Bugbook Reference Series is a user-oriented text/workbook covering the best design of the various types of low-pass, high-pass, bandpass and notch filters built around operational amplifiers. 26 experiments, design graphs, tables and numerous illustrations make BRS-2 an excellent guide for the experimenter and hobbyist. An inexpensive 4-function calculator can be used to solve all equations and calculations. The parts to do *all* of the experiments come as a separate package, known as the BK-2.

SUGGESTED RESALE PRICE **$8.50**

BRS-3 — The third addition to the Bugbook Reference Series describes D-Bug. Use the BRS-3 to debug assembly language programs for any 8080 microcomputer system. D-BUG may reside in either 1,024 words of EPROM or R/W memory and can be used to examine and modify the contents of memory, punch and read paper tapes (audio cassettes) and single step through an assembly language program using the breakpoint feature. Two complete source listings are included, and examples are used throughout the book to demonstrate valid D-BUG commands and operations.

SUGGESTED RESALE PRICE **$5.00**

ADDbook One — The ADDbook directly integrates the ADD-8000 and the Electronic Measurements for Scientists to form a truly comprehensive teaching system for Analog and Digital techniques. A large format (8½" x 11") book of 400 pages. It gives experimental implementation of the ideas brought out in the Electronic Measurements for Scientists, in up to the minute hardware designs.

SUGGESTED RESALE PRICE **$7.00**

Designers Primer and Handbook CMOS-M — Our recent publication in the CMOS circuitry area has been updated. New IC's have been covered, additional reference material added and redesigned. We also are offering CMK-1, a kit containing the necessary components to do all of the experiments.

SUGGESTED RESALE PRICE **$6.00**

Digital Electronics and Laboratory Computer Experiments by Plenum Press, New York and London
This new guidebook is designed to teach the basic principles of digital electronics and microcomputer applications in the laboratory.

By the proven use of graded experiments, the student is instructed in the application of computer technology to scientific data collection and analysis problems in the laboratory. All seventeen experiments have been thoroughly tested and found to be error free, making this book a reliable manual for both laboratory courses and self-instruction.

The DD-1 Digi-Designer has been used to work one-to-one with each of the experiments.

SUGGESTED RESALE PRICE **$15.00**

Digital Fundamental DC-2 — An experimental approach to understanding digital electronics. The DC-2 is supplied in a lab binder format, with ample area for diagramming and circuit design. This volume covers items from simple switching devices to the complex 74181 Arithmetic-Logic Chip. The text ties directly into the DD-1 Designer and can be easily integrated into formal courses as a lab book. All the IC's necessary to do all of the experiments in the DC-2 are available in the kit IC-1.

SUGGESTED RESALE PRICE **$9.00**

DM-1A — Digital Configuration Manual
This soft cover text lists almost 6000 IC's with their general type called out and referenced to one of 700 different pin outs. All types, including TTL, ECL, DTL, CMOS, MECL, MOS and LSI, are included.

SUGGESTED RESALE PRICE **$7.00**

OP-AMP Experiment Manual OM-1 — The OP-AMP Experimenter's Manual. This book is a useful tool for understanding how Op-Amps work. The softbound volume contains 12 chapters on various experiments for learning linear integrated circuits. It is designed to work with the Op-Amp designers; the Op-Amp Breadbox, or Starter Kit.

SUGGESTED RESALE PRICE **$4.00**

Integrated Circuit Applications and Experiments OA-2M — A compilation of almost 200 experiments mainly covering linear circuitry with added information on complementary digital circuitry. The OA-2M covers an up-to-date spectrum of applications of IC's that range from simple circuits through complex wave form generators. Designed to be used with the OA-2 or the OA-3.

SUGGESTED RESALE PRICE **$4.00**

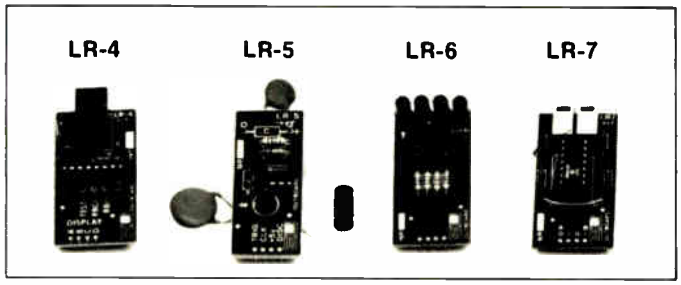
Innovator

Innovator Series

With this inexpensive, easy to use teaching system, students are involved on their very first day with the exciting world of digital electronics. Text/workbooks are integrated with the hardware. A separate teacher's manual gives the instructor valuable lesson information, insight into the problems a student will encounter, supplemental course work and answers to the text questions. Each idea presented by the authors, Rony and Larsen, is immediately reinforced with an experiment. The low cost of the materials makes it possible for each student to have his own work station and to learn by doing. The experimental unit is small and portable, allowing the possibility for lab homework and extra experimentation by the ambitious student. The component parts used to demonstrate various aspects of digital circuitry are plug-in outboards. These outboards plug into one of the SK series on the outer edge leaving the center portion open to build the particular circuit under study. The student actually uses IC's, resistors, transistors, LED's, etc. The system approaches the student first with the individual outboards as tools leaving later lessons open to theory.

BASIC OUTBOARDS

The "Basic Outboards" make up the initial system. They contain the fundamental modules needed to carry out the associated experiments in Bugbooks I & II. They are used to control and monitor what's going on in the breadboarded digital circuit under design/study.



LR-1 POWER OUTBOARD

Used when operating the SK-10/Outboard System from a 6 volt battery. It guarantees that power cannot be applied backwards; it also gives the user a positive indication of power on. It comes complete with 2 insulated Alligator clips for attaching to a battery.

Specifications

Polarity reversal protected
Indicator Light — LED
Lead lengths — 18"
(45, 7cm) terminated in Alligator clips.

SUGGESTED RESALE PRICE
ASSEMBLED — $11.50, KIT — $6.76

LR-2 LOGIC SWITCH OUTBOARD

Allows user to set either logic state 1 or 0 at output terminals.

Specifications

4 logic switches — spdt — rated ½ Amp @ 125V
4 "pull up" resistors connected to Vcc

SUGGESTED RESALE PRICE
ASSEMBLED — $16.40, KIT — $8.50

LR-4 SEVEN SEGMENT DISPLAY WITH DECODER/DRIVER

Gives a numeric readout (0 to 9) based on Binary Code Decimal (BCD) Input. Used in counting circuits, 0/1 indication, etc.

SPECIFICATIONS

Input: BCD, TTL input (5 volts nominal)
Indicator: LED, 7 segment display
Current (max.): 140 ma.
Miscellaneous: (4) BP25's — solderless interconnecting jacks for independent connections to Lamp Test, Blanking Output, Blanking Input and Decimal Point. Display and Associated IC are mounted in IC sockets allowing replacement without soldering.

SUGGESTED RESALE PRICE
ASSEMBLED — $26.65, KIT — $19.00

LR-5 CLOCK OUTBOARD

An outboard that can be used as a standard TTL "clock" that is adjustable via external capacitors inserted across the "C" terminals or as a timer through external components that can be constructed on the SK-10 when the Outboard is installed. The Outboard contains its own indicator for showing the output condition (e.g. — when clocked at a specific frequency, the light blinks on/off at that frequency).

Specifications

Clock: Frequency adjustable from .1 to 20K Hz. for a capacitance range of 5pf to 100 μf.
Capacitors supplied: .03, .33 and 1.0 μf.
Miscellaneous: Indicator Light — LED: 20 ma. (max.)

SUGGESTED RESALE PRICE
ASSEMBLED—$14.80, KIT—$10.50

LR-6 LED LAMP MONITOR OUTBOARD

This outboard gives the user an indication of the logic levels at various points in the circuit under observation. Because the input is used to drive a transistor, a high input resistance results so the circuit is not "loaded" down by the indicator.

Specifications

4 Logic Lights — LED Indicators
On:
logic state 1 (greater than 2.5 volts)
Off:
logic state 0 (less than .5 volts)
Input Impedance:
4,700 ohms
Current:
80 ma. (max.)

SUGGESTED RESALE PRICE
ASSEMBLED — $15.00, KIT — $10.00

LR-7 DUAL PULSER OUTBOARD

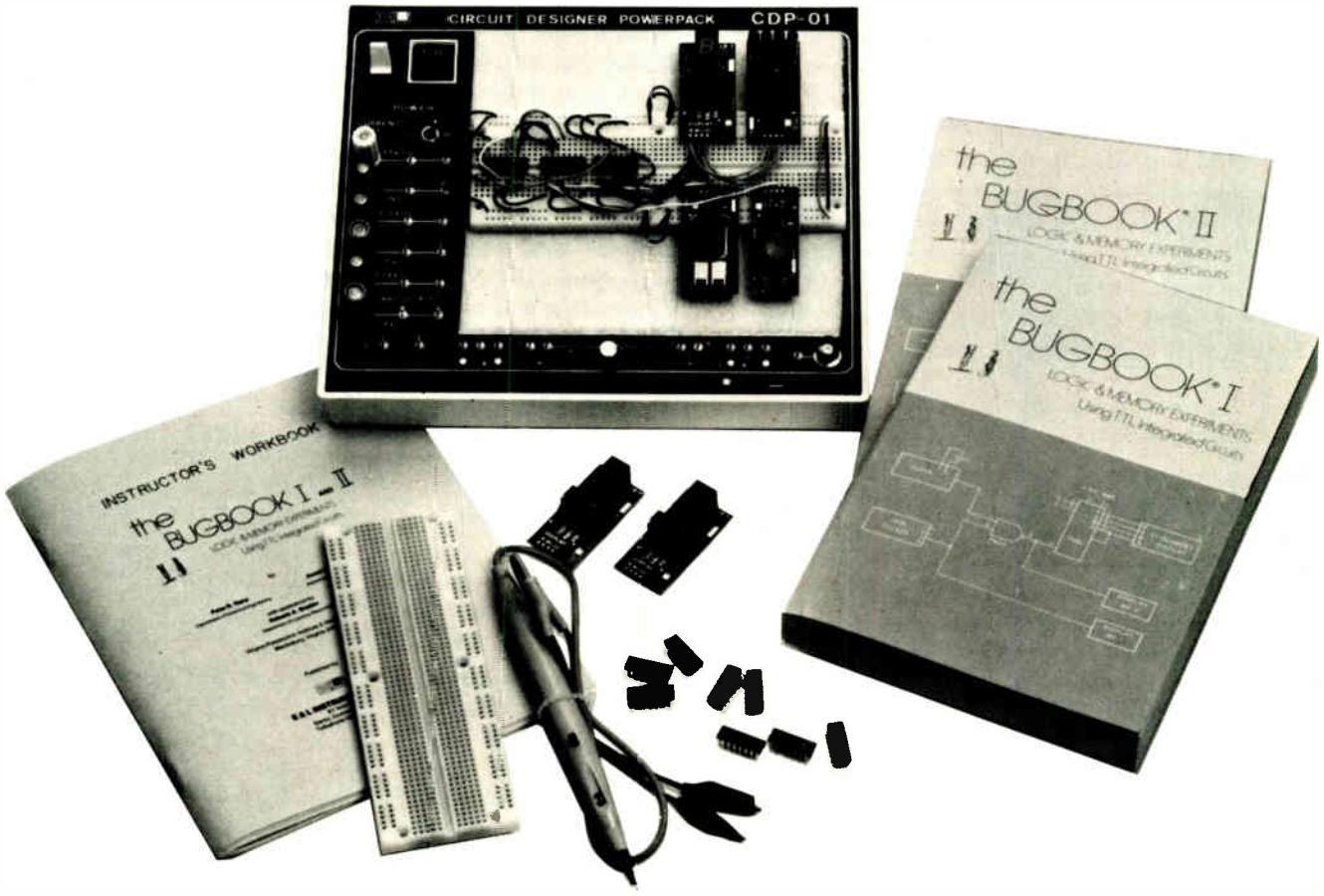
Two miniature spring loaded switches are electronically "debounced" — that is, change state from 0 to 1 or 1 to 0, without any spurious signals when accuated.

Specifications

2 miniature spring-loaded momentary contact switches. Outputs: 2 each switch: one normally "zero," one normally "one." Outputs reverse on switching.
Current:
20 ma. (max.)

SUGGESTED RESALE PRICE
ASSEMBLED—$15.55, Kit—$11.50

Series



Innovator Systems

E&L has put together a number of specific combinations of the outboards and associated items for ease of specification and use by teachers and individual users.

IS-2 — Basic outboards, IC's, wire, SK-10, Bugbooks I & II, a comprehensive assemblage for the beginner. As the student progresses, additional IC's and a power supply may be added to cover all topics and in-depth analysis of particular phases of interest. Available in Kit (IS-2K) or Assembled (IS-2A).

SUGGESTED RESALE PRICE
ASSEMBLED — $138.65, KIT — $105.00

IS-5 — All of the above (IS-2) plus an additional LR-4, IS-EC1 electronics component package. CDP-01 power supply, LT-2 (Logic Probe) instructor's manual and label set BGB-1. Available in Kit (IS-5K) or Assembled (IS-5A)

SUGGESTED RESALE PRICE
ASSEMBLED — $377.05 KIT — $295.76

INSTRUCTOR'S PACK IS-IP-1

To adequately handle most contingencies in a classroom situation, including the need for demonstration experiments, extra work assignments, special projects, and replacement Outboards and wire, E&L recommends that each instructor equip himself with the following items:

Contains Accessory Packages 1, 2 and 3 (see separate listing) Plus All of the Following:

1. Four extra SK-10 sockets
2. One CDP-01, assembled
3. Two "Bugbook I and Bugbook II."
4. Two Instructor's Manuals
5. Two BGB-1 Bugback packages.
6. Additional Outboards. Two each of the following:
   a. LR-1A Power Outboard
   b. LR-2A Logic Switch Outboard
   c. LR-4A Seven-segment LED Display Outboard
   d. LR-5A Clock Outboard
   e. LR-6A LED Lamp Monitor Outboard
   f. LR-7A Dual Pulser Outboard
   One each of the following:
   g. LR-10A Programmable Counter/Timer Outboard
   h. LR-11A Universal Outboard
7. Zero-insertion-force sockets
   a. Two 24-pin IC sockets
   b. Two 40-pin IC sockets
8. No. 22 gage solid wire cut to length with ¼" (6,4mm) stripped ends.
   Six (6) colors of each of the following lengths:
   a. Ten (10) lengths of 1¾" (4,5cm)
   b. Ten (10) lengths of 3" (7,6cm)
   c. Four (4) lengths of 6" (15,2cm)

Additional Software
   a. TTL Databook by Texas Instruments
   b. TTL Cookbook (Lancaster) by H. Sams

SUGGESTED RESALE PRICE $890.00

Innovator

THE DATA TRANSMISSION OUTBOARDS

One area of great concern to individuals in digital electronics today is interfacing and Scientific Data transmission. To meet this need E&L offers three unique outboards that directly use Bugbook IIA for their experiments.

LR-13 LINE DRIVER/RECEIVER — RS232 INTERFACE OUTBOARD.

A dual line driver/receiver specifically intended for a UART to Modern Interface

- Can interface any TTL to Modern/MODEM to TTL
- Acts as a schmitt trigger, sine to square wave converter
- Exhibits either a high differential or high common mode noise immunity
- Use with the LR-21 to interface to MODEM

SUGGESTED RESALE PRICE
ASSEMBLED — $39.80, KIT — $28.00

LR-14 TTL/20 MA CURRENT LOOP INTERFACE OUTBOARD.

Interface TTL (+5V) to teletypes and CRT's.

- +5V TTL I/O; fan in of 1; fan out of 10
- logic 1 with 3 ma; logic 0 with 15ma.
- optically isolated for ground loop elimination
- on board regulation (regulator not isolated from ground)
- data speed — DC to 30 K bit/sec. (typ)

SUGGESTED RESALE PRICE
ASSEMBLED — $40.00, KIT — $28.80

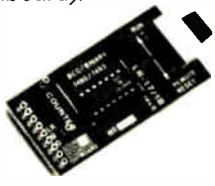
THE "STACKABLE" OUTBOARDS*

E&L's Stackable Outboards include a number of circuits that are configured in such a manner that they may be inserted directly into the SK-10, or they may be vertically assembled onto each other to perform a complete function in a number of ways. There are a number of these combinations that have been evolved, for example: *To obtain a complete counting circuit, assemble on the LR-17 (BCD Decode Counter) the LR-19 (LATCH) and finally, the LR-4 (7 segment Readout/Decoder Outboard).*

LR-19 LATCH OUTBOARD

The LR-19 incorporates a positive edge triggered latch which can be used as a 4-bit memory with complementary outputs, Q and Q. STROBE and CLEAR inputs are provided.

SUGGESTED RESALE PRICE
ASSEMBLED — $29.00, KIT — $25.00



LR-17/18 BCD DECADE COUNTER/4 BIT BINARY COUNTER

These Outboards differ only in the substitution of a 4-bit binary counter IC chip (LR-18) for a BCD decode counter IC chip, (LR-17). A DPDT switch permits either a free running counter or a counter that can be reset to 0 from a remote input. The decade counter can also be remotely reset to 9.

SUGGESTED RESALE PRICE
LR-17 ASSEMBLED — $18.25, KIT — $15.25
LR-18 ASSEMBLED — $18.50, KIT — $15.25

LR-21 UNIVERSAL ASYNCHRONOUS RECEIVER/TRANSMITTER (UART)

LR-21 covers 8 bit parallel binary input asynchronous serial output and visa-versa.

- It operates at speeds to 30 kilobaud.
- Double buffered allowing storage while another word is being sent or received.
- Has 3 state outputs permitting positive buss operation.

SPECIFICATIONS

Two supply voltages are required, +5 volts and −12 volts. It is possible to replace the latter by a −15 volt supply. Fanout at each output: one TTL load.

Will accept clock frequencies to 480 KHz, and transmits data at rates of up to 30K baud.

Requires the following minimum pulse widths for the indicated inputs:

Input	Minimum pulse width, nsec.
Clock Pulse	1000
Control Strobe	300
Data Strobe	190
External Reset	500
Status word enable	500
Reset data available	250
Received data enable	500

Permits the following options for the asynchronous serial data work:

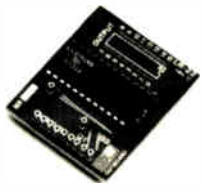
Start bit	1	Parity bits	0 or 1
Data bits	5, 6, 7 or 8	Stop bits	1 or 2

Provides the following flag signals:

Transmitter buffer empty	Parity error	Overrun
End of character	Transmitter buffer empty	Framing error
Data available		

Contains an independent buffered receiver and an independent buffered transmitter that can be clocked independently. However, the control bits apply to both receiver and transmitter simultaneously, so both the transmitted and received words must have the same number of data bits, parity bits, and stop bits.

SUGGESTED RESALE PRICE
ASSEMBLED — $60.00, KIT — $40.00



LR-22 DECODER OUTBOARD

This 4-line to 16-line decoder Outboard can be stacked into the LR-18 binary counter to produce a 16-state sequencer. Its main use is as a microprocessor output decoder.

SUGGESTED RESALE PRICE
ASSEMBLED — $24.00, KIT — $16.50

LR-23 MULTIPLEXER OUTBOARD

The LR-23 is a 16-line to 1-line multiplexer that can select information appearing at any one of sixteen different input channels and provide it in inverted form at a single output. It is very useful for multiplexing data into a microprocessor input port.

SUGGESTED RESALE PRICE
ASSEMBLED — $23.50, KIT — $15.50

Series

SUPPLEMENTAL OUTBOARDS

In keeping with the concept of flexibility and expansion of the basic Innovator Series, the following items are now available to complement the original Outboards®, Bugbooks®, and CDP-01.

LR-16 VARIABLE POWER SUPPLY

With 15 VDC input, this small variable supply adjusts the output voltage continuously from approximately 3 to 14 volts DC.

SPECIFICATIONS

(With 15 volts in)
Output voltage: 3 to 14 volts
Regulation: –1%
Output current: 100 ma. (max.)

SUGGESTED RESALE PRICE
ASSEMBLED – $18.50, KIT – $16.00

LR-25 TTL BREADBOARDING OUTBOARD

The LR-25 combines the functions of the basic outboards on a single DC board. All the basic controls and monitor elements needed for digital work are contained in a very hard supplement suitable for even advanced design work. The HEX decimal display is not supplied with the base unit but is available as an option.

SPECIFICATIONS

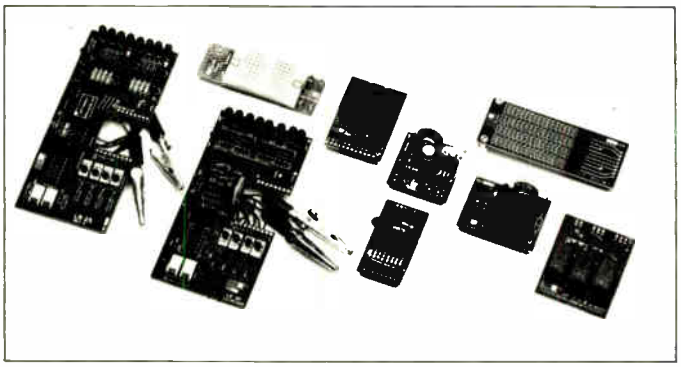
(8) LED type indicators
(4) Logic Switches
(2) Bounce-Free Pulsers
(1) Variable Clock (frequency selected by external capacitor)

SUGGESTED RESALE PRICE
LR-25 ASSEMBLED – $61.10
LR-25 KIT – $36.50
HEX OPTION – $22.50

LR-110 KLUGE CARD OUTBOARD

This board complements the LR-11. It represents a simple way of building permanent circuits that are routinely used as part of a design.

SUGGESTED RESALE PRICE $6.65



LR-30 CMOS BREADBOARDING STATION

Identical in function to the LR-25 but modified to operate over a range from 3 to 15 volts. This unit is not available with the HEX decimal optional display.

SPECIFICATIONS

Input voltage 3-15 volts
(8) LED indicators
(4) Logic Switches
(2) Bounce-Free Pulsers
(1) Variable frequency clock selected by external capacitor; adjustable through outboard potentiometer.

SUGGESTED RESALE PRICE
ASSEMBLED – $43.00, KIT – $33.00

LR-27/28 THREE DIGIT LATCHES

Three character HEX-decimal displays. The 27 and 28 are identical except for independent displays with common strobe on the 28.

SUGGESTED RESALE PRICE
LR27 & 28 ASSEMBLED – $87.50
LR 27 & 28 KIT – $75.00

LR-11 UNIVERSAL OUTBOARD

The SK-20 Universal component socket is combined with BP-25 solderless breadboarding pins. All connections are made without soldering – only 22 gage solid wire is needed for interconnections.

SUGGESTED RESALE PRICE–$11.00

LR-15 PULSE GENERATOR

A variable pulse generator that covers a broad spectrum of frequencies: the pulse width is adjustable by the built-in potentiometer. The base frequency is selected by external capacitors that simply plug into the two BP-25's at the rear of the generator.

SUGGESTED RESALE PRICE
ASSEMBLED – $16.00, KIT – $11.25

LR-10 PROGRAMMABLE TIME/COUNTER

A counter/timer that allows the user to program various combinations of time delays and frequency generation.

SPECIFICATIONS

Programmable Timer/Counter

	XR2240/2340
Timer Length	microseconds to days: accurate to .5%
	TTL Outputs
Maximum "toggle" rate	1.5 meg. hz.
Current:	10 ma. (max.)

8-BP25's – solderless interconnecting pins for connections in parallel to 16 pin IC socket and header for programming.

NOTE: One unused 16 pin header is supplied for user's designed projects; one 16 pin header is supplied with components for experimental use.

SUGGESTED RESALE PRICE
ASSEMBLED – $48.50, KIT – $29.00

LR-31 FUNCTION GENERATOR OUTBOARD

The LR-31 Function Generator Outboard can generate a square wave and either a sine wave or a triangle wave. Frequencies of 0.01 Hz to 1 MHz are possible, depending on the value of the user selected capacitor. With a single capacitor the dynamic frequency range is greater than 1000:1.

SUGGESTED RESALE PRICE
ASSEMBLED – $46.40, KIT – $36.00

LR-32 4 DECADE COUNTER OUTBOARD

The LR-32 Decade Counter Outboard is a complete 4 decade counter including 4 decade counters, latches, display drivers, display multiplexing circuitry and 4, 7-segment LED displays. The carry output of the LR-32 4 Decade Counter Outboard is available so that LR-32's can be easily cascaded. When used in conjunction with the LR-33 Quartz Crystal Outboard, frequency counters, period meters and event counters can be easily constructed.

SUGGESTED RESALE PRICE
ASSEMBLED – $99.00, KIT – $77.00

LR-33 QUARTZ CRYSTAL OUTBOARD

The LR-33 Quartz Crystal Outboard uses a state-of-the-art MOS-LSI technology to provide stable, programmable frequency source. With the on-board thumbwheel switch or jumpers on the bread-boarding socket, you can select an output frequency of from 1 MHz to 0.01 Hz, by factors of ten.

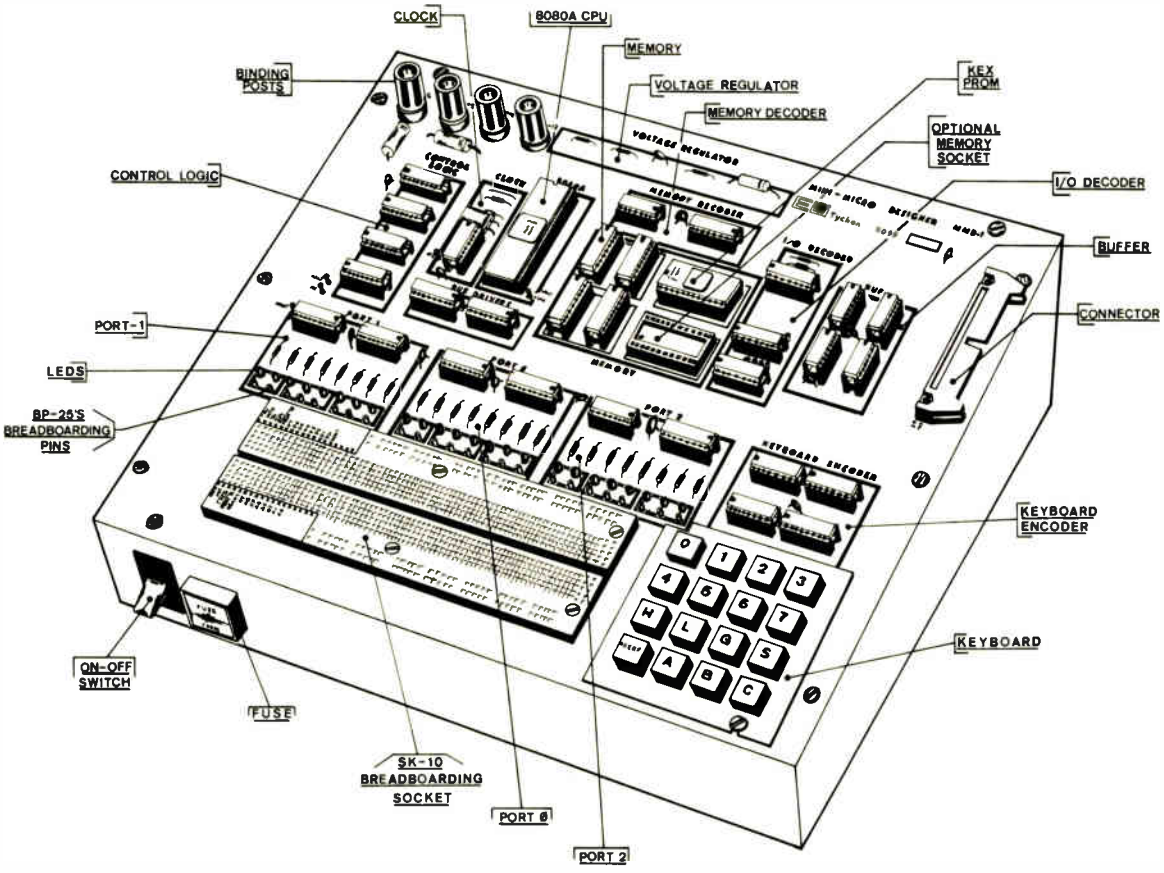
SUGGESTED RESALE PRICE
ASSEMBLED – $75.00, KIT – $50.33

LR-34 UNIVERSAL TRANSISTOR OUTBOARD

The LR-34 Universal Transistor Outboard enables you to easily breadboard TO-3 and TO-220 power transistors, SCR's, triacs and solid state voltage regulators. With transistor sockets provided on the outboard, it is very easy to switch between either a TO-3 or TO-220 device.

SUGGESTED RESALE PRICE
ASSEMBLED – $15.00, KIT – $10.80

Microprocessor



CONTROLS, SOCKETS, CONNECTORS, AND CIRCUIT FUNCTIONS

FIGURE-1

MMD-1

MMD-1 8080A Based Computer for training and hardware development. The Mini-Micro Designer is a low cost, expandable system totally supported by The Bugbook educational materials. The Bugbooks are the ideal introduction to computers for the beginner as well as those with considerable technical background and experience. The texts, which double as laboratory manuals, start with digital coding and microcomputer programming and advance the student to the practical aspects of programming and interfacing. The MMD-1 features direct keyboard entry of data and instructions in easily understood octal code.

The MMD-1 is the only microcomputer system now on the market that permits the user to design his own interface in 10 to 20 minutes and implement the design with ordinary hook up wire and standard readily available 7400 series IC's. No special assembly tools are needed.

All in all, the student can carry out over 60 experiments in the Bugbook texts as well as many other circuit designs without the need for soldering or the construction of simple circuit functions. Available either in kit (MMD-1k) or assembled (MMD-1A) form at either 115V or 230V operation.

See separate brochure #803-0144.

SUGGESTED RESALE PRICE ASSEMBLED — **$600.00**, KIT FORM — **422.80**

SPECIFICATIONS

Central Processor
8080A or equivalent

Memory
Read/Write, Random Access (RAM); 512 words by 8 bits furnished on main MMD-1 circuit board.
Expandable up to a total of 65,536 words. (Additional power required over 2500 words.)
Programmable Read Only (PROM) programmed to permit keyboard entry of data in octal code; keyboard executive program (KEX) 256 words by 8 bits.
(Open socket on board permits an additional 256 words.

Display
Light-emitting diode lamps (LEDs); three groups of eight individually latched and addressable under software control.
LEDs display low address, high address and memory contents.

Data Entry
Keyboard; 16-switch with keys organized in octal code 0 to 7, Hi address (H), Lo address (L), go (G), reset (RESET), examine/deposit (S) and three optional keys (A, B, and C).

Interface Socket
E & L SK-10/IF 18. Direct interface connection includes $\overline{D}_0$ - $\overline{D}_7$; $\overline{A}_0$ - $\overline{A}_7$; $\overline{In}$, $\overline{Out}$, $\overline{MEMW}$, +5, GND $\overline{MEMR}$, INT, INTE, WAIT, READY, $\overline{I\,ACK}$.
Open area on socket will take up to five 16-pin ICs and discrete components with 20 to 26 AWG wire leads.

Ribbon Cable Connector
Dual, 20-pin wired the same as the SK-10 interface socket with A8 thru A15 added.

Internal Power Supply
Line Voltage - 115V or 230V ac, fused

Outputs
+ 5V dc @ 1.5A
+12V dc @ 150mA
−12V dc @ 150mA

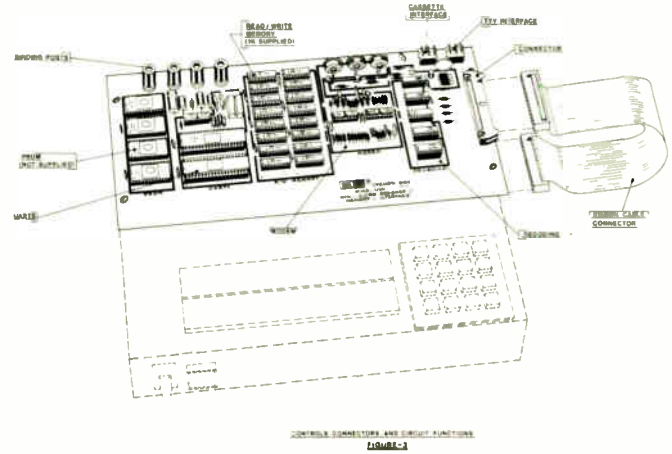
Microprocessor Chip Set

1	8224	Clock Generator and Driver
4	8111-2	1024-bit (256 by 4) static MOS RAM
2	8216	4-bit parallel bidirectional bus drivers.
1	1702	2048-bit (256 by 8) programmable read only memory (PROM) (Factory programmed as KEX PROM)

Dimensions
12" (30,5cm) by 10" (25,4cm) by 3½" (8.9cm)

Weight
6.3 pounds (2,86kg.)

Systems
AND ACCESSORIES



MMD-1/MI
MEMORY-INTERFACE BOARD

The Memory and Interface Board (M/I) is an accessory designed to permit hardware and software development to be performed on the MMD-1 microcomputer system.

The M/I board provides additional memory and teleprinter and audio cassette recorder interface. The use of an Audio Cassette Recorder allows for low cost storage of data in the course of software development.

The M/I board uses two universal asynchronous receiver transmitters (UART) for synchronization, formatting and parallel series conversions necessary for communications with teleprinters. The UARTS handle data in blocks of 8-bits. The American National Standard Code for Information Interchange (ASCII) is employed in the 8-bit data block.

The M/I board contains a relay driver circuit for use with a teleprinter paper tape reader relay. This option permits software control of all reader start/stop operations.

No restrictions are placed on the format for communications with the audio recorder as the recorder need not be directly interfaced with any other terminal for printing or display of readout.

Available in kit (MMD-1/MIK) or assembled (MMD-1/MIA) form.

SUGGESTED RESALE PRICE
ASSEMBLED — **$250.00**, KIT — **$194.50**

SPECIFICATIONS

Power Consumption
(with maximum memory installed):
+5V dc @ 1A
+12V dc @ 0.1A
−12V dc @ 0.25A

Memory:
Read/Write (RAM) 2048 words capacity. (1024 words supplied.)
Programmable ROM (PROM) 1048 word capacity (non supplied).

Teleprinter Interface:
Full Duplex, 20mA current loop
110 Baud
Reader Relay Control

Audio Recorder Interface:
Software controlled.
Two-tone audio 2125 Hz/2975 Hz (FSK)
UART formatted
300 Baud Data Rate
Output Impedance: 47K ohms
Output Signal: 1volt ac (2V P-to-P)
Input Impedance: 10K ohms
Input Signal: 1 volt ac (2V P-to-P)

Ribbon Cable Connector:
Dual, 20-pin wired to full computer buss. (Interconnecting cable supplied — 6" long.)

MMD-PP PROM PROGRAMMER

In those applications where the user of the MMD-1 needs to permanently hold his programs, he will find the MMD-PP a valuable tool. It is specifically designed to pop the 1702A PROMS used in the MMD-1 and is remarkably easy to use thanks to the control PROM that accompanies the MMD-PP . . . only a few strokes on the keyboard and the transfer of data can take place. The Programmer allows the 1702 to accept data from the memory on board the MMD-1 or from another PROM when inserted in the "master" socket on the Programmer itself.

The Programmer allows the user to verify the popped PROM versus the master or versus the program in MMD-1 memory. Zero insertion force sockets are used to minimize the danger of damaging the PROM's leads. The unit comes complete with interconnecting cable to attach it to the MMD-1 and is available in kit (MMD-PP/K) or assembled (MMD-PP/A) form.

SUGGESTED RESALE PRICE
ASSEMBLED — **$216.50**, KIT FORM — **$161.00**

SPECIFICATIONS

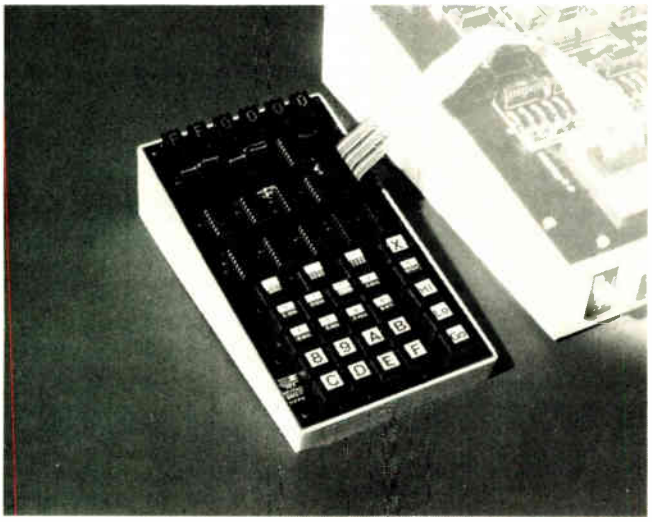
Capable of Programming: 1702 (A) Only
Typical Time to Program: Four (4) Minutes
Programming Mode:
A.) Copy a Master PROM.
B.) Copy any 256 word block of MMD-1 Memory, i.e. RAM or PROM.
Verify Mode:
A.) Compare contents of the programmed PROM with contents of a Master PROM.
B.) Compare contents of the programmed PROM with any 256 word block of MMD-1 Memory, i.e. RAM or PROM.
Transfer Mode:
Transfers (copies) cata from a Master PROM to a fixed buffer zone in MMD-1 RAM. The data can then be modified (edited) and a new PROM programmed directly from the buffer zone.
Power Supply:
Self contained (not available for external use), no external supplies required.
115/230 volt operation.
MMD-1 Clock Speed:
The standard 6.750 MHz crystal *must* be used when using the PROM programmer.
Control Prom:
The PROM Programmer makes use of the MMD-1 computer to perform its function via a Control PROM located on the popper. This PROM resides at address 377 000 through 377 377 in the MMD-1 memory array.

Zero insertion force sockets are used for MASTER, VERIFY and PROGRAM positions.

Size: 3.5" H (8,9cm) x 7.6" W (19,3cm) x 9" L (22,9cm)
Weight: 7 lb x. (3,18Kg)
Accessories — Accessory # 1 — Additional 40 pin connector and Interconnect Cable **$15.00**

Microprocessor

HEX KEYPAD



The Hex Keypad has been developed as a general purpose, microcomputer, data entry/display device for persons who find it convenient to work with Hex-decimal Coding. The keyboard section generates four bit Hex code corresponding to the legends on the keys. The keys are priority encoded such that if two or more keys are struck simultaneously the value of the highest order will be output. This feature prevents the generation of false codes and simplifies the processing of data from the Keypad. The Keypad can also be jumper selected for device codes 0 thru 7.

The Keypad is used in conjunction with E&L's Mini-Micro Designer (MMD-1) to permit direct Hex programming of the computer or as a separate I/O device. To convert the MMD-1 for direct hexidecimal programming simply replace the existing KEX prom, in position "O" with the Hex L/D prom provided and interconnect the two units with the cable provided.

MMD-HEX-1 (without displays)

SPECIFICATIONS

Data Entry: The keyboard section has a 16 key Hex Encoded keypad plus 8 encoded function keys, priority encoded.

Interfacing: Interconnect capable via a 28 pin DIP double ended ribbon cable. One end goes to the committed portion of the SK-10 on the MMD-1 and the other end goes to the 28 pin DIP socket on the keypad. The following signals are utilized:

GND, +5V — Breadboarding pins provided for external use

IN
OUT
AO thru A7
DO thru D7

Power Requirements: Approx. 1/4 AMP

Device Selection: The keypad is jumper selectable for device codes 0 thru 7. Factory wiring is for use with the HEX L/D PROM.
Keyboard — Device Code 001

Physical: Dimensions — 7 3/4" (19,7cm) L x 4 5/8" (11,4cm) W x 3" (7,6cm) D
Weight — Approx. 1 lb

SUGGESTED RESALE PRICE
ASSEMBLED — **$125.00**, KIT — **$105.00**

MMD-HEX-2 (with Displays)

SPECIFICATIONS

Displays: Three pairs of Hexidecimal Latched Displays, provided for. One pair is supplied standard while the additional two pairs are optional

Data Entry: The keyboard section has a 16 key Hex Encoded Keypad plus 8 encoded function keys, priority encoded

Interfacing: Interconnect capable via a 28 pin DIP double ended ribbon cable. One end goes to the committed portion of the SK-10 on the MMD-1 and the other end goes to the 28 pin DIP socket on the Keypad. The following signals are utilized:

GND, +5V — Breadboarding pins provided for external use

IN
OUT
AO thru A7
DO thru D7

Power Requirements: Approx. 1 AMP (fully loaded with all displays)

Device Selection: The keypad and each pair of Hex Displays is jumper selectable, for device codes 0 thru 7, via headers. Factory wiring is for use with the Hex L/D Prom

Keyboard — Device Code 001
Data — Device Code 002
Lo Address — Device Code 000
Hi Address — Device Code 001

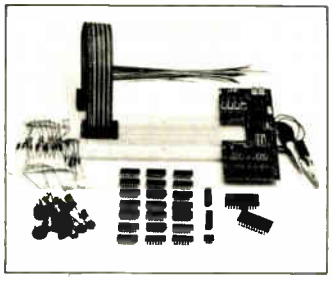
Physical: Dimensions — 7 3/4" (19,7cm) L x 4 5/8" (11,4cm) W x 3" (7,6cm) D
Weight — Approx. 1 lb.

Accessories — Accessory # 1 — Two (2) Hexidecimal displays (T.I. #311) **$33.00**

SUGGESTED RESALE PRICE
ASSEMBLED — **$185.00**, KIT — **$155.00**

MMD-1/SS

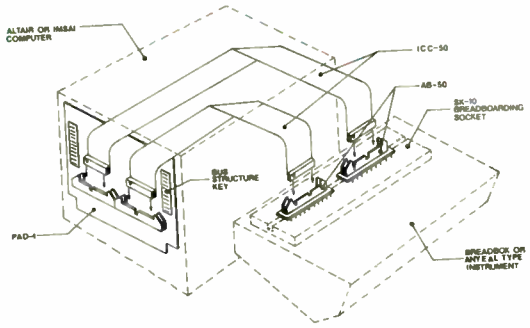
The Student Station is a package built around the LR-25. This package will give the user the material to do most of the experiments in Bugbooks V and VI. It includes an extra SK-10 socket, IC's, 28 pin dual interconnecting Cable, wire and miscellaneous components.

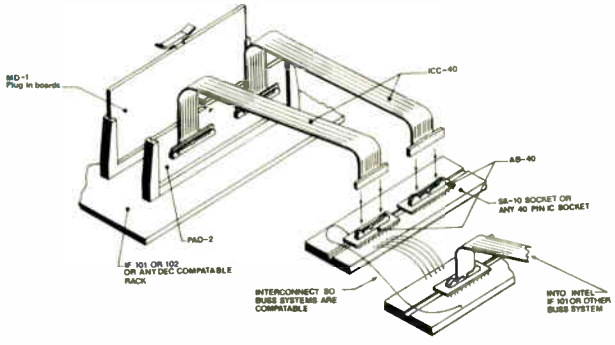


SUGGESTED RESALE PRICE
ASSEMBLED ONLY — **$150.00**

Accessories

COMPATIBLE ACCESSORIES





ALTAIR®/IMSAI® COMPATIBLE

PAD-1 — New breadboarding aid for the Altair®/Imsai® owner; plugs directly in the Altair®/Imsai® buss. Use with optional cable and dual-in-line adapter, listed below, with your PAD-1 to plug your Altair™/Imsai® unit into an SK-10 Breadboarding Socket, Breadbox, or other E&L Breadboarding instruments.
SUGGESTED RESALE PRICE **$35.00**

AB-50 — A plug/socket combination to adapt 50 wire strip cable to 50 pin dual-in-line plug. Use with PAD-1 to plug into the SK-10 Socket.
SUGGESTED RESALE PRICE **$22.50**

ICC-50 — 50 wire strip cable with female, strain-relieved connector on each end. Comes standard at 18" (45,7cm) long. Plugs directly into the AB-50.
SUGGESTED RESALE PRICE **$32.50**

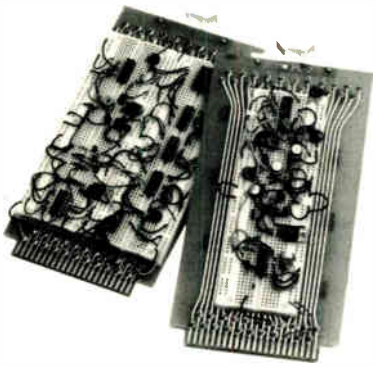
MD-1/DEC® COMPATIBLE

PAD-2 — For MD-1 and DEC® buss system owners. This board is similar to the PAD-1 but configured to plug into the MD-1 Interface Board or any other system using a dual DEC connector.
SUGGESTED RESALE PRICE **$27.50**

AB-40 — A plug/socket combination to adapt 40 wire strip cable to 40 pin dual-in-line plug. Use with PAD-2 to plug into the SK-10 Socket.
SUGGESTED RESALE PRICE **$20.00**

ICC-40 — 40 wire strip cable with female, strain-relieved connector on each end. Comes standard at 18" (45,7cm) long. Plugs directly into the AB-40.
SUGGESTED RESALE PRICE **$31.50**

PL1, PL2

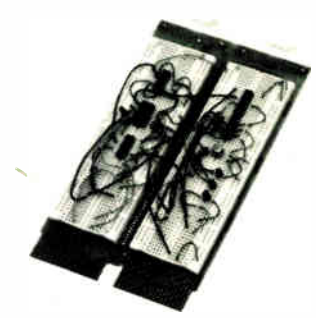


The Plug In Socket Boards are used to construct semi-permanent wired circuits in a totally solderless manner. They can be plugged into card edge connectors (such as those on the Adam or Elite) that are part of larger breadboarding systems, or can be used in card racks as part of "finished" systems.

The PL 1 and PL 2 offer standard SK-10 sockets all of which are available for construction of circuitry; external connections to the edge connector are made by "jumping" to the appropriate interconnecting jack with 22 gage wire.

SUGGESTED RESALE PRICE
PL-1 — **$52.50**, PL-2 — **$38.50**

DEC 2



The DEC 2 uses the interfacing version of the SK-10, which hard wire a portion of the socket directly to edge connectors eliminating the need for jumpers. The DEC 2 uses standard DEC spacing on the edge connector and is particularly useful as a supplemental card in the MD-1 Microprocessor.

SPECIFICATIONS

Printed Circuit Boards: 1/16" (1,57mm) G10
Size: 4.5" (114,33mm)w x 9.5" (25,44cm)L.
Edge Connectors: Gold Plated
Card Pullers: Molded Plastic

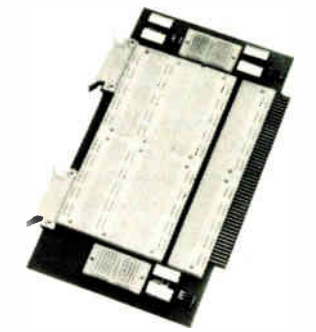
(2) SK-10-1F 18 Sockets
(72) Contact Card Edge Connector: 125" (3,18mm) spacing

SUGGESTED RESALE PRICE **$76.50**

S-100 BREADBOARDING CARD

The S-100 will buss and fit into Altair or Imsai units to build semi-permanent interfaces and circuits.

Hardwired interface sockets contact the edge connector of the plug-in card giving the user access to every signal generated by the microcomputer, including those presently unassigned. The Data and Address buss structures are segregated for easy identification and external connection can be made through the AB40 or AB50.



Standard 10" x 5" card size, with 100 gold plated fingers. Breadboarding area committed to S-100 buss.
SUGGESTED RESALE PRICE **$69.00**

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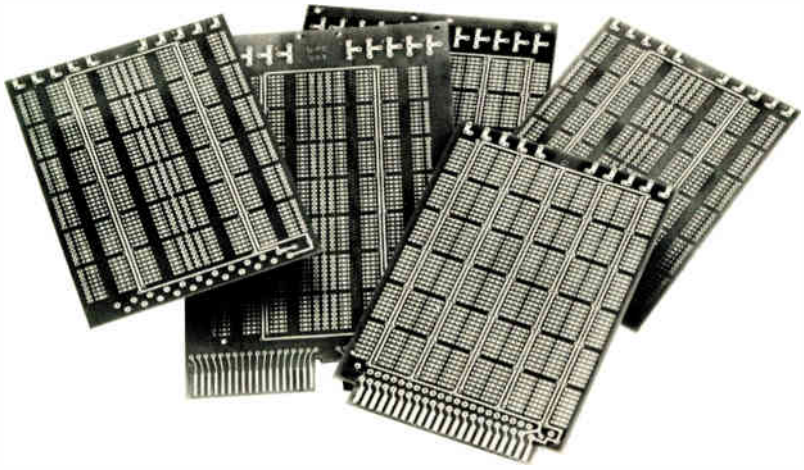

AB-8 & AB-10 — Two reusable adapter boards that allow the instant use of 8 or 10 pin To-5 devices in any DIP socket or SK breadboarding socket.

SUGGESTED RESALE PRICE
AB-8 — $3.05, AB-10 — $3.35

You will find E&L an excellent source for standard printed circuit boards for those instances where permanently soldered circuits are required. All items are made from 1/16" (1,57mm) G10 with 2 ounces of copper. All edge connectors have a heavy-wear gold plate. Hole size is .040" (1,01mm) (drilled, *not* punched).

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UPC-301 — Same as 201 but has dual DEC termination (.125" (3,2mm) centers).
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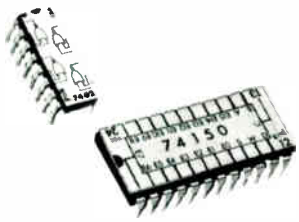
SUGGESTED RESALE PRICE $38.90

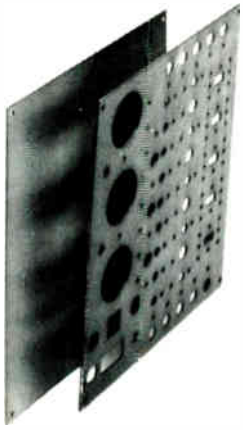
SPECIFICATIONS

LT-2	
Operating Voltage	5V ± 10%
Full "on" Current	80 ma
Frequency Response	DC-12MHz
Input Impedance at DC	600K ohm
Min. Pulse Width Detection	50 nsecs
Storage Feature	Yes (Switchable)
Indicating Levels	Red LED "on" at greater than 2.4V Green "on" at less than .7V Both off on open circuit
Weight (Shipping)	½ lb
Size	6.65"(16.9cm) × 6"(15,2mm) (supplied with 2 probe tips)
LT-3	
Operating voltage	5V ± 10%
Full "on" Current:	100ma
Input Impedance:	30K ohm min. in parallel with 50 pf
Pulse Duration: Min. Det. Width	200
Storage Feature:	No
Indicating Levels:	Red LED on at greater than 1.5V Green lights with pulse of 200 ns. or more
Output Impedance:	100 ohms max
Output Pulse Width	approximately 1 millisec.
Output Pulse Amplitude:	4.0V min. (P-P open circuit)
Weight (Shipping):	½ lb.
Size	6.65"(16,9cm) × .6"(15,2mm)

Design Aids

In the various books E&L publishes, components are required to do the referenced experiments. These have been gathered together in packages for your convenience They are:





BGB-1 — This concept for the identification of DIP integrated circuit chips consists of approximately 500 individual self-adhesive labels with printed "pin-outs" that show the logic function and pin numbers for the commonly used 7400-series TTL integrated circuit chips. These labels stick to the backs of the ICs. They eliminate the need to constantly refer to manufacturer's specifications for individual pin functions.
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SJ-160 — E&L has prepackaged 160 different lengths of pre-stripped 22 gage wire to make your circuit work that much easier.
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UMP-02 — An unpunched panel (7¾" x 9¼" (19,7cm x 23, 5cm))
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H-06 — The high impact molded case used to mount the UMP-01.
Same case as used on the DD-1.
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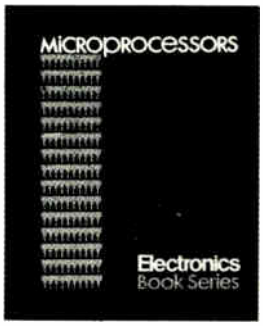

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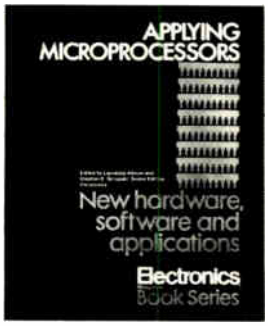

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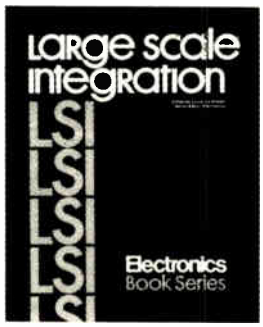

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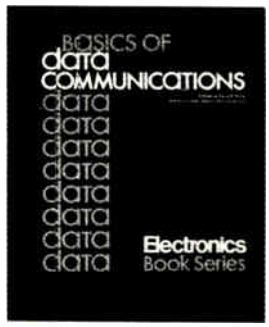

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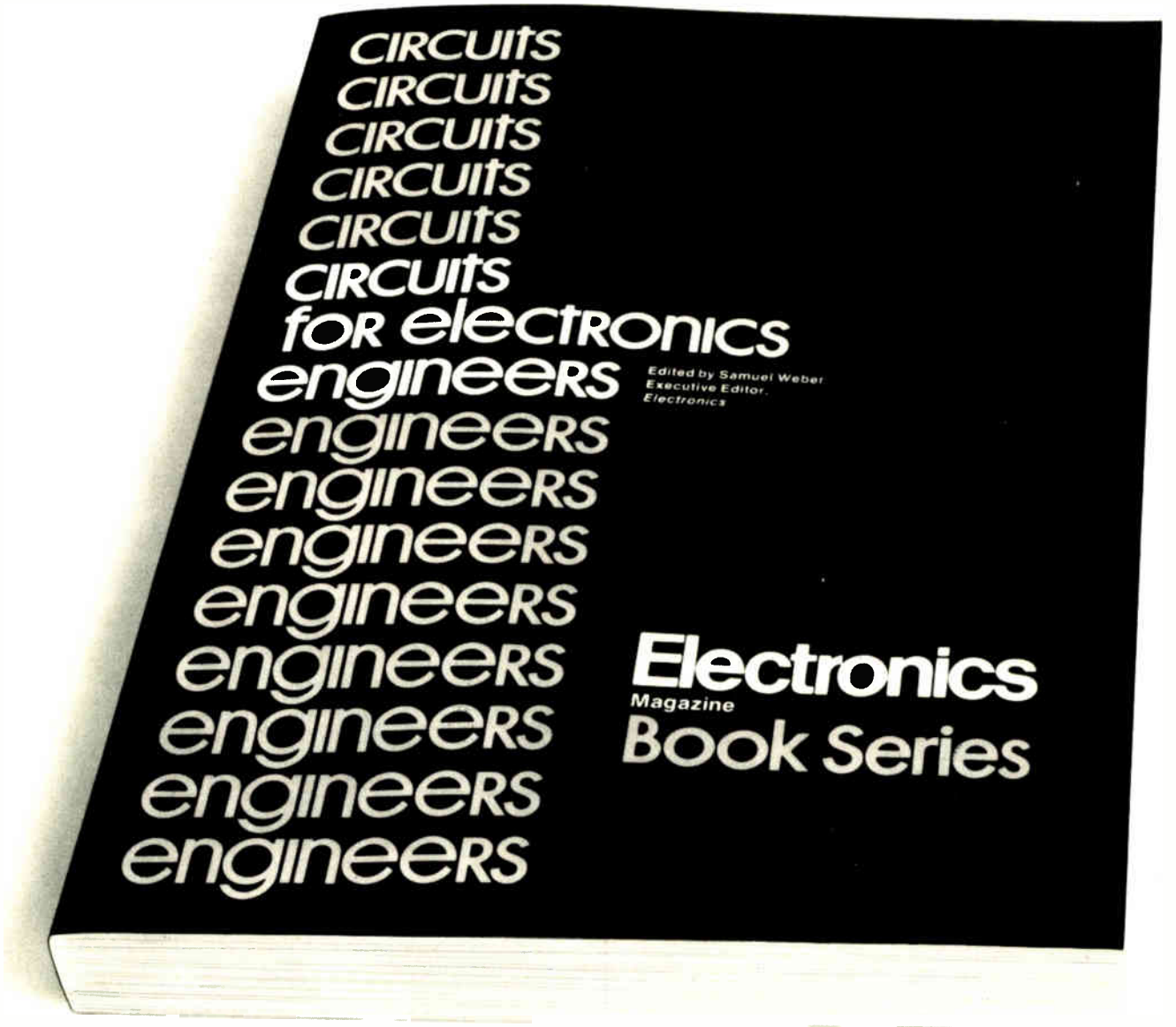

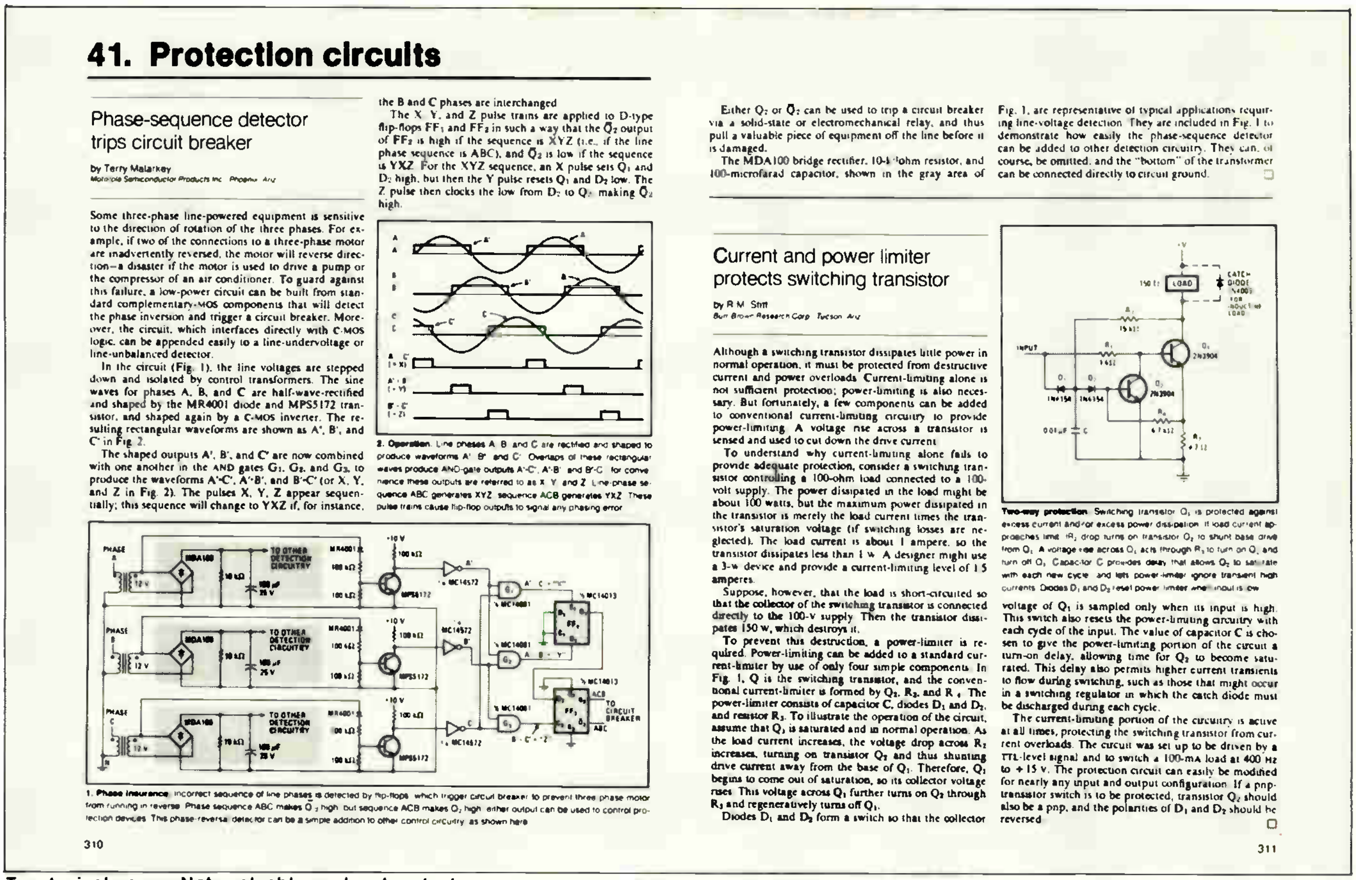

41. Protection circuits

Phase-sequence detector trips circuit breaker

by Terry Malarkey
Motorola Semiconductor Products Inc., Phoenix, Ariz.

Some three-phase line-powered equipment is sensitive to the direction of rotation of the three phases. For example, if two of the connections to a three-phase motor are inadvertently reversed, the motor will reverse direction—a disaster if the motor is used to drive a pump or the compressor of an air conditioner. To guard against this failure, a low-power circuit can be built from standard complementary-MOS components that will detect the phase inversion and trigger a circuit breaker. Moreover, the circuit, which interfaces directly with C-MOS logic, can be appended easily to a line-undervoltage or line-unbalanced detector.

In the circuit (Fig. 1), the line voltages are stepped down and isolated by control transformers. The sine waves for phases A, B, and C are half-wave-rectified and shaped by the MR4001 diode and MPS5172 transistor, and shaped again by a C-MOS inverter. The resulting rectangular waveforms are shown as A', B', and C' in Fig. 2.

The shaped outputs A', B', and C' are now combined with one another in the AND gates G_1, G_2, and G_3, to produce the waveforms A'-C', A'-B', and B'-C' (or X, Y, and Z in Fig. 2). The pulses X, Y, Z appear sequentially; this sequence will change to YXZ if, for instance, the B and C phases are interchanged.

The X, Y, and Z pulse trains are applied to D-type flip-flops FF_1 and FF_2 in such a way that the $\bar{Q}_2$ output of FF_2 is high if the sequence is XYZ (i.e., if the line phase sequence is ABC), and $\bar{Q}_2$ is low if the sequence is YXZ. For the XYZ sequence, an X pulse sets Q_1 and D_2 high, but then the Y pulse resets Q_1 and D_2 low. The Z pulse then clocks the low from D_2 to Q_2, making $\bar{Q}_2$ high.

2. **Operation.** Line phases A, B, and C are rectified and shaped to produce waveforms A', B', and C'. Overlaps of these rectangular waves produce AND-gate outputs A'-C', A'-B', and B'-C'; for convenience these outputs are referred to as X, Y, and Z. Line-phase sequence ABC generates XYZ; sequence ACB generates YXZ. These pulse trains cause flip-flop outputs to signal any phasing error.

1. **Phase insurance.** Incorrect sequence of line phases is detected by flip-flops, which trigger circuit breaker to prevent three-phase motor from running in reverse. Phase sequence ABC makes $\bar{Q}_2$ high, but sequence ACB makes Q_2 high; either output can be used to control protection devices. This phase-reversal detector can be a simple addition to other control circuitry, as shown here.

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Either Q_2 or $\bar{Q}_2$ can be used to trip a circuit breaker via a solid-state or electromechanical relay, and thus pull a valuable piece of equipment off the line before it is damaged.

The MDA100 bridge rectifier, 10-k-ohm resistor, and 100-microfarad capacitor, shown in the gray area of Fig. 1, are representative of typical applications requiring line-voltage detection. They are included in Fig. 1 to demonstrate how easily the phase-sequence detector can be added to other detection circuitry. They can, of course, be omitted, and the "bottom" of the transformer can be connected directly to circuit ground.

Current and power limiter protects switching transistor

by R. M. Stitt
Burr-Brown Research Corp., Tucson, Ariz.

Although a switching transistor dissipates little power in normal operation, it must be protected from destructive current and power overloads. Current-limiting alone is not sufficient protection; power-limiting is also necessary. But fortunately, a few components can be added to conventional current-limiting circuitry to provide power-limiting. A voltage rise across a transistor is sensed and used to cut down the drive current.

To understand why current-limiting alone fails to provide adequate protection, consider a switching transistor controlling a 100-ohm load connected to a 100-volt supply. The power dissipated in the load might be about 100 watts, but the maximum power dissipated in the transistor is merely the load current times the transistor's saturation voltage (if switching losses are neglected). The load current is about 1 ampere, so the transistor dissipates less than 1 W. A designer might use a 3-W device and provide a current-limiting level of 1.5 amperes.

Suppose, however, that the load is short-circuited so that the collector of the switching transistor is connected directly to the 100-V supply. Then the transistor dissipates 150 W, which destroys it.

To prevent this destruction, a power-limiter is required. Power-limiting can be added to a standard current-limiter by use of only four simple components. In Fig. 1, Q is the switching transistor, and the conventional current-limiter is formed by Q_2, R_2, and R_4. The power-limiter consists of capacitor C, diodes D_1 and D_2, and resistor R_3. To illustrate the operation of the circuit, assume that Q_1 is saturated and in normal operation. As the load current increases, the voltage drop across R_2 increases, turning on transistor Q_2 and thus shunting drive current away from the base of Q_1. Therefore, Q_1 begins to come out of saturation, so its collector voltage rises. This voltage across Q_1 further turns on Q_2 through R_3 and regeneratively turns off Q_1.

Diodes D_1 and D_2 form a switch so that the collector voltage of Q_1 is sampled only when its input is high. This switch also resets the power-limiting circuitry with each cycle of the input. The value of capacitor C is chosen to give the power-limiting portion of the circuit a turn-on delay, allowing time for Q_2 to become saturated. This delay also permits higher current transients to flow during switching, such as those that might occur in a switching regulator in which the catch diode must be discharged during each cycle.

The current-limiting portion of the circuitry is active at all times, protecting the switching transistor from current overloads. The circuit was set up to be driven by a TTL-level signal and to switch a 100-mA load at 400 Hz to +15 V. The protection circuit can easily be modified for nearly any input and output configuration. If a pnp-transistor switch is to be protected, transistor Q_2 should also be a pnp, and the polarities of D_1 and D_2 should be reversed.

Two-way protection. Switching transistor Q_1 is protected against excess current and/or excess power dissipation. If load current approaches limit, R_2 drop turns on transistor Q_2 to shunt base drive from Q_1. A voltage rise across Q_1 acts through R_3 to turn on Q_2 and turn off Q_1. Capacitor C provides delay that allows Q_1 to saturate with each new cycle and lets power-limiter ignore transient high currents. Diodes D_1 and D_2 reset power limiter when input is low.

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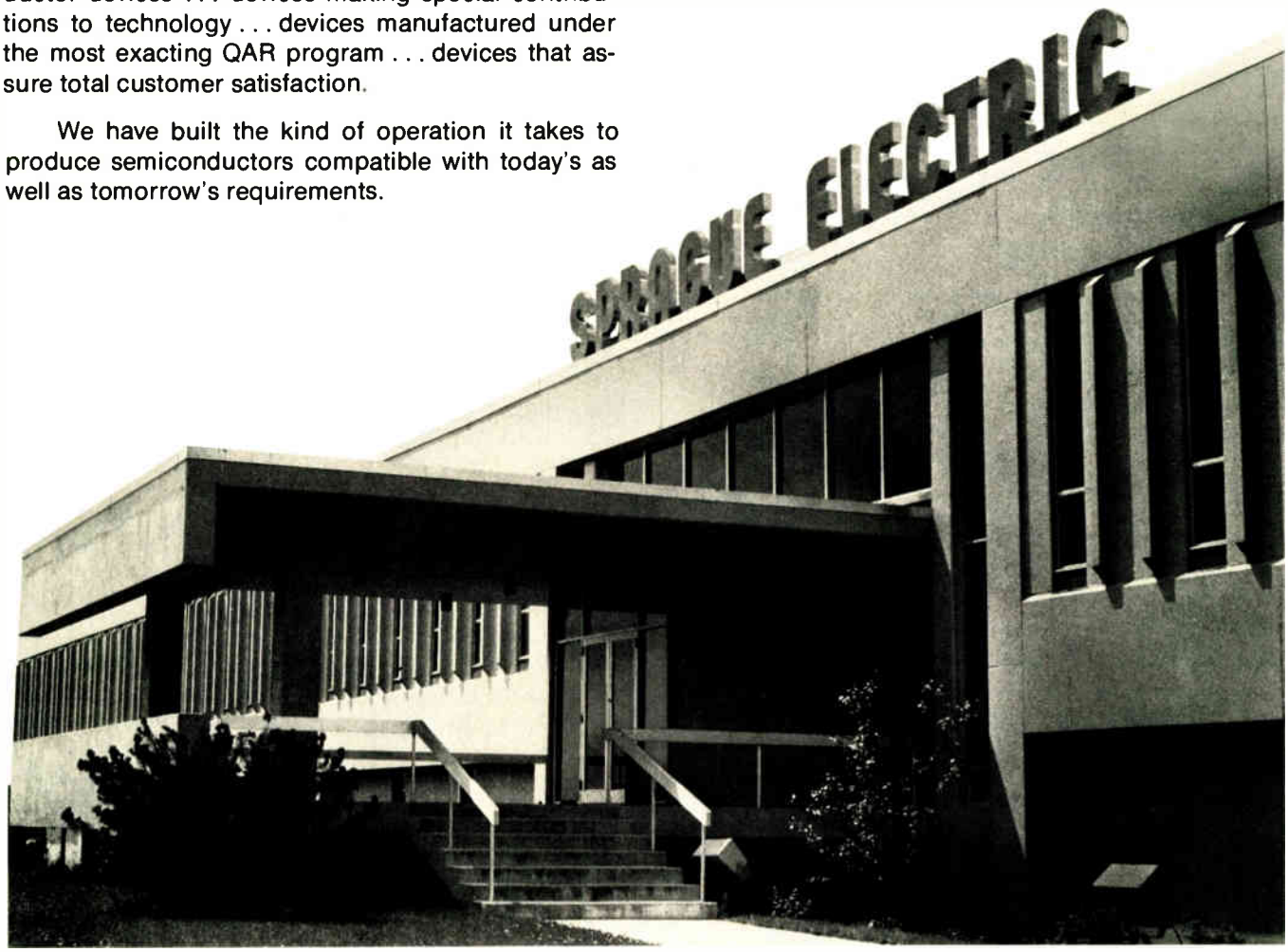

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Washington newsletter

White House cancels CDC Soviet sale; Peking unit shipped

Control Data Corp. has won one and lost one in its two-year struggle to get U. S. approval of the sale of two of its Cyber series computers to the Soviet Union and the Peoples Republic of China. The proposed sale to Russia of a large Cyber 76, worth $13 million, **was in effect canceled this month** when President Carter's adviser for national security affairs, Zbigniew Brzezinski, wrote Commerce Secretary Juanita Kreps that the President opposes the sale. The Commerce Department grants export licenses subject to presidential approval.

The Cyber 76, proposed for world weather watch studies as part of Soviet membership in the World Meteorological Organization, has a large 60-bit-word core memory of 30.72 megabits, a smaller semiconductor memory of 1.98 megabits, seven input/output channels, and six peripheral processors plus another for maintenance control. The Department of Defense vigorously opposed the sale. But CDC says it gained approval and shipped early this spring a smaller $3 million Cyber 172 to Peking to analyze seismic data in that nation's drive to locate new oil reserves. The Cyber 172 and its 10 peripheral processors, 12 I/O channels, and 1,000-nanosecond cycle time are within U. S. export guidelines [*Electronics,* Nov. 27, 1975, p. 59].

Satellite solar-power systems a distant possibility, Frosch says

A satellite solar-power system "appears to be technologically feasible," but its development and use are "between 25 and 100 years" away, Robert A. Frosch told a Senate committee in June hearings to confirm his nomination as head of the National Aeronautics and Space Administration. Supposing thermal energy were collected by large space-based solar-cell arrays, **"we have only the sketchiest ideas of the costs"** of converting that energy into electricity and transmitting it to earth for distribution by microwaves or other means, Frosch said.

But NASA will get a better handle on satellite solar-power economics—including the cost of erecting large space structures—when it begins using the Space Shuttle, Frosch believes. The transmission problem "will have to be attacked on its own merits," but only after "we have a better capability for the appropriate structures and experiments in space."

Military export barriers seen raising U. S. costs

Military electronics and weapons exporters are braced for a declining market and higher U. S. unit costs following President Carter's policy statement that "the dollar volume [in constant fiscal 1976 dollars] of new commitments in fiscal 1978 **will be reduced from the fiscal 1977 total"** of more than $20 billion. America "will not be the first supplier to introduce into a region newly developed, advanced weapons systems which would create a new or significantly higher combat capability," Carter ruled. "Also, any commitment for sale or coproduction of such weapons is prohibited until they are operationally deployed with U. S. forces, thus removing the incentive to promote foreign sale in an effort to lower unit costs for Defense Department procurement." Development or significant modification of advanced systems for export is also barred, the President added.

Industry sources declined to be quoted for attribution on the new policy—"we don't want that 'merchants of death' tag," one explained—but most agreed that the policy would further escalate unit costs of U. S. systems, particlarly of tactical aircraft and missiles.

Washington commentary

Expendable RPVs stumble on avionics costs

With the Carter Administration stressing short-term improvements in existing defense systems plus a number of major programs described by one general as "the big eaters"—the B-1 bomber and missile-firing submarines are two examples—money for the engineering of new systems is tight. Remotely piloted vehicles are one casualty of that trend, and the frustration of money-hungry RPV contractors was much in evidence at the recent Washington meeting of the National Association of RPVs.

"This place sounds like the terminal ward in a hospital," complained one registrant after listening for two days to industry and military leaders who regularly exchanged criticism of each other. They could agree only that the need for RPVs lacks significant support from military users and has not been sold to Congress.

The meeting had more whimper than bang right from the start when the Directorate of Defense Research and Engineering's William E. Stoney, tactical progams chief, labeled the $30 million forecast for fiscal 1978 RPV programs as a "zero growth" budget. Nor is the outlook likely to change next year, he said later. While contractors like Boeing Co. and Northrop Corp. argued that RPV "technology is here" and has been proved cost-effective, Air Force Lt. Gen. Robert Marsh, commander of the Electronic Systems division, said industry proposals have done no more than "tickle my fancy" but have not yet convinced him he would be doing the country a disservice if he failed to recommend them. This, Marsh said, is what still needs to be done.

Vietnam's plateau

RPV development reached a plateau following a high level of success by Israel in the Middle East and by the U.S. Air Force in Vietnam. Israelis employed them for anti-tank missions and electronic jamming and as decoys to draw surface-to-air missile fire away from following fighter-bombers over the Golan Heights. Marsh cites the 25 million frames of high-resolution reconnaissance photographs taken during 25,000 sorties by modified, recoverable Firebee drones over Vietnam. The Firebees represented "quick and dirty" modifications but were expensive, Marsh said. They contained an estimated $2 million reconnaissance package, industry officials say, including a special $500,000 electronically controlled camera developed by Itek Corp.

But that is history. Significant military support for RPVs is unlikely to come until industry can make them small, cheap and expendable, for use on a one-shot basis for tactical reconnaissance and, more importantly, for such defense suppression missions as taking out enemy radars in advance of an air strike.

That is now the electronics industry's biggest challenge, since there is good reason to believe that recoverable RPVs may never be successful. As one advocate of the technology at the Air Force Systems Command puts it: "In a combat situation, you don't want to have to determine whether an incoming vehicle is theirs or ours. It takes too much time, manpower, and money. If all ours are expendable, then you know you can shoot down anything coming over your lines because it must belong to the enemy." Expendables would also eliminate another problem with RPVs—shipboard recovery at night and in bad weather on a rolling sea.

The avionics costs barrier

But if single-shot RPVs are to be cheap, their avionics costs must come down substantially. Rear Adm. Carl J. Seiberlich, deputy naval operations chief for air warfare, figures the $20,000 to $25,000 cost of an RPV airframe and engine can be halved for expendables, but not the $100,000 required for avionics in an over-the-horizon reconnaissance and targeting system. "That leaves a high unit cost for a nondestructive vehicle," he points out.

Gen. Marsh's lighthearted observation that "maybe a toy manufacturer should produce RPVs, since he's unfamiliar with the aviation [industry's] push to get performance" and to meet tough military specifications first (before considering costs) did not sit well with his audience. The suggestion is not as ludicrous as it sounds. The costs of large-scale-integrated semiconductor chips are still coming down, and the technology is still moving fast, while fiber-optics technology for jam-resistant interconnections is not far behind. March's other recommendation—that lower avionics costs may be obtainable by "putting more of the 'smarts' on the ground" and using either a data link or preprogrammed RPVs for missions—holds greater promise.

Whichever way RPV advocates choose to go with their technology, the military message at their association meetings was clear: if remotely piloted vehicles are to have a future in the defense marketplace, they must be both cheap and expendable—goals that can be achieved only by electronics engineering of the most innovative kind.

Ray Connolly

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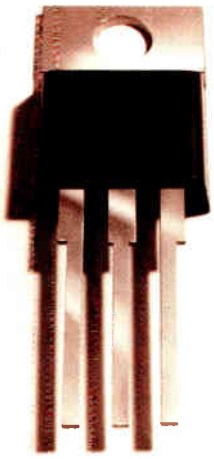

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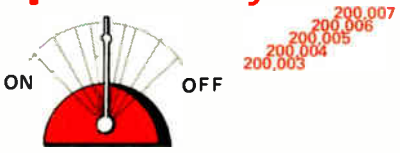

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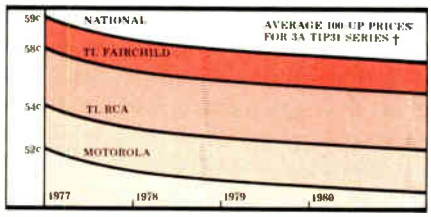

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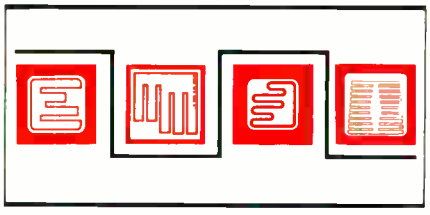

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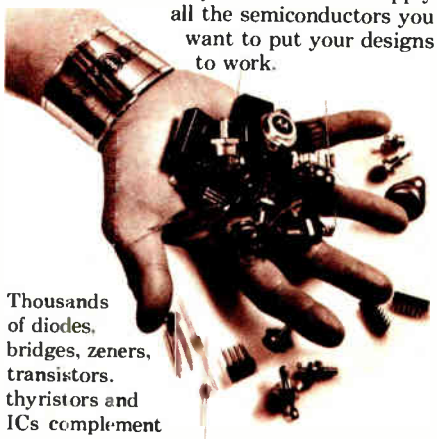

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TORONTO, Ont.	Zentronics, Ltd.	(416) 789-5111
TOWN OF MOUNT ROYAL, P.Q.	Zentronics, Ltd.	(514) 735-5361
VANCOUVER, B.C. V5X 3J4	Intek Electronics Ltd	(604) 324-6831
VANCOUVER, B.C.	Varah's	(604) 873-3211
WILLOWDALE, Ontario	Electro Sonic, Inc.	(416) 494-1555
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MOTOROLA Semiconductors

Versatility is written all over its face.

First thing you probably notice—it's a dual filter. Each of the 24db/octave filters can be used as high pass, or low pass, with selectable gain of 1 or 10.

Consider the possibilities.

Connect the dual channels in series for bandpass, 48db/octave high pass, and 48db/octave low pass, with selective gain of 1, 10, or 100. Butterworth and Bessel modes are available at the push of a button. And you can select AC or DC coupling.

Versatility is not just skin deep.

Switch selectable frequency settings ensure repeatability of settings from 10Hz to 1MHz. And repeatability of settings, combined with only .005% distortion at 20 volts output, means you can predict results—without having to calibrate your tail off.

Look a little deeper and you'll find 100db outband noise rejection, and a remarkably low 25 μvolts noise.

Ask for a demonstration.

Versatility like this should be seen to be believed. And wait till you see the price. $655. Not bad for all that versatility.

Call or write John Hanson at Ithaco, Box 818, Ithaca, N.Y. 14850. Phone (607) 272-7640.

ITHACO

Circle 75 on reader service card

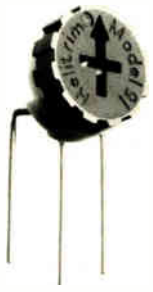
7 trimmers handle 95% of your applications.

Single-turn

With these industry standard cermet trimmers, you're assured design versatility, high quality, and fast delivery.

Just decide what you need regarding: (1) single- or multiturn; (2) sealed or not; (3) size; (4) resistance; (5) pin spacing; and (6) price.

Then call your local Beckman Helipot distributor for *free* evaluation samples. To get his number, or immediate technical literature, call (714) 871-4848, ext. 1776. See how fast and easily you can solve trimmer problems.

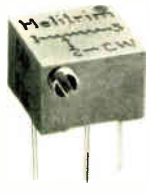


Model 91
- High quality—low price
- Unique brush contact
- Excellent setability
- Protective dust cover
- Top or side adjust
- Standoffs prevent rotor binding, permits board washing
- Small ⅜" dia. size

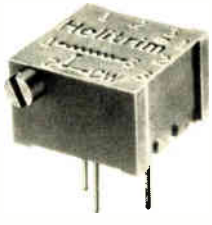
Model 72
- ⅜" square
- Sealed for board washing
- Available in flame-retardant SEO housing
- Top or side adjust
- Brush contact
- Excellent setability
- 2 ohms of end resistance

Model 82
- ¼" dia. by 0.150" max. height
- Sealed for board washing
- Flame-retardant SEO materials
- 82P—top adjust; 82PA—side adjust
- Brush contact for excellent setability
- Resistance range: 10 Ω to 1 meg Ω

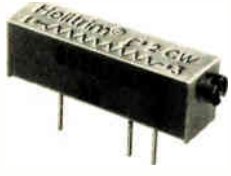
Multiturn



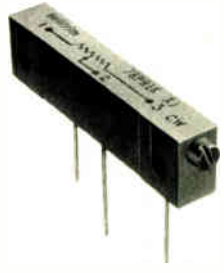
Model 64
- Miniature, sealed
- 22 turns of adjustment
- 0.25 watt at 85°C
- Resistance range: 10 Ω to 1 meg Ω
- ¼" square for tight P.C. board packaging
- Unique brush contact
- Adjustability—voltage ratio within 0.01%



Model 68
- Low-cost
- Sealed for board washing
- 18 turns for adjustment accuracy
- ⅜" square housing
- Brush contact
- 3 pin styles for efficient packaging
- Broad resistance range: 10 Ω to 2 meg Ω
- Operates with ½ watt at 25°C



Model 89
- Our lowest cost multiturn
- Sealed for board washing
- ¾" rectangular, 0.250" high
- 15 turns for accurate adjustment
- 7 pin styles for mounting versatility
- Panel mount available
- Resistance range: 10 Ω to 2 meg Ω



Model 78
- Military performance, industrial price
- 1¼" rectangular, 0.195" wide
- Sealed
- 3 terminal styles: flex leads, P.C. pins, solder lugs
- Power rating: 0.75 watt at 70°C
- 22 turns of adjustment
- Resistance range: 10 Ω to 2 meg Ω

BECKMAN®

HELIPOT DIVISION

International newsletter

German laser glass boasts index of 0.63

West German glass producer Glaswerk Schott has unveiled a laser glass exhibiting a relative nonlinear refractive index of only 0.63, an unprecedentedly low value, according to the company. **The small index, which is said to compare with 0.9 to 0.95 for the best laser glasses produced by other firms thus far, makes the Schott material well suited for high-energy laser applications.**

Being shown at the current Laser 77 optoelectronic exhibition in Munich, **Schott's LG802 glass is made from fluorophosphate that is enriched with 2% of neodymium.** Because of its small relative nonlinear refractive index, the glass can withstand many more laser shots than conventional phosphate glass, Schott points out. This is a big advantage in high-energy lasers, such as are needed to produce the plasma used in nuclear fusion experiments.

Bubble memory from Fujitsu comes in a cassette

Fujitsu Ltd. has developed **a bubble-memory cassette that contains four 73-kilobit chips and is compatible with equipment of other manufacturers.** With a maximum capacity of 294,912 bits and average access time of 290 milliseconds for a single-loop bubble chip or 3.6 millisecond, for a major-minor-loop chip, the cassette has a power drain of 8.5 watts in operation. It measures 5.2 centimeters long, 5.9 cm wide, and 1.7 cm high and weighs 210 grams. It can be removed more than 20,000 times and is interchangeable with floppy disk, paper tapes, and cassettes for intelligent-terminal, computer, and educational systems.

Amdahl tilts at IBM in Europe

Not content with chipping away at IBM in the U. S. market for large mainframe computers, Amdahl Corp. is going to take on the computer giant in Europe, too. To penetrate the European market, the company is **opening a software and service support center in Great Britain and a manufacturing plant in Dublin, Ireland,** to make and maintain its new 470/V 5, 6 and 7 series of computers. When fully operational in 1978, the new manufacturing base will supply all countries outside the U. S. The company expects to make announcements soon about negotiations with 20 prospective European customers, having already sold two computer systems in West Germany and one in Norway.

Personal computers move to Europe

To better penetrate the growing European personal-computer market, Southwest Technical Products in the U. S. plans to become the first kitmaker to set up an assembly plant in Great Britain. Though final papers have not been signed, **London's pioneering dealer, Computer Workshop, says it has agreed in principle to make the Southwest kits in its new factory in Ware, Herts., for distribution as a joint venture between the two companies.** Computer Workshop now sells the Southwest kits—built around a Motorola 6800 microprocessor, 12 kilobits of random-access memory, a cassette interface, and terminal keyboard—for about $1,700, but the company says that the price should drop once the factory cranks up in September.

The Cube widens the gap...

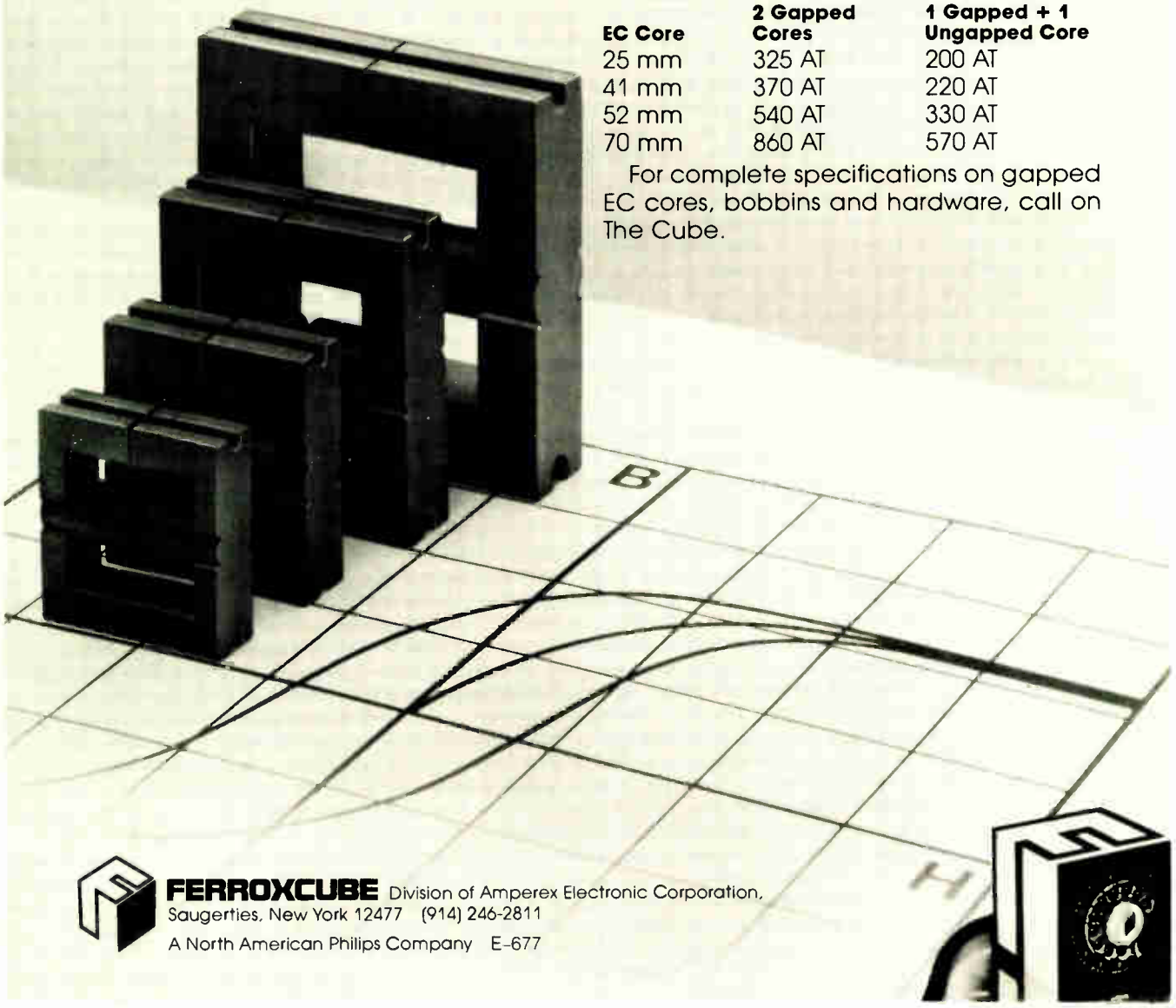
In Power-Ferrite EC cores for switching power supply chokes

Now available from Ferroxcube are standardized gapped EC cores in four sizes: 35, 41, 52 and 70 mm. The gap lengths have been optimized to prevent saturation of the core due to a high DC field while simultaneously providing maximum impedance to the AC ripple current.

For extreme cases of DC bias, two gapped cores should be used. Under less stringent conditions one gapped and one ungapped core can be used. The chart below shows the DC ampere-turns for both 2-gapped and gapped/ungapped core combinations that will provide a 10% decrease in permeability.

EC Core	2 Gapped Cores	1 Gapped + 1 Ungapped Core
25 mm	325 AT	200 AT
41 mm	370 AT	220 AT
52 mm	540 AT	330 AT
70 mm	860 AT	570 AT

For complete specifications on gapped EC cores, bobbins and hardware, call on The Cube.



FERROXCUBE Division of Amperex Electronic Corporation,
Saugerties, New York 12477 (914) 246-2811
A North American Philips Company E-677

Video-disk recorder aims at jobs in broadcasting

So far, developers of video disks have mainly had mass consumer markets in mind when they conceived their hardware. Not so the people at Bosch-Fernseh, a big West German producer of broadcast equipment. They turned up at this year's Montreux international TV symposium with a working model of a laser picture-storage system that records in real time with "studio" standards.

Fernseh brought its new hardware to the biennial Swiss video show more to sound out the potential market than to try to actually write orders. "We wanted to get broadcasters' reactions," says Hermann Zickbauer, the company's product manager for TV studio equipment. Zickbauer also figures that police departments, libraries, and similar organizations that need to store pictures and look them up fast could be buyers. "We think it will turn out cheaper than microfiche or computer disk storage," he maintains.

Storage. The system, which was developed at the research labs of Robert Bosch GmbH in West Berlin and in Lonay, Switzerland, fits about 12 minutes of video signals on a 32-centimeter disk. The frames are stored with a full broadcast bandwidth of 5 megahertz and a signal-to-noise ratio higher than 45 decibels. Audio can be coded in, too, by a sound-in-synch technique.

For stills, the 12-minute playing time works out to 18,000 pictures. Each can be coded with an address and called up within a second.

The recording medium is transparent plastic with a metal film deposited onto one side. Signal tracks are laid down by burning tiny holes in the surface with a frequency-modulated laser beam. The light power involved is between 60 and 100 milliwatts, and the holes are about 1 micrometer wide. For motion pictures, the tracks are laid down in a spiral; for stills, the tracks are circular. Either way, the disk spins at 25 revolutions per second and one full revolution gives a full frame or picture.

For playback, an unmodulated laser beam is focused onto the signal track. The light shining through the holes is picked up by a photodiode and amplified. The resulting high-frequency voltage is demodulated to regain the video signal.

Actually, to accomplish all that

Japanese ready battery-operated liquid-crystal display panel

Battery-operated terminals with large-screen character displays are among the possibilities opened up by a new liquid-crystal display soon to go into production at Hitachi Ltd. Prototype displays shown recently have four rows of 32 alphanumeric characters on a panel measuring 38 millimeters high by 175 mm wide. Each character is a 5-by-7-dot matrix, although each character position is actually a 5-by-8-dot matrix if the cursor dots are included. Production displays will include panels with eight rows, for a total of 256 characters, as well as panels with 7-by-9-dot matrixes for display of the Japanese Katakana syllabary.

The units operate at a maximum unipolar voltage of 15 volts and use complementary-metal-oxide-semiconductor integrated circuits in all drive circuits. Power consumption runs about 100 milliwatts, but most is used in power-supply circuits that set various needed levels and not in actual drive circuits or the panel itself. Thus larger panels and those with more dots per matrix operate at the same power level.

requires some sophisticated techniques. For one thing, the laser light modulator is based on an acoustic crystal with a basic 250-MHz supersonic wave that is amplitude-modulated to diffract the light onto the disk in step with the fm video signal. Then, too, a precision servo system is needed to keep the modulated recording spot focused on the surface of the disk, which is never absolutely flat.

Still another problem is keeping the scanning spot on the right track during playback. This is done by a mirror tilted by a piezoelectric effect. The control signal is derived by shifting the spot at right angles to the track at 25 kilohertz. The track control also makes it possible to freeze frames or to have slow motion or fast motion by making the scanning spot jump tracks as needed during blanking. □

West Germany

Selenium plate records X rays as charged images, makes paper copies

Chalk up another use for that versatile material, selenium: as an X-ray recording medium. First introduced industrially for rectifiers in 1928, selenium is used in such devices as photosensing elements, infrared detectors, photocopying machines, and lithographic equipment.

Now, at ITT's subsidiary Standard Elektrik Lorenz AG in Nuremberg, West Germany, engineers of the components division are working on various types of selenium charge carriers. One of them comes in the form of a plate and is aimed at replacing film in X-ray diagnostic equipment. A specific application is in mammography, the technique for examining a women's breast for cancer by X rays. Concerned over the rising number of women suffering from breast cancer, the German government is funding the SEL work.

Both the selenium plate and its development apparatus have been put through their paces at a West Berlin hospital. But there is still much work to be done before the equipment is ready for the market, the firm cautions. It figures the first perfected and fully automatic units for routine use in hospitals will not be available for two to three years.

Charged. The principles underlying the plate's recording capability are fairly simple and are based on the well-known effects exploited in photocopying techniques. When exposed to light or other electromagnetic radiation, amorphous selenium exhibits a conductivity that is several orders of magnitude better than under dark conditions.

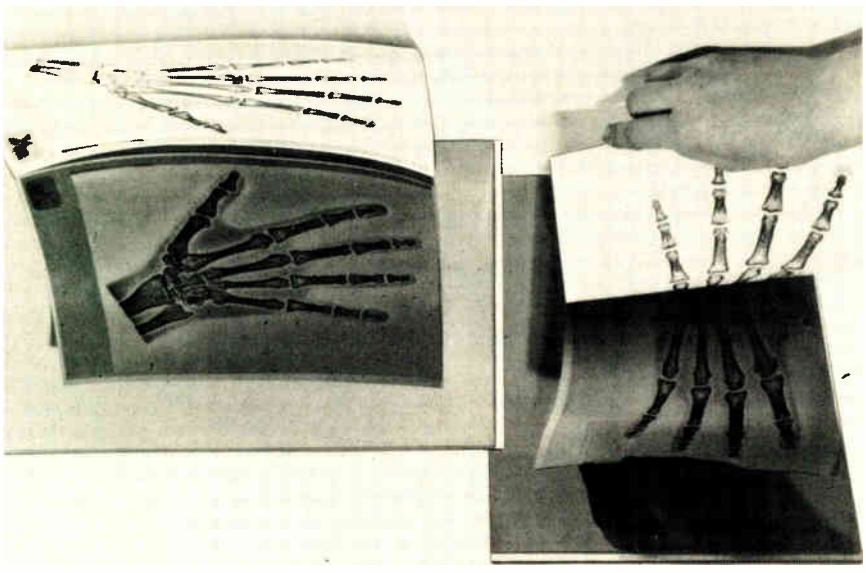
Depending on the intensity of radiation, the surface charge in a layer of selenium drifts towards its substrate. So, on a charged selenium plate, the radiation impinging on it can be recorded as a charged image. Ink-powder development techniques make the image visible.

Simple as the basic principles are, implementing them for SEL's application is a bit tricky. At this stage of development, the Nuremberg firm does not want to reveal all that goes into the making of the plate.

The fundamentals of the technology involved, however, are straightforward. In an evaporation process carried out in a vacuum, an aluminum plate with a well-defined surface roughness is covered with a layer of selenium. Crucial parameters in this process, the firm says, are the rate of evaporation, the doping level for the selenium, the degree of purity for certain intermediate layers, and the substrate temperature during evaporation. Depending on the application, the selenium layer is from 100 to 500 micrometers thick. Since it can easily be damaged, the layer is covered after evaporation with a thin coating of an organic material.

Besides reusability and the low radiation dose required for producing a record, the selenium plate has a number of other advantages over silver films normally used in diagnostic X-ray equipment. For one thing, its high resolution—0.1 millimeter—allows spotting even tiny tumors, which would be unrecognizable on silver film.

For another, because of the plate's ability to produce high-contrast contours, a clear distinction can be made between fibrous tissue, skin, fatty tissue, and glands. Still another advantage is that the information-storage medium can be simple typewriter paper. And the plates help conserve expensive silver. □



The General Purpose EXPLORER II

New digital oscilloscope for low-frequency, high precision signal measurement.

EXPLORER II is an oscilloscope in every sense of the word—for use in the same way as other oscilloscopes. It has the same sweep controls, trigger controls and amplifier controls.

What makes it different is its precision and enormously improved waveform storage capability. EXPLORER II is a digital oscilloscope. Because of this and careful human engineering, a dozen old operating problems have just disappeared.

Great Storage: Storage occurs at the touch of a button. The captured waveform has the same quality as live waveforms — amazing quality. There is no trace fading or blooming. If you wish, you can tuck the waveform away, out of sight, for later recall and continue to use the oscilloscope for other things in the meantime. Storage at the touch of a button means more than saving operating steps. It means no blank screen before storage.

Automatic Persistence: The EXPLORER always displays the last signal waveform until the next signal occurs, even when signals occur only rarely. There are no adjustments or mode switching.

CRT Independence: No longer is accuracy dependent on the cathode-ray tube. True voltage and time numerics for any selected point end that problem. The numbers can show differences in both times and voltages, for two selected waveform points. Accuracies and resolution are an order of magnitude greater.

Write-through Storage: At the touch of a switch, both live and stored waveforms are shown superimposed. This is far better than split-screen storage, which shows a stored waveform in one area of the screen and live waveforms in another. Write-through storage allows you to see changes as small as 0.025% while they are happening!

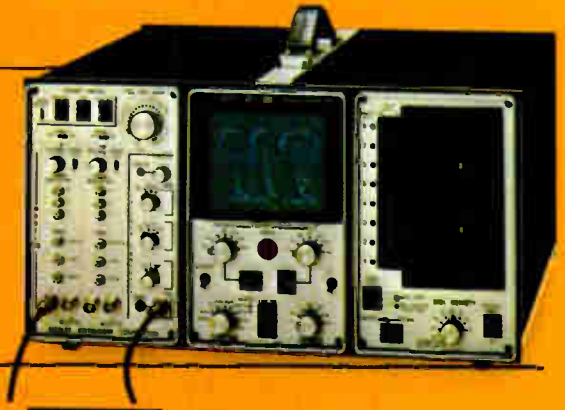
Dual Beam: EXPLORERS with two-channel plug-ins are "dual beam". Both signals are accepted together. There is no need for alternate sweeps or chopped sweeps.

Cursor Triggering: It used to be that all you could see on a 'scope was the result of an event. With EXPLORER you can see what caused an event to happen. Move the vertical marker line to any desired position. In the cursor trigger mode, this will be time zero, the time the sweep trigger occurs. The trace shows you what happened before and after the trigger.

Easy Operation: It's as difficult to describe the "feel" of EXPLORER II as it is to describe the feel of a great sports car to someone who has only driven "soft" passenger cars. But once you've had an hour or two of familiarization and used this new digital 'scope you'll know. You'll never want to go back to anything else.

EXPLORER III

Identical to EXPLORER II, this unit incorporates an added module that contains a magnetic disk memory and a digital input/output port. To document waveforms for future reference, the diskette preserves the accuracy and resolution of the original. There is no compromise as with a photo document. For computation, the digital I/O allows interface to computers and calculators, also IEEE 488 interface.



See It Demonstrated. *To really appreciate either of these new 'scopes you have to see them in action. For complete details, including descriptive brochures, send the reader service card or call Bruce Hervey at 608/271-3333.*

NICOLET INSTRUMENT CORPORATION

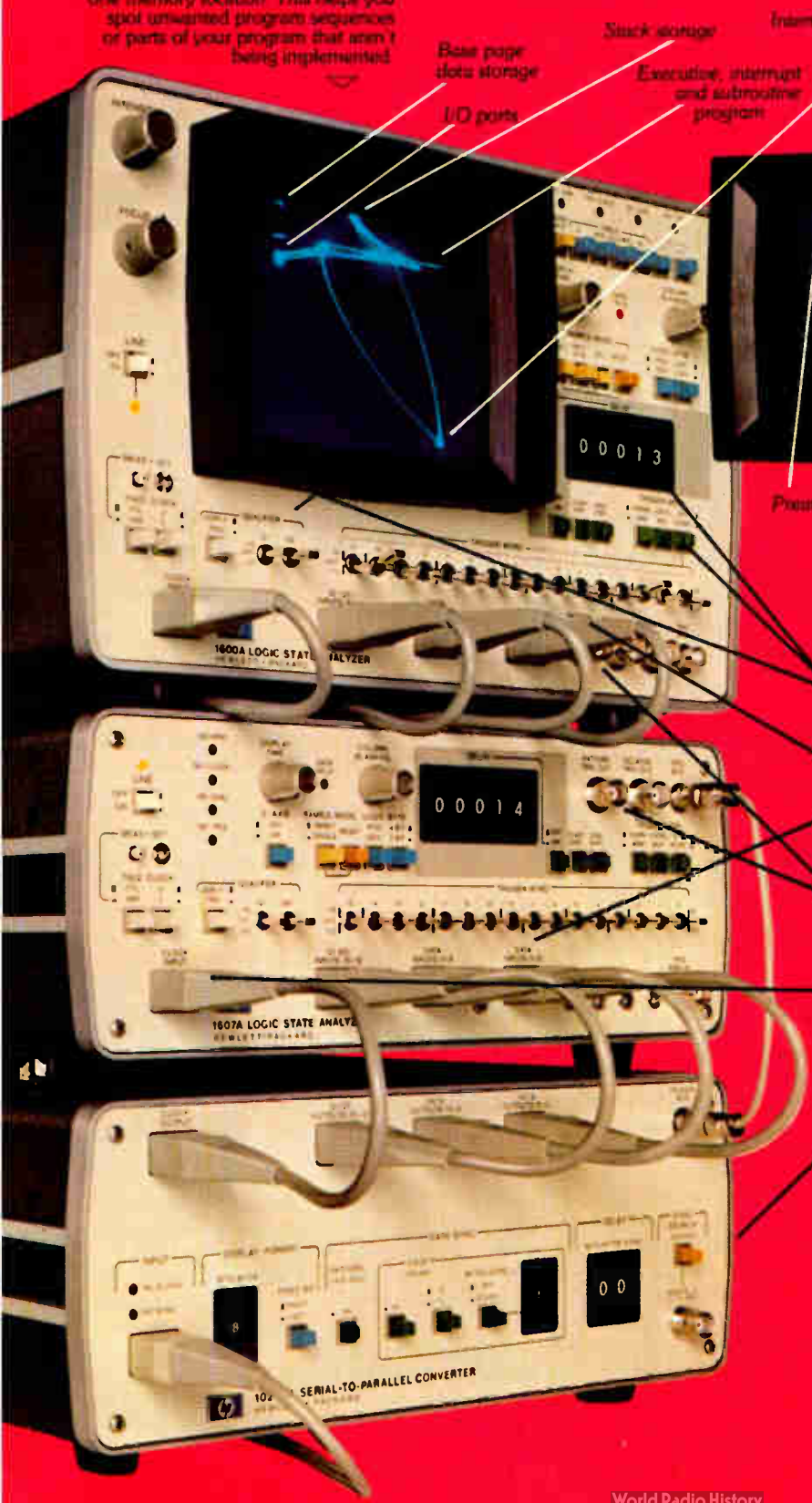
5225 Verona Road
Madison Wisconsin 53711
Telephone: 608.271-3333

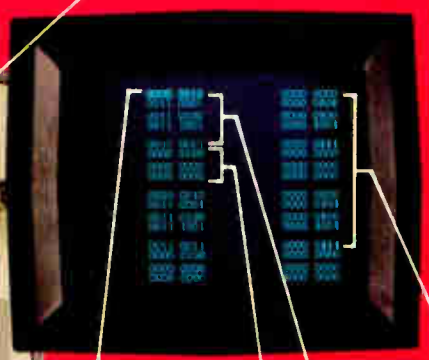
For Demonstration circle 80

For Information circle 81

Designing microprocessor

Get a system overview with this memory map. The 1600S shows how your memory is being utilized in an operating program. Knowing how your memory is organized, you can see at a glance what your program is doing and the relative time being spent in any one memory location. This helps you spot unwanted program sequences or parts of your program that aren't being implemented.





Monitor a serial data stream and compare new data with that previously stored. This display shows software conversion of BCD data at a 7-segment display to an ASCII format. Column blanking simplifies display by showing only 8 of 16 bits available.

Intensified bits are those that have changed since start-up.

Qualifiers, *digital delay and various local or bus triggering modes give you pinpoint selection of data flow for effective program tracing.*

Up to 32 channels *let you see all the action on the microprocessor address and data buses plus the I/O, peripherals or any other logic section of your microprocessor system.*

Output triggers *drive your scope—at the right instant—for making electrical measurements in the time domain.*

Dual clock *means you can easily relate bus activity to events occurring elsewhere at a different clock rate.*

Serial-to-Parallel Converter *(HP's 10254A) lets you directly view serial data in relation to parallel data on the system bus.*

FREE DATA DOMAIN SEMINAR

Find out for yourself how HP Logic State Analyzers can broaden your view of the data domain and speed digital design and debugging of your microprocessor based system.

Seminars are scheduled in a number of cities throughout the country. Ask your HP field engineer about specific details on seminars in your area.

based systems? You've discovered a new set of problems. Now discover HP's solutions.

HP's Logic State Analyzers give you a real-time view to help you spot and diagnose intermittent system operation. That can mean faster microprocessor system design and debugging.

The 1611A, priced at $5000*, can be tailored to either 6800 or 8080 microprocessors now. And more "Personality Modules" will be available soon. The 1611A lets you view bus activity and external events from the microprocessor's viewpoint. And, mnemonic decoding greatly simplifies interpretation.

The 1600S, with up to 32 input channels, dual clock capability and priced at $7100*, gives you a detailed real-time view of system activity from any vantage point, regardless of differences in clock rate. Add the 10254A Serial-to-Parallel Converter for $975* and you can simultaneously view serial data at peripherals.

One or more HP Logic State Analyzers give you greater insight for better understanding of your system's capabilities. That can mean earlier product introduction, lower development costs, a faster return on the development investment.

Your local HP field engineer has all the technical details. Give him a call today. And also ask him about HP's FREE seminars—An Introduction to the Data Domain.

*Domestic U.S.A. prices only

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Circle 83 on reader service card

ANNOUNCING THE WORLD'S BROADEST LINE OF FIBER OPTIC CABLE.

THE FUTURE IS NOW.

If you're working in a field that uses connectors like the ones shown here, you now can be working with fiber optics.

Because now there's Galite.®

The world's first line of optical communication cable that's broad enough to let you select exactly the right cable for your application. (Of course, your replacement optical connectors may look quite different from these old standards.)

So now you can bring the major advantages of optical communications to your product before it starts to look—and act—obsolete.

The world's broadest line of fiber optic cable begins with Galite 3000, which covers the biggest range of applications, and can be used up to 1100 feet. With its wide acceptance angle of light, it's the most efficient cable to couple, splice, and connect. And in most applications, it allows you to use proven, efficient, and durable LEDs, rather than the more fragile and temperature sensitive semiconductor lasers. But that's just the beginning.

We also offer, with varying light acceptance angles, Galite 1000, for use up to 150 feet. Galite 2000, for up to 250 feet. Galite 4000, for up to 3300 feet. Galite 5000, for beyond 3300 feet. And soon we'll be producing Galite 6000 and 7000 for even greater distances and wider bandwidths.

With this kind of choice, you can specify the exact characteristics for optimum performance in your application—strength, propagation efficiency, thermal compatibility, chemical resistance, weight—and cost.

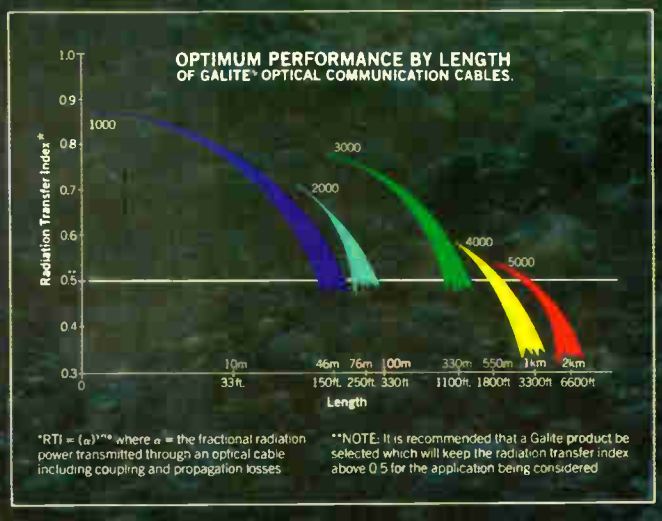
What's behind this line of fiber optic cable nobody else can offer is a company with experience nobody else can match. We've pioneered in glass fiber optic products since 1959 and are now the world's largest manufacturer, with over 2 trillion feet shipped.

We also have the country's most integrated production facility where we do everything from formulating the glass to making complete systems including light sources, detectors, and connectors. So we can keep reliability up. And costs down.

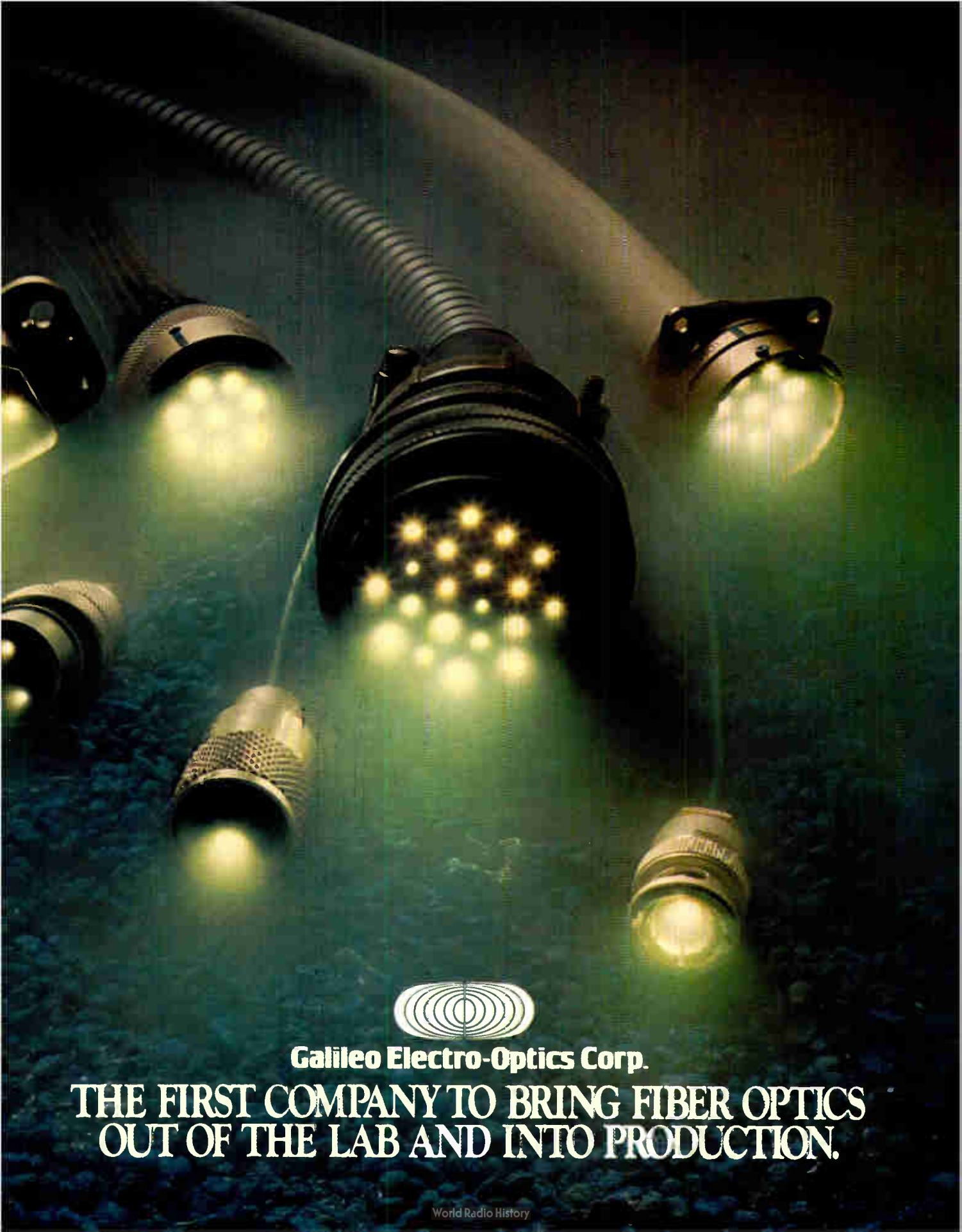
Why not call, write, or circle the reader service number for our new information package, "Fiber Optics Now."

But don't put it off until tomorrow. Because tomorrow is already here.

Galileo Electro-Optics Corporation, Galileo Park, Sturbridge, Massachusetts 01518, 617-347-9191.

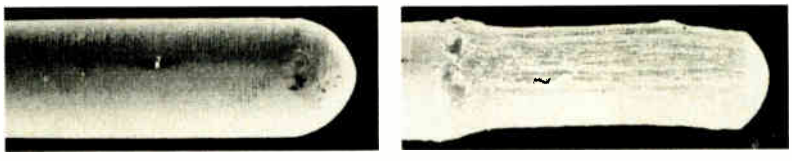


Circle 85 on reader service card



AMP research discovered Bonded Lubrication 5 years ago.

It's now today's better way to extend contact life without compromising performance.

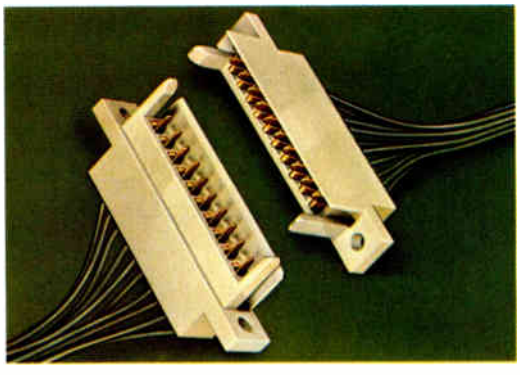


Dramatic difference in wear between contacts utilizing the unique AMP Bonded Lubrication Process and ordinary contacts is shown by these electron images.

Through the electron microscope, the dramatic improvement AMP Bonded Lubrication makes in contact life and performance is clearly evident.

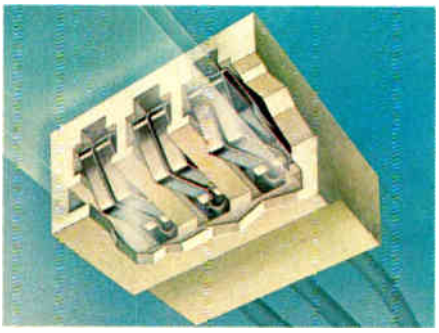
With the popular DUALATCH connectors, Bonded Lubrication has reduced plating thickness requirements and more than doubled the previously accepted cycle life of 10,000 insertions and withdrawals.

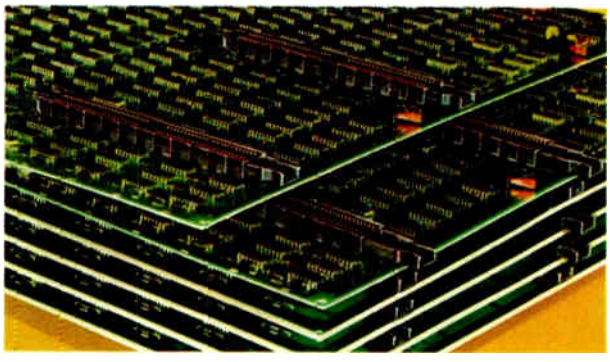
For example, look at the effect on the connector contact shown. Not only is wear to the plated surface greatly reduced by the permanent lubrication but it

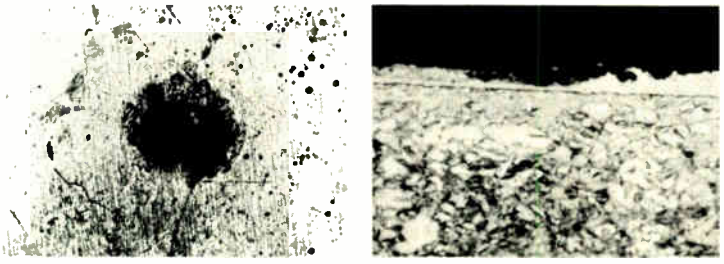


significantly lowers the insertion forces when mating high-pin count connectors. Now Bonded Lubrication can be applied to a variety of contact geometries without compromising electrical performance.

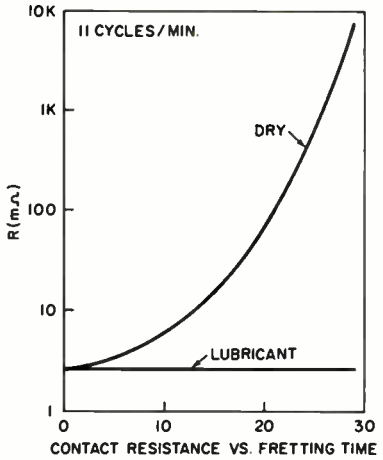
Or consider what AMP lubrication leadership has done for contacts used in our tin-plated products like surface mount ZIF connector and Bifurcated Leaf types. Their lubricated contact surfaces are protected from the detrimental effects of oxidation and fretting corrosion. Indeed, there are now applications where high performance tin-plating, with the correct contact design and Bonded Lubrication, can be used in place of noble metals.







High Resolution scanning electron microscope at AMP's Materials Research Laboratories displays 3-dimensional pictures of surface oxidation and fretting corrosion on non-lubricated contacts.



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AMP lubricated contacts are today's answer to extended contact life and performance, and together we can search out better ways to assist your designs.

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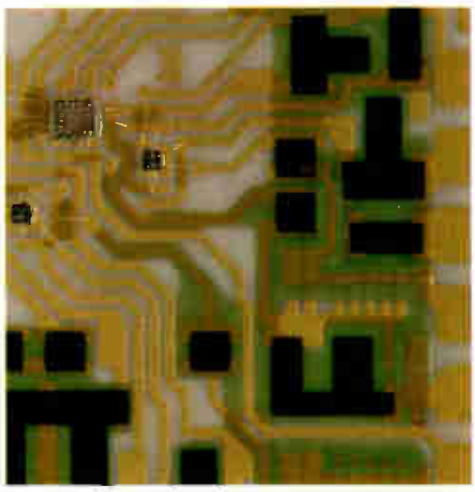
Look inside today's innovative electronic products. You'll find more and more circuitry on hybrids. Take, for example, the TEKTRONIX P6451 Data Aquisition Probe shown above. Thanks to hybrid circuitry, the P6451 is the most versatile data aquisition probe on the market. (In fact, almost all its circuitry resides on two thick-film hybrids.) That's why more resources are being dedicated to hybrid design, fabrication, and testing than ever before.



However, it takes more than innovative hybrid design to be successful in the fast-paced electronics marketplace. Successful designs must be repeatable and manufacturable. How does a circuit designer know when the design *is* repeatable and manufacturable? By testing.

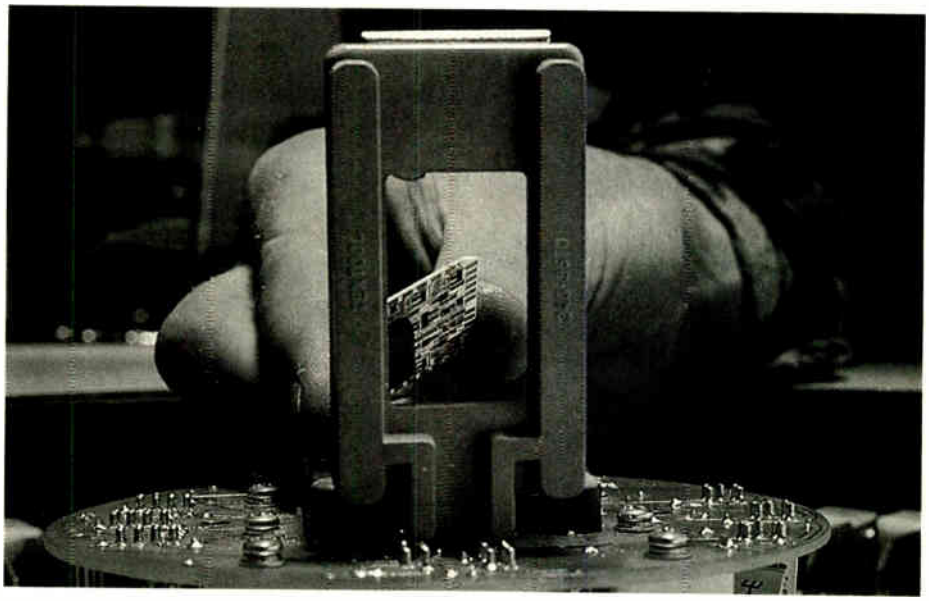
At Tektronix, hybrid prototypes are evaluated using a TEKTRONIX S-3260 Automated IC Test System. The evaluation team—the hybrid designer and test engineer—begins by investigating whether or not the prototype functions as designed. This sometimes leads to a complete device characterization, a process that requires exhaustive testing.

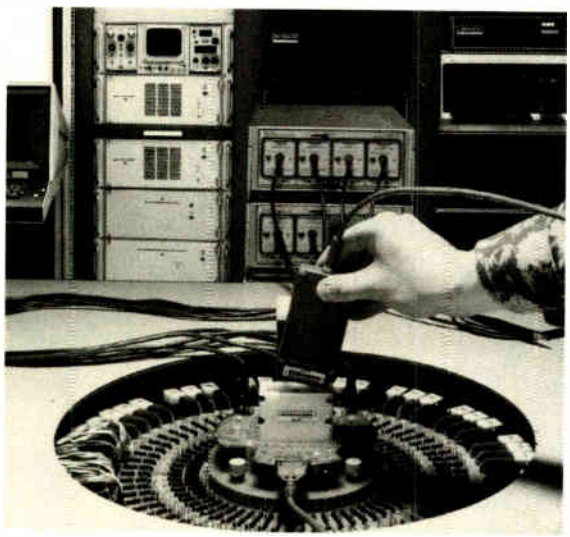
When a hybrid is characterized, every measurable parameter and function is tested, actual limits of performance are determined, and then its behavior is documented for all the various sets of input conditions in all their combinations and permutations. That's a lot of testing and it can quickly build mountains of test data. A system that merely performs accurate and repeatable tests is not enough. The evaluation team must also have the tools to reduce the data mass into a useable form. The S-3260 is a combination general-purpose IC test system and a data processing system—a totally integrated package that both acquires and processes test and measurement data.

You'll find TEKTRONIX S-3260's used for device characterization, process evaluation, production testing, and field failure analysis. Tektronix IC test systems are used by the world's leading communications companies, aerospace contractors, computer manufacturers, semiconductor manufacturers, and by the military.

Serious about performance? Then you should know about Tektronix IC test systems. Write Tektronix, Inc., P.O. Box 500, Beaverton, OR 97077. In Europe write Tektronix Limited, P.O. Box 36, St. Peter Port, Guernsey, Channel Islands.

"It works, but . . ."
Test engineer and device designer evaluating the prototype. Information gathered here guides the circuit designer as he adjusts his design for volume production.





Hybrid circuits are tested throughout the manufacturing process. Information gathered here alerts production engineers to manufacturing and process problems.

Final test of the completed data acquisition probe. Information gathered here dramatically reduces the labor involved in calibration and troubleshooting.

Serious about performance? Then you need to know about Tektronix IC Test Systems.

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For Technical Data circle 88 on Reader Service Card

For Demonstration circle 89 on Reader Service Card

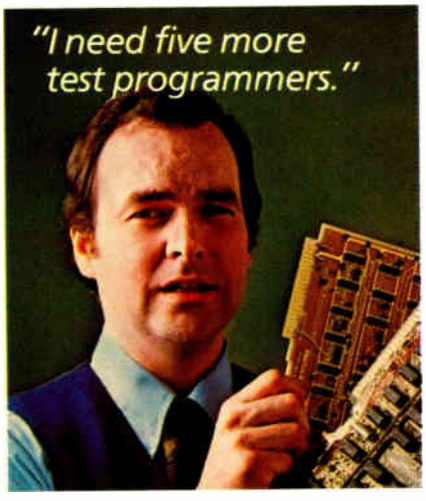
The P400 makes excuses obsolete.

A new product comes on line and the circuit boards start piling up. This is when the excuses begin:

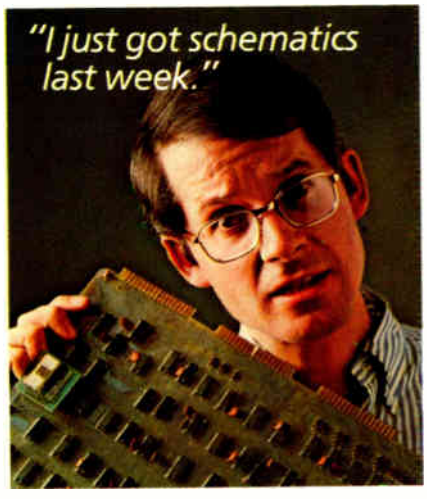
"I can't get near the computer."

"I need more programmers."

"I just got schematics last week."



It's a difficult time for a test engineer because the success of an important product can hang in the balance.



But Teradyne's P400 Automatic Programming System has changed all that. Used with L100 series test systems, the P400 creates the entire test program

automatically. It gives you all input patterns, provides all diagnostic data, and resolves all races. It cuts programming time from weeks to days. And it does it all without tying up the computer on your production tester or increasing your programming staff.

Suddenly, new programs can be ready on time, even in the face of the tightest schedules. And even for the most complex boards.

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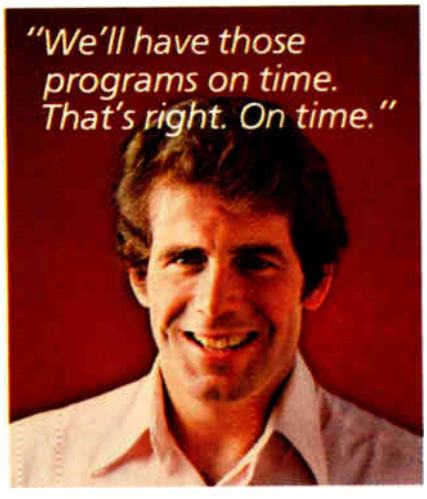
And we think that's the way you want it.



TERADYNE

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Earth station market widens

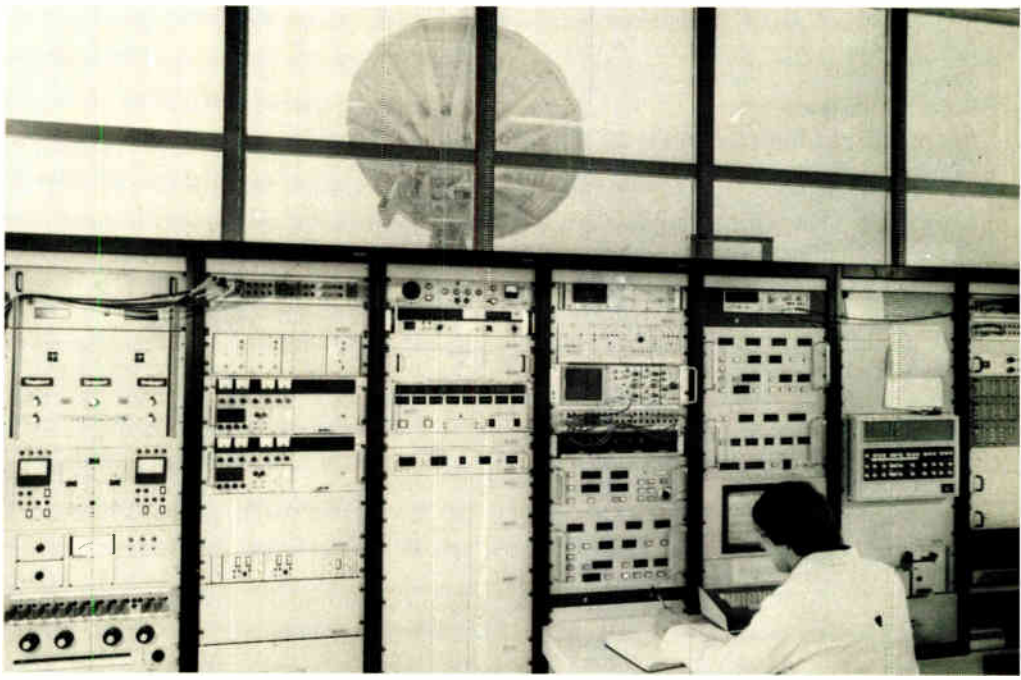
Standard B terminal, with its smaller antenna and price tag, permits poorer nations to join satellite communications club

Next month, international telecommunications service using a new class of satellite earth station will begin in the West African nation of Mali. The country's Standard B earth station, the first of its kind to become operational anywhere, will begin providing two-way telephone and Telex service, plus television reception.

Supplied by GTE International Systems Co. in Waltham, Mass., the station represents a substantial reduction in the entry fee a country must pay to use international satellite communications. Until recently, the outlay had been between $5 million and $6 million for the much larger Standard A stations with 30-to-32-meter-diameter antennas. The B stations have an antenna 11 m in diameter and usually cost from $1 million to $2 million for a turnkey system—antenna, ground structures, and the electronics equipment.

The price tag of the Standard A stations, plus the charge of $7,380 a year to lease a channel on one of the Intelsat IV or IVA geostationary orbiting satellites, was never an obstacle to the large industrial countries. But the smaller emerging nations simply could not afford it. Now, the Standard B's lower price has opened a market that could reach $80 million in the next five years, says Glenn T. Sacra, president of the GTE company. Most of his competitors agree on the market size.

But GTE is by no means alone in winning or bidding for new Standard B business. Nippon Electric Co. is generally conceded to be the company to beat in the race for the 30 to 50 stations most competitors think will be built in the next five years. The company has technical ability, a good product, and a financing arrangement for needy countries that nettles competitors (see "Competing with Japan," p. 92).



Big ear. Earth station installed by GTE International Systems in Fucino, Italy, is similar in size and complexity to Standard B stations. It is used for Marisat communications.

Other companies in the Standard B race include California Microwave Inc. of Sunnyvale, Calif.; Collins Radio group of Rockwell International Corp., Dallas; Com/Tech Laboratories Inc. of Smithtown, N. Y.; Marconi Communications Systems Ltd., Chelmsford, Essex, England; Sistemi di Telecommunicazioni via Satelliti, an Italian consortium; and Telespace, a French joint venture.

STS is made up of Italy's three major telecommunications companies—GTE Italia, SIT-Siemens and Sitri, which, together, have a turnkey system. Telespace unites France's two largest electronics companies—Thomson CSF and Compagnie Générale d'Electricité.

Nippon Electric Co. figures to be a big winner for still another major reason. Not only does it supply turnkey systems, but the company is also one of the few that make the modulation equipment. The others are Digital Communications Corp., Gaithersburg, Md., and ITT Space Communications Inc., Ramsey, N. J.

The Japanese firm has installed or is building 25 earth stations similar to Standard B but using the earlier frequency-modulation/frequency-division multiplexing. GTE is building

15 such installations. "I expect there will be another 30 to 50 Standard B stations sold worldwide in the next two or three years," says Ronald Lutz, head of Technology Resources, a suburban Paris consultant firm that NEC uses for its earth station business.

Telespace's business in the 11-meter fm/FDM stations has been mainly with French-speaking African nations—one each to Chad and Mali—and there are 12 on order from Tahiti. Bernard Cheney, commercial director for Telespace, adds that the French post office has also ordered several.

Colonies. England's Marconi Communications Systems Ltd., Chelmsford, Essex, has sold a station similar to a Standard B for the Apollo spacecraft network in the Atlantic. Philip R. Clowsen, space sales and systems manager, will not specify which countries Marconi is eyeing, but he hints that former British colonies are the likely markets. Com/Tech Labs' group manager for international marketing, John Smith, says, "We have proposals outstanding with NATO people in Europe and with just about everybody in the Middle East."

California Microwave is dealing with Oman and Thailand and has made proposals to about 10 other emerging nations, according to Robert Friedman, vice president for satellite communications. At ITT Spacecom, general manager John Lamoreaux says the company has supplied 15 domestic earth stations to Indonesia. These are usually smaller than Standard B facilities. Lamoreaux pegs the Standard B market at $25 million over the next 14 months, "but the potential market is many times larger if you can count those [countries] who say they're thinking about putting a system in but don't have firm plans and need financing."

In the Italian joint venture, STS general manager Marcello Pahor notes that GTE Italia provides the receiving-chain hardware for the turnkey system the company offers, with SIT-Siemens being responsible for the transmitting chain and Sitri handling integration, installation, and testing. Pahor probably best sums up the competitive situation in the Standard B business: "In this field, you have to be everywhere or not at all. A lost bid gives you a lot of experience."

Similar stations smaller than Standard A units have been in use, but the $1.5 million Mali station will be the first to use equipment featuring single-channel-per-carrier, pulse-code-modulated/phase-shift-keying modulation techniques instead of the earlier fm/FDM. All Standard B stations must use single-channel-per-carrier modulation beginning next year.

The newer African nations are prime sites for Standard B stations because of their relatively crude voice communications systems—usually entailing high-frequency radios or days of waiting to place international phone calls. Some of the countries identified by manufacturers as candidates include Sierra Leone, Botswana, Swaziland, Chad, Uganda, Tanzania, San Salvador, and Costa Rica. Island sites also targeted by station suppliers include Malta, Cyprus, and Cuba.

The companies going after the business usually act as system integrators: they purchase or manufacture some of the major subsystems and assemble and test the stations before delivery. Antennas are supplied principally by Com/Tech Laboratories; E-Systems Inc. of Dallas; and R F Systems Inc., Cohasset, Mass.

Meets standards. Carl Faflick, vice president for engineering at GTE International Systems, says the single-channel-per-carrier PCM/PSK modulation technique was selected last year by the Intelsat consortium for Standard B because it meets international standards for such characteristics as noise distortion and bandwidth established by the CCITT. The single-channel-per-carrier feature, while not new, requires less radiated power from the earth station because the channel is cut off when no transmission is taking place. (Usually 60% of a telephone conversation involves no transmission.) But the technique requires more satellite power than earlier modulation schemes. That is reflected in Intelsat's charge per channel, which is 1.5 times that for leasing a Standard A channel, or a little more than $11,000 a year since the Standard A charge has been reduced to $7,380 from $8,600 a year.

The Standard B stations will typically have 12 to 24 channels each, supporting that many two-way phone conversations. But as many as 24 Telex circuits can be put on one voice channel, so Telex traffic will undoubtedly be heavier than voice communications as the emerging nations link with overseas sites. □

Competing with Japan

It is a familiar theme. The non-Japanese competitors for Standard B earth station business have a lot of respect for Nippon Electric Co. But there is some irritation, too, with the financing advantage the Japanese firm has through government-backed loans. Typical comments include these:

- Glenn Sacra, president of GTE International Systems Co.: "Standard A stations in Egypt and Paraguay were financed on a concessionary basis by the Japanese, and NEC got both of those. It was the equivalent of a soft loan that might be offered by the U. S. Agency for International Development for, say, 15 to 30 years at 2% to 4%." In contrast, U. S. competitors must work with the Export-Import Bank and can do no better than six to eight years at 8% or 9%.
- Robert Friedman, vice president, California Microwave: "The government-sponsored financing policies Nippon is able to offer many of these emerging countries are important. They're pretty hard to beat."
- John Lamoreaux, general manager of ITT Spacecom: "The Japanese are extremely tough. They've got the technical know-how and good product and good financing to make it tough for all of us in this business."

This article was written in Boston by Senior Editor Lawrence Curran. Reporting was contributed by Arthur Erikson in Paris, William Arnold in London, Lois Bolton in Milan, Charles L. Cohen in Tokyo, Bruce LeBoss in New York, Lawrence Waller in Los Angeles, and Bernard Cole in San Francisco.

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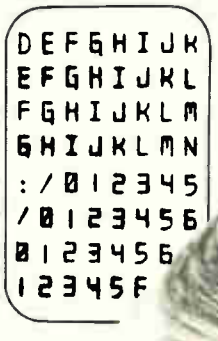

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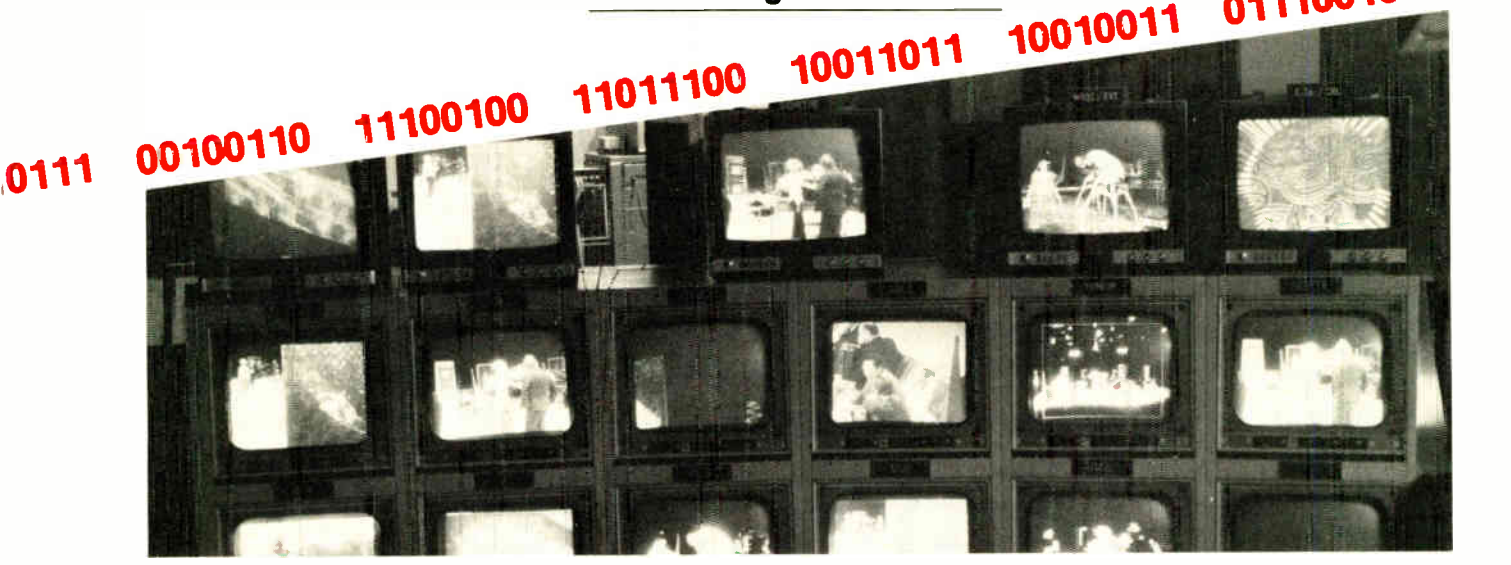


Communications

Digital TV: when, not if

Technology and first generation of hardware are available amid predictions of takeover starting in mid-1980s

by Arthur Erikson, Managing Editor, International

A switch to digital television would obsolete millions of conventional TV sets around the world. But the time is fast approaching when broadcasters will be working not with analog waveforms but with bit streams from their cameras up to the transmitters. By the mid-1980s, certainly, digital video processing will dominate in many studios in many countries. By that time, too, receivers with frame stores could well be on the market.

"The technology is already here," maintains Charles Rhodes, chief engineer for television products at Tektronix Inc. of Beaverton, Ore. Already here, too, is a first generation of hardware. For example, at Montreux' international TV symposium in early June, held biennially at the Swiss lakeside resort, just about every video-tape recorder company had a digital time-base corrector to talk about. Digital frame stores turned up in the offerings of a half-dozen manufacturers, some of them paired with special-effects systems. Thomson-CSF Laboratories, in fact, had a digital noise reducer based on a frame store. All the new character generators for superimposing titles and headlines on TV screens were digital. Also, of course, where the video is still handled in analog form, the controls are usually digital if the system is at all elaborate.

Revolution. "We're in the midst of a technological revolution," says Joseph Flaherty, vice president for technology at Columbia Broadcasting System. Indeed, semiconductor technology is moving so fast that video-equipment designers face a special kind of future shock, pointed out a panelist at a Montreux round table on equipment trends. Step advances in very large-scale-integrated circuits (VLSI) will come along at much shorter intervals than generations of TV equipment.

Even if they cannot come up with a transmission standard, broadcasters and equipment makers figure to keep on moving toward fully digital processing. Just before Montreux, Britain's Independent Broadcasting Authority demonstrated the major elements for a digital studio video-processing chain including mixer, switcher, tape recorder, and color-bar generator. The experimental equipment, IBA reports, produces excellent half-width color images. The coding is at eight levels with a sampling frequency of four times the PAL color subcarrier of 4.3 megahertz.

No equipment maker as yet has a complete digital video-processing chain to offer, but many of the necessary links have already been forged. They are impressive, particularly those that convert analog video waveforms into digital words and then read a whole TV frame of 525 or 625 words into a semiconductor memory. Once in the memory the digital "picture" can be manipulated numerically to achieve all sorts of wondrous results.

Potential. One possibility with frame stores is reconstructing a 625-line PAL or Secam picture from a 525-line NTSC picture. Standard converters that do this have been on the market for some five years. Marconi

Communications Systems was first, with a $500,000 design based on hardware developed at IBA. Since then, converters have been decked out with all sorts of additional features even though their prices have been slashed as memory-package costs have slid down the learning curve. Quantel Ltd., a small British firm, lauds its new $150,000 DSC converter, which is as much a frame synchronizer as a converter. Working in a PAL/PAL mode, for example, the equipment can correct timing errors on poor tapes.

Art form. The frame stores also help produce video effects—fades, dissolves, wipes, zooms, split screens, and the like—that can startle the most jaded televiewer. "Because of technology, TV is becoming an art form," enthuses Robert Cobler, who heads the international operations for the Grass Valley Group Inc., a California subsidiary of Tektronix. Grass Valley's new production mixer, first shown at the late-March meeting of the National Association of Broadcasters and also very much on view at Montreux, derives its panoply of video effects from hardware developed by the Nippon Electric Co. The frame synchronizer is NEC's 16,384-bit-memory packages and its Z-80 microprocessor, and the video processor NEC's DVP-15. The interface is courtesy of Grass Valley, of course.

Grass Valley, obviously, is not the only company around that can arrange a neat frame-up. Britain's Quantel had a brand new frame processor to show at Montreux, its DFP 5000, which carries price tags starting at $65,000 and running on up to $120,000. The equipment is based on a 4-megabit memory built up from 16,384-bit packages, with one Motorola 6800 microcomputer to exercise the memory and a second for the video effect controls.

Then there is the "squeezezoom" frame store synchronizer, which can manipulate four video inputs at a time. It comes from a small Gainesville, Fla., company called Vital Industries. Company president Nubar Donoyan says the secret is the way the memory, built around 4,096-bit packages, is managed by a 6800 processor. He quotes a price of $85,000 for the first channel, plus $18,000 for each of the other three. "We will have a simple frame store built around 64-k packages and priced around $39,000 by next year," proclaims Donoyan, who may find himself waiting for the semiconductor houses to deliver.

Not all the frame store makers have video effects in mind. "We're not thinking of going into digital effects," reports Renville McMann, president of Thomson-CSF Laboratories, the Stamford, Conn., arm of the big French company. "We're thinking more of digital color correction and digital amplifiers."

McMann's lab already has a strong foothold in digital TV with a $20,600 digital noise reducer introduced at NAB in March and seemingly destined to sell well—already 50 have been ordered. The instrument cuts overall noise in color TV signals by anywhere from 8 to 12 decibels. For chroma noise, the figures are even more impressive—20–24 dB. The coding rate is at three times the subcarrier frequency, using an 8-bit analog-to-digital converter. Fast emitter-coupled logic is used, and the memory is built around 192 16-k packages.

McMann expects to see all-digital production plants within 10 years. He also expects that frame stores will spill over from studio equipment into home receivers one day. Although he thinks they may actually be charge-coupled devices rather than purely digital, frame stores that will add somewhere between $50 and $70 to the cost of the set sound feasible to McMann. "People will pay the extra money," he figures, "because you can demonstrate the results in a showroom."

Soon here. Before then, drastic price drops in sight for frame stores figure to push them into studio equipment. Bosch-Fernseh, the big West German producer of studio equipment, unveiled at Montreux a $10,000 multipurpose frame store that can be paired with Bosch's BCN tape recorders to facilitate editing, get fast or slow motion, or turn tapes into archive storage. Hermann Zickbauer, Bosch's product manager for TV broadcast equipment, is convinced the cost of a full field store will get down to several hundred dollars one day. □

Military electronics

Lasers to keep GIs on target

Systems help train troops by keeping track of hits at war games, teaching recruits to handle rifle, and improving marksmanship

by Lawrence Curran, Boston bureau manager, and Stephen E. Scrupski, Instrumentation Editor

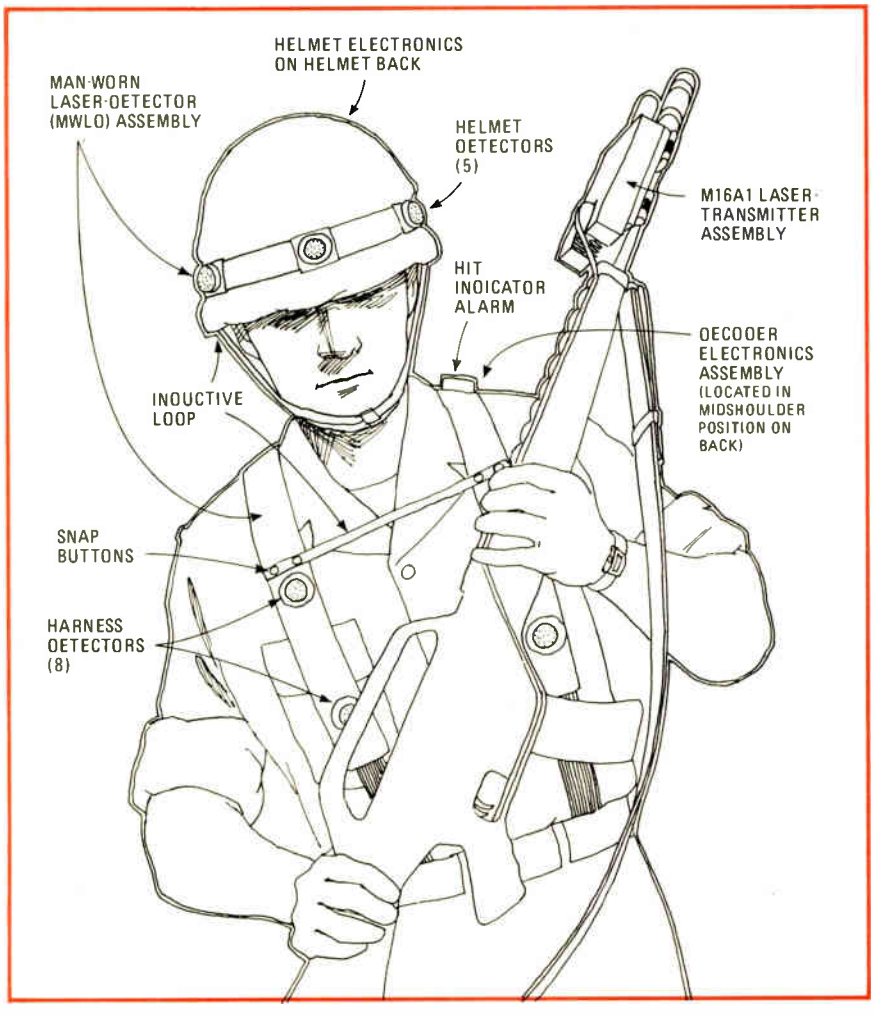
Surging military interest in the laser as training tool has spurred development of at least four systems designed to sharpen combat tactics or improve marksmanship. One is already in use, while the others are well on their way along the development route. The four are:

- Miles (for Multiple Integrated Laser Engagement System), for use as a scoring system in war games.
- IDFSS (for Infantry Direct Fire Simulator System), somewhat similar to Miles.
- Capon, intended to help familiarize the recruit with proper firing procedure.
- Lasertrain, a marksmanship training system.

Miles is now in the engineering development phase for the Ground System division in Orlando, Fla., which is part of the Army's Materiel, Development and Readiness Command. Xerox Corp.'s Electro-Optical Systems operation in Pasadena, Calif., has the $7.5 million prime contract for the system. Lt. Col. David Cours, project director in Orlando, says full-scale production is planned for early 1979.

Realer games. It combines gallium-arsenide lasers and complementary-metal-oxide-semiconductor microprocessors to add realism to war games. Using a laser attached to a weapon and silicon photodetectors on men and vehicles, Miles is more objective than the present method of using an umpire to judge if an infantryman is "killed" by the "enemy." In its simplest form, a 1-pound transmitter incorporating a GaAs-diode laser is mounted on an infantryman's M-16 rifle; detectors are on his helmet and a body harness. The transmitter's wavelength is 9,040 angstroms, in the near infrared.

In use, the sound of a blank round being fired triggers the transmission of a pulse-code-modulated laser beam from the transmitter, which is battery-operated. When the beam is detected by the target's photodetectors, the logic in the receiver electronics decodes it to sound an alarm. A rifleman "killed" by a well-aimed shot hears a continuous buzzing, which he can stop only by removing a key from the laser transmitter on his own rifle. His transmitter can then be made to work again only when one of the war-game controllers inserts a special key. For a



Miles gear. Equipment detects hits from others with similar laser guns.

near miss, an intermittent buzzing warns the infantryman.

The major difference between Miles and IDFSS, says Warren Birge, director of the special programs division at International Laser Systems Inc. in Orlando, which makes IDFSS as well as Lasertrain, is that Miles is intended to train troops in combat tactics while IDFSS evaluates the combat tactics of trained units.

IDFSS also uses laser-equipped rifles and a set of p-i-n photodiode detectors. But it has a radio telemetry unit and antenna in the helmet to transmit hit information back to a central computer. When a man is "hit," his rifle is disabled, and the computer is notified. The computer enables a commander to run several tactical variations of an attack, then compare kill statistics. Birge says there are now 66 IDFSS setups in use by the Army at various installations.

Zeroing in. On the target-firing level, a pair of systems is being evaluated. The newer one is called Capon and was developed at the Naval Training Equipment Center in Orlando. For use before the recruit goes out to the range, it teaches proper aiming, breathing, and trigger-squeezing procedures. Capon uses a GaAs laser and battery pack mounted on the rifle; the target comprises four photodetectors—one at each corner of a diamond shape—and lights to show the direction of offset from the bull's-eye. When the laser illuminates all four photodetectors simultaneously, the bull's-eye lights up. When the shot is off, only the detectors in the direction of the miss will be illuminated by the laser, and a corresponding light will flash. The system recently went through tests by the Marine Corp at Parris Island, S. C., and Quantico, Va. The next stage would be engineering, followed by production.

While Capon does not help the inferior marksman, the Army is now evaluating a system that is aimed at doing that: International Laser System's Lasertrain. It uses a replica of the M-16 rifle with a laser on the barrel and batteries in the stock. A detector assembly on the target senses the hit, and a television screen on the scoring console displays the location for the coach. □

Companies

Burr-Brown nears $25 million mark

Credit for the move into new data conversion and acquisition markets goes mainly to president Burns and his low-key management style

by Larry Waller, Los Angeles bureau manager

Tucked away out of the industry mainstream in sun-washed Tucson, Ariz., Burr-Brown Research Corp. is carefully picking new niches to win a widening part of its market: data conversion and acquisition devices and control components and subsystems. One result is that the privately owned firm sailed profitably through the recession, with sales jumping from $12 million in 1975 to $16 million last year. Now, they are soaring through projections, officials say, approaching $25 million.

What is Burr-Brown doing right in a field marked by fierce competition with much larger firms?

Generally, credit is given by associates to president James J. Burns, an informal, low-pressure ex – Motorola engineer who not only reoriented Burr-Brown's product line, but whose management style is decidedly different from his predecessor's. It started in 1971, "when I came here and took an undefined job, with no title and no one working for me," he recalls. At that time, from all reports, Burr-Brown was stuck at the $7 million level and seeking a fresh viewpoint to jolt it forward.

What Burns found, after choosing his own title of "director of new business development" (which made him "kind of an internal consultant"), was "technology approaching the obsolete." But Burr-Brown did have strong points in existing analog circuit and interfacing capabilities, which he quickly augmented by acquiring a company with experience in thin-film hybrid and monolithic integrated circuits. After a close look at more than 100 potential market segments, Burns says that he concluded in 1973 that "data conversion was the place we had to be." Programs to implement this decision proved the takeoff point, he says.

By late 1974, the company had its first such product, called Micromux, a two-wire system for remote acquisition of data used in severe-environment process control. Shortly after, Burr-Brown began turning out analog-to-digital and digital-to-analog converters, both sold separately and incorporated into subsystems. It also jumped into the microcomputer peripheral field with an interface board for Intel processors, the first of what is now its fastest-growing product line. The company, in sum, has been turning out two new products a month since 1975.

That pace has gained the respect of Burr-Brown's competitors. Robert Boole, corporate marketing director at Analog Devices Inc. in Norwood, Mass., sees Burr-Brown "as a strong competitor. They seem to be looking for the same kind of growth we've had in recent years." From $30 million in 1975, sales at Analog are expected to be near $50 million this year.

Boole adds that he looks for Burr-Brown to put more effort into monolithic devices at the same time that Analog is getting its hybrid circuit operation up to speed. "There's room for both of us to grow in the way each wants," he says, "especially with the boom in interface circuits for microprocessors."

Basic to what Burns describes as a marketing-oriented strategy is "searching out those product niches where Burr-Brown can offer a

At ease. The style of James Burns at Burr-Brown is informal, with ties "sort of frowned on." Meetings are open-door affairs.

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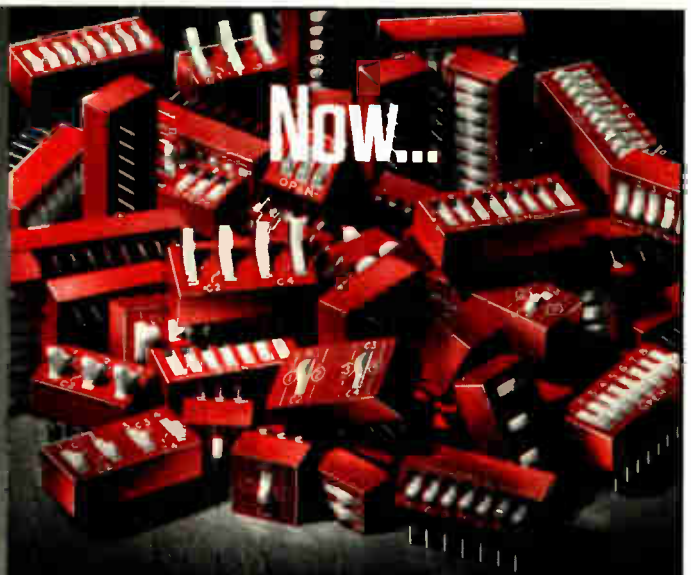

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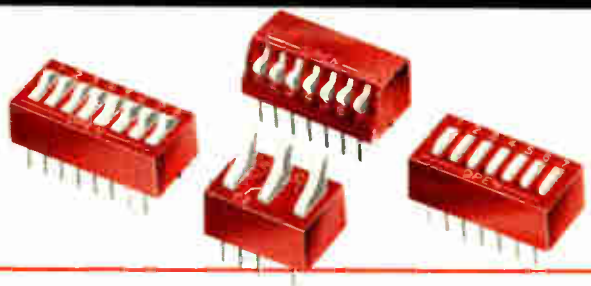
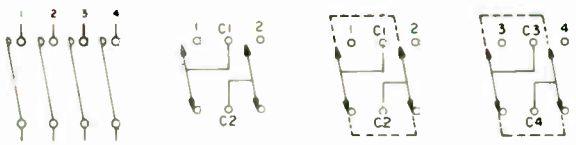


Different circuitries

SPST in 9 sizes, from 2 to 10 rockers; the DIP-C®, SPDT switching and the Double-DIP™, DPDT circuitry in 1, 2, 3 and 4 rocker versions.

Toggle DIP™ available with SPDT circuitry, 2, 3 or 4 stations; DPDT with 1 or 2 stations.

Piano DIP™ (side actuated) from 4 to 10 stations, SPST circuitry under each rocker.



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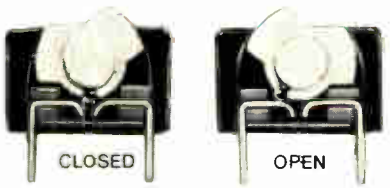

Different delivery standards, too

Most Grayhill DIP Switches are available off the shelf in production quantities from Grayhill or its nationwide distributor network.

For detailed information on Grayhill DIP Switches, consult *EEM* or write for Bulletin #276 to Grayhill, Inc., 561 Hillgrove Ave., La Grange, Illinois 60525, phone: (312) 354-1040.

Grayhill INC

Circle 99 on reader service card 99

unique advantage." The one-board processor interfaces are an example, he says, containing complex hybrid circuits and proprietary monolithic chips available nowhere else. Burr-Brown has attempted to position itself in this way throughout its data-conversion lines.

Philosophy. Another part of the Tucson firm's philosophy is that, because it is relatively small, "we can't afford to make big mistakes." Putting it another way, marketing manager and 11-year veteran Gene E. Tobey says, "We don't expect to be a developer of new technology, but to be among the first to use it." Several years ago, for instance, Burr-Brown got in the forefront with active laser trimming of networks. "This permits trimming out offsets and nonlinearities that couldn't be done with passive trimming," Tobey explains. "The result is a premium product that commands top prices."

In the development cycle, Tobey says, lead time varies from six months to several years. "Hybrids and discrete assemblies go pretty fast; monolithic chips are the riskiest in terms of time." For a small firm, Burr-Brown plows a hefty percentage of sales into research and development: about 7% to 8% now, with hopes of pushing it perhaps to 10%.

Tobey notes a "considerable shift in the character of the company over the past three years" and attributes it to Burns. Besides the product changes, he points to "tighter operations, a commitment to growth, and insistence on long-range planning." Another indication is the changing sales mix, which in 1974 saw 25% of revenues from microcircuits and 75% from modular devices. Now, more than 60% of sales comes from microcircuits incorporated into signal conditioning—data conversion components and assemblies.

Possible clouds on the horizon, on which Burns keeps a wary eye, are semiconductor giants pushing their high-volume converter chips into the subsystem level. But "it's nothing new that the semi houses are moving toward us," Burns observes. "We'll have to keep moving away from them and search out those niches." □

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Consumer electronics

Timex goes on the offensive

As LCD watch competition expands, Timex turns to marketing and distribution strengths to counter heavy impact of watch-making semiconductor firms

by Gerald M. Walker, Consumer Electronics Editor

"Timex is in to stay—we are a leader and still will lead," declares Carl Igelbrink, corporate manager of marketing electronics for Timex Corp. "There's more to the watch market, even the digital-watch market, than price."

With that challenge, Timex underscores its determination to do battle with the semiconductor manufacturers whose digital-watch lines have pounded deep wedges into its traditional lower-cost domination. This year the battle ground is clearly the new liquid-crystal-display lines that arrived in force at this month's Consumer Electronics Show.

Making its first appearance at this big, multi-product Chicago show, Timex introduced 10 LCD watches in its Marathon line, some with six digits and stopwatch, priced from $46.95 to $65. The firm now has 41 LCD models, the lowest being pegged at $27.95.

As in the past, however, Texas Instruments startled the field, this time by unveiling 15 LCD watches at $27.95 to $48.95—all backlighted by phosphor-lined tubes filled with radioactive tritium. (The tritium excites the phosphor coating of the tubes.) The new line gives TI altogether 60 light-emitting-diode and LCD watch models.

National Semiconductor Corp.'s Consumer Product division, which also has LCD watches at the $27.95 price point, got into the tritium backlight competition with a range starting with standard four-digit models and going upward through lithium-battery models and six-digit models to the top of its line: six-digit tritium-lit chronographs.

As though anticipating the next move in the market, Fairchild Camera and Instrument Corp.'s Consumer Products group has come out with a metal-case LCD watch at $19.95 and another with a metal strap at $24.95. Fairchild will probably have a tritium model as well.

Advantages. Thus, facing formidable competition, how will Timex manage? After-sales service, advertising, point-of-sale displays, and one of the world's largest distribution systems will make the difference, says Igelbrink. As for the technology, Timex has had good results from its acquisition of RCA's former liquid-crystal manufacturing operation but is also buying modules.

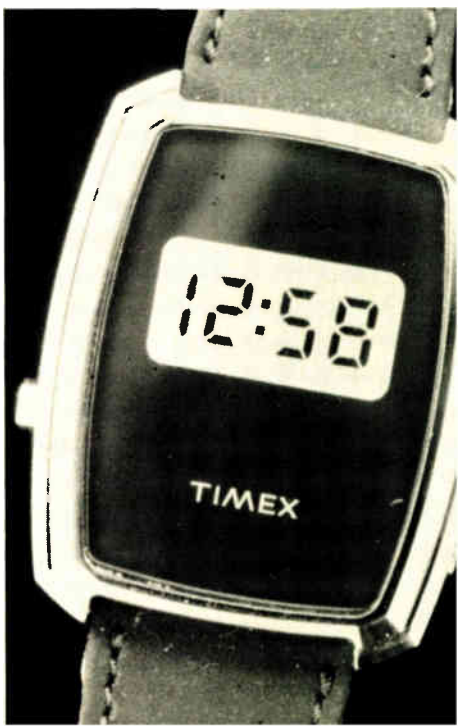
"The semiconductor firms have a technology reservoir, but that reservoir is big enough to be available to everyone," the former General Foods marketer comments. Nor is Timex overly concerned about a price war. "It is a misconception that Timex makes the lowest-priced watches in the U. S. We have survived against competitors having lower prices in the past."

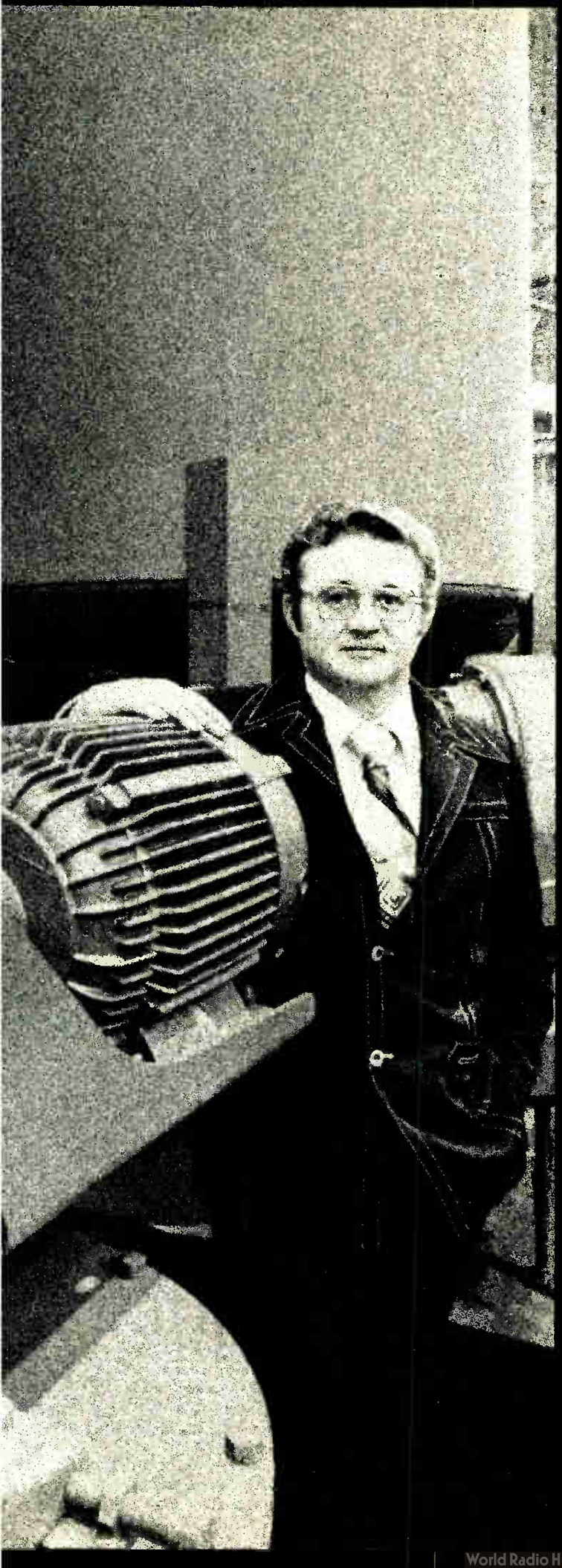
Perhaps its major head-on competitor, Texas Instruments, is also convinced that Timex is not about to quit the growing sector of the market represented by digital watches. Thus, after establishing price leadership in LED watches where Timex was not heavily committed, TI now is driving on the LCD field where Timex is heavily committed. The new line uses complementary-MOS chips rather than the integrated-injection-logic circuits put into the LED watches.

Although TI made its impact in LED timepieces through an intensive automation program, the LCD line is at present only about 50% along toward total automation, says Ronald W. Shelly, manager of the time products division. Part of the reason for going across the board with the tritium backlights was to simplify the automation program; the main reason was to insure high-volume use to bring cost down rapidly.

Neither Timex nor TI is anxious to add extra features. Shelly comments that as market segments for calculator watches, chronographs, and the like grow, TI "will look into these opportunities." Timex's Igelbrink is more emphatic. "You won't see a Timex watch that gives you high tides in Hawaii—not even in Hawaii." However, he adds that Timex will have a tritium-lighted watch if this feature proves to be a seller. □

Bright time. One of 10 models in Timex' Marathon line. Firm made its first appearance at Consumer Electronics Show.





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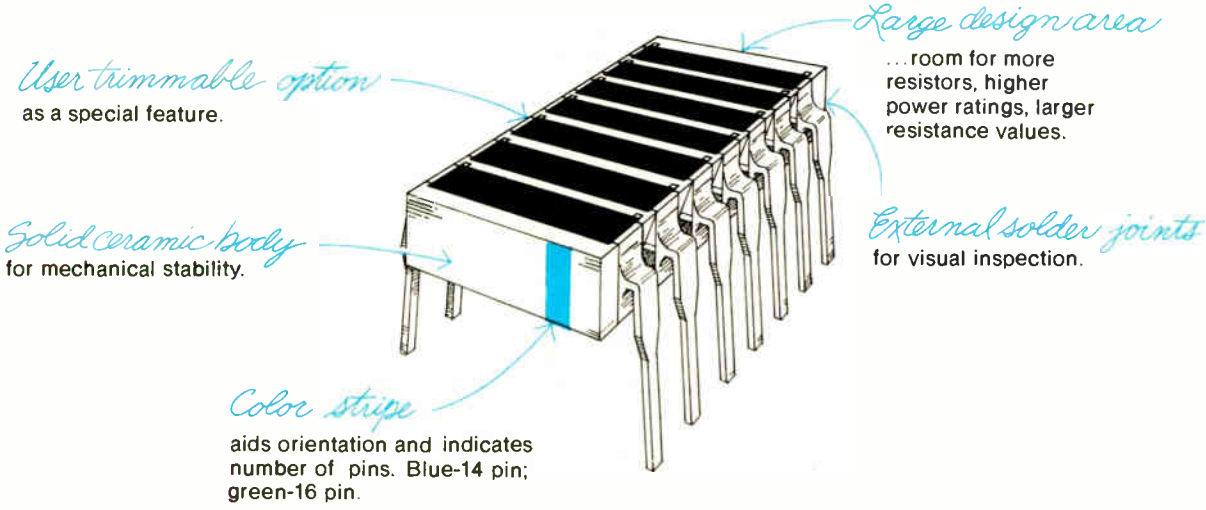

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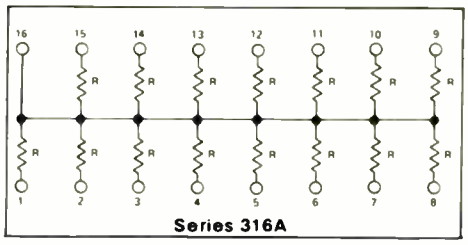
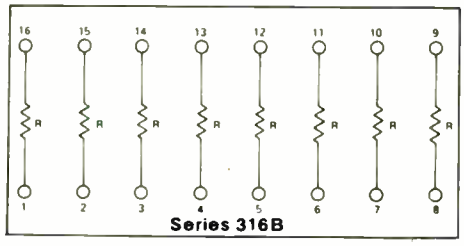
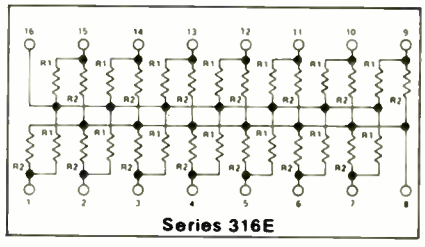

Series 316A

LINE TERMINATION
Two basic configurations (314B-14 pin; 316B-16 pin). Each available in 81 resistance values for transmission line termination, power gate pull-up, current limiting and logic level translation.


Series 316B

PARALLEL TERMINATION
Two basic configurations (314E-14 pin; 316E-16 pin). Each available in eight R1/R2 combinations for a wide range of impedance values.


Series 316E

Standard Resistance Values R (Ohms), ± 2% Tolerance

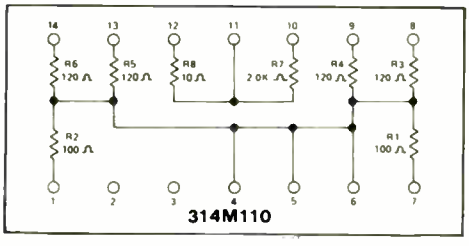
22	51	120	300	680*	1600	3900	8200	20K	47K*	120K	680K*
24	56	130	330*	750	1800	4300	9100	22K*	51K	150K*	1M*
27	62	150*	360	820	2000	4700*	10K*	24K	56K	180K	
30	68	160	390	910	2200*	5100	11K	27K	62K	220K*	
33	75	180	430	1000*	2400	5600	12K	30K	68K*	270K	
36	82	200	470*	1100	2700	6000	13K	33K*	75K	330K*	
39	91	220*	510	1200	3000	6200	15K*	36K	82K	390K	
43	100*	240	560	1300	3300*	6800*	16K	39K	91K	470K*	
47	110	270	620	1500*	3600	7500	18K	43K	100K*	560K	

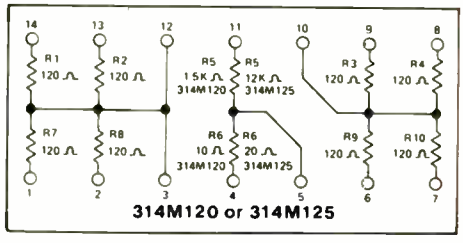
Characteristic Impedance Z_0

R1/R2	Z_0	R1/R2	Z_0
81/130	50	220/330	132
120/200	75	330/390	179
90/660	80	330/470	194
130/210	80	330/680	222
160/260	100	1 5K/3 3K	1 03K
220/270	121	3K/6 2K	2 02K
180/390	123		

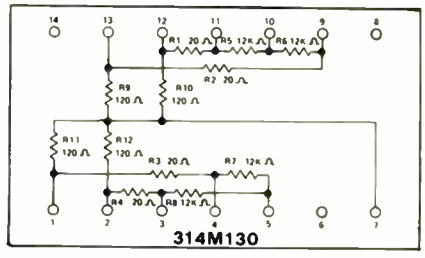
±1% TOLERANCE
The values marked with an asterisk of Series 314A, 314B, 316A and 316B in the table above are available with ±1% tolerance. Add the letter "F" on the end of the part number to indicate the optional ±1% tolerance.

SENSE AMP TERMINATOR
Three basic configurations complement the 7520 series of core memory sense amps.


314M110

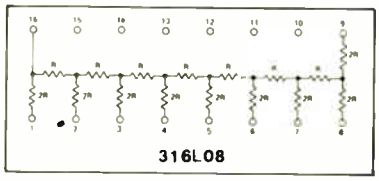

314M120 or 314M125

For sense line applications with two 711 dual voltage comparators.

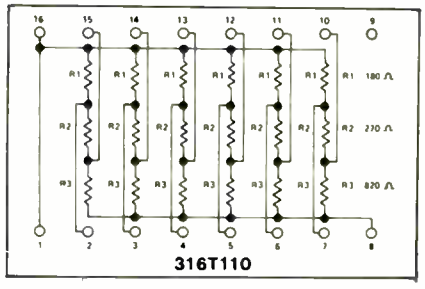

314M130

8 BIT R/2R LADDER NETWORKS
Designed for use with D/A and A/D converters with bipolar or CMOS switches.

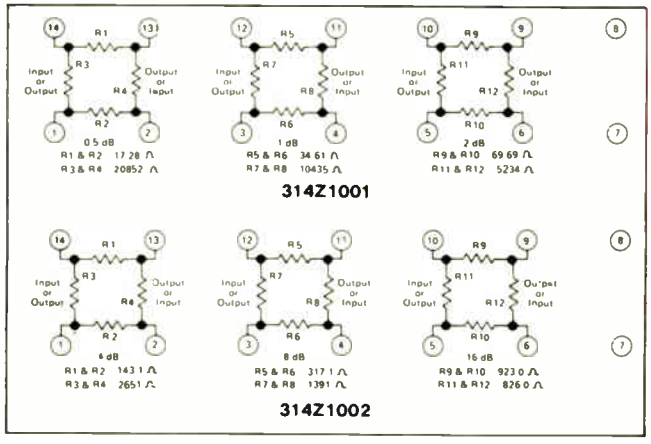
Part No.	R Value
316L08253	25K
316L08503	50K
316L08104	100K


316L08

TTL to ECL TRANSLATOR
Contains six TTL to ECL translators.

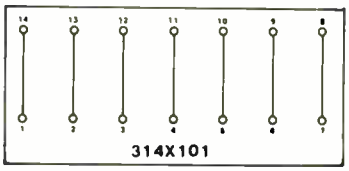

316T110

O-PAD ATTENUATOR
Two basic circuits for fixed voltage attenuation with impedance matching.



314Z1001
314Z1002

INTERCONNECT NETWORKS
For shorting and matrix interconnections, 14 pin, 314X101; 16 pin, 316X101. Other configurations available.


314X101

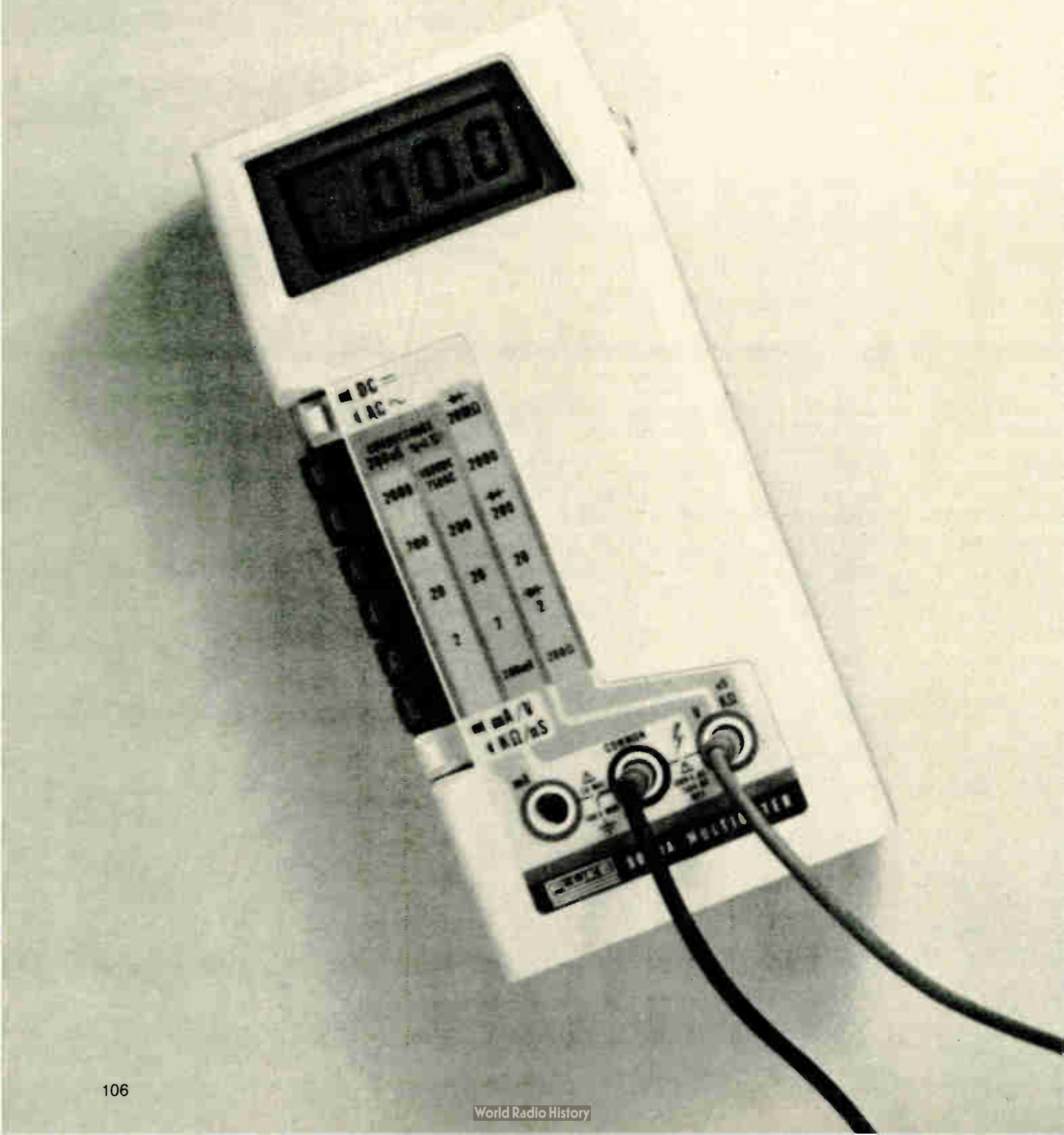
ALLEN-BRADLEY
Electronics Division
Milwaukee, Wisconsin 53204

EC164

Product development profile

Rough life of digital multimeter puts tough demands on design

by Norman Strong, *John Fluke Manufacturing Co., Mountlake Terrace, Wash.*



Hand-held instrument has custom analog-to-digital converter chip, as well as a liquid-crystal display that is directly driven; combination reduces parts count and keeps power demand low

☐ The hip-pocket life of a portable digital multimeter calls for a tough instrument. The portable DMM must put up with rough handling, electrical abuse, adverse environments, and long periods without calibration. The instrument also must be small, light, operate from batteries, and sell for less and work more easily than does its bench counterpart.

To meet these stringent demands was the goal of the designers of the 8020A. Long battery life immediately suggested a liquid-crystal display coupled to complementary-metal-oxide-semiconductor logic. Small size and low cost dictated a low parts count. And a tolerance for electrical and mechanical abuse required a sturdy plastic case and good input-protection circuitry.

A-d converter chip

Although there were several good one- and two-chip analog-to-digital converters on the market, with more to come, each one had drawbacks that made it unsuitable for multimeter applications—especially when used with an LCD display. Every general-purpose a-d converter required the addition of external display drivers, as well as dual power supplies and the usual passive components. These requirements largely vitiate the advantages of large-scale integration.

Fluke chose to simplify external circuitry by designing a custom C-MOS a-d converter chip capable of directly driving an LCD display and incorporating additional features useful in a multimeter application. The conversion technique chosen was a version of the familiar dual-slope converter; it has high accuracy, adequate speed, and enjoys general acceptance throughout the electronics industries. The design goals for the chip, built by Intersil Inc., Santa Clara, Calif., are:

- 2,000 count (±1,999) for higher precision than with 1,000-count instruments.
- Single 9-volt battery operation to keep size small and operating costs low.
- Direct LCD drive to simplify circuitry.
- Crystal-controlled clock oscillator for near-perfect rejection of line interference.
- Digitally selected 2-v and 200-millivolt ranges requiring no external components changes.
- True differential input for a simpler ac-to-dc converter.
- A single, floating, external reference voltage to simplify the ohmmeter protection circuits.
- Ratio accuracy to within one count when making measurements of high resistance.
- Near-zero bias current at all input terminals.

The inputs to the chip (Fig. 1) are routed through a series of switches (actually MOS transistors), which set up operations during different portions of the measurement cycle. Each measurement cycle is divided into automatic-zero, integrate, and deintegrate periods (Fig. 2).

During auto-zero, switches connect the buffer and integrator inputs to the internal common-voltage line. This closes a loop around the integrator and comparator to the auto-zero capacitor, C_2, removing the system offset voltage. The switches also connect capacitor C_1 to the 1-v reference, charging C_1 in preparation for the deintegrate period.

Because the 8020A is designed to operate from a supply as low as 6 v, the usual 6.4-v reference zener had to be replaced with bandgap type of reference, which operates at the bandgap voltage of silicon, (about 1.2 v) and has exceptional stability. A voltage close to the desired 1-v reference also makes for a much less critical voltage divider.

During integration, the unknown input voltage is connected to the noninverting inputs of the buffer and the integrator. These are both high-impedance inputs and allow a true differential measurement.

Two integration periods

There are two available integration periods. For the 2-v range (used for three resistance-range inputs), there is the 1,000-count period corresponding to one cycle of the ac 60-hertz line (which helps the meter to reject external 60-Hz signals). For the 200-mv range (used for all other inputs), there is the 10,000-count (10 60-Hz cycles), which increases the sensitivity by a factor of 10. A logic signal applied to the three-state range pin on the chip selects either integration period or a third choice in which the reference input is swapped with the unknown to allow inverse resistance measurements.

After integration, C_1 is connected to the buffer through the deintegrate switches in the opposite polarity from the unknown (which is determined by the output state of the comparator). When the integrator returns to the threshold, the comparator changes state and the count is transferred to the decoder and LCD driver for display. A new auto-zero period begins.

The reading rate is three per second, ideal for liquid-crystal readout, where faster rates might

Strong competition

The Fluke 8020A enters one of today's most competitive arenas in electronic instruments—3½-digit portable digital multimeters. There are at least nine other such DMMs on the market with prices ranging from approximately $100 to about $250. As with any instrument, potential buyers will have to size up the total specification package, along with convenience features.

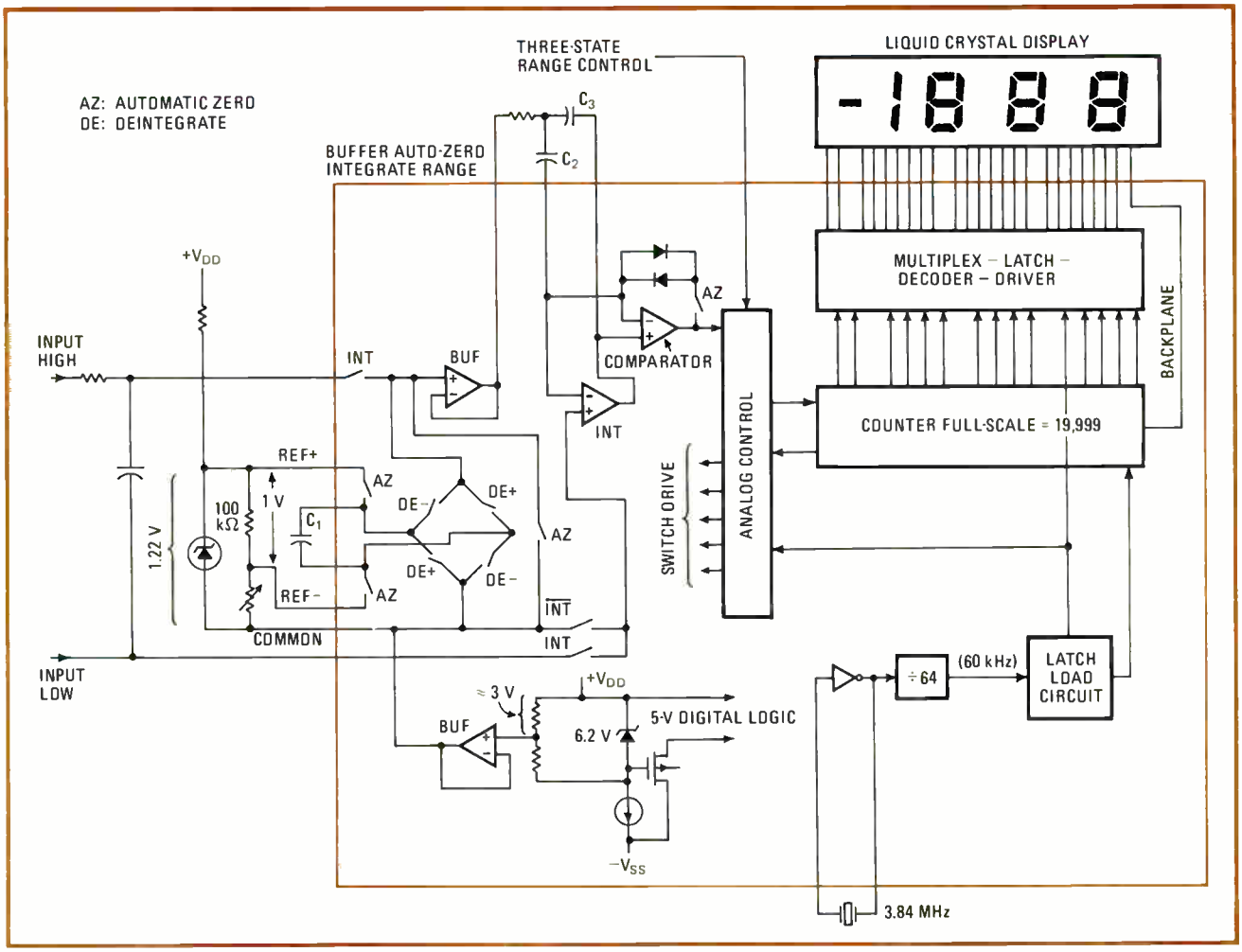
One of the basic requirements is accuracy. For dc voltages, the $169 8020A has an accuracy to within 0.25% of reading ±1 digit. This beats all lower-cost instruments and even some higher-priced ones, such as the $195 Weston 6000, which has 0.35% ±2 digit accuracy. (But Weston's unit also has automatic ranging, which the Fluke unit and others do not). There are at least five higher-priced units that come in with 0.1% ±1 digit accuracies on dc volts—the $279 Ballantine 3028A, the $249.50 Danameter II 2100A, the $234 Data Tech model 22, the $189 Data Precision model 175, and the $235 Simpson model 464D. (Prices differ because different features are offered.) Their manufacturers say the accuracy specs will hold for a time span of one year.

Accuracy on ac voltage ranges gets a little more complicated, since it can vary with frequency. Most meters are specified with at least three different ac voltage accuracies, each over a certain frequency range. Here, the 8020A's basic ac voltage accuracy of 0.75% +2 digits from 45 hertz to 1 kilohertz appears to be about right for its price. Again, it is possible to do better with higher-priced instruments, as is true with accuracies for ac and dc currents and for resistance readings.

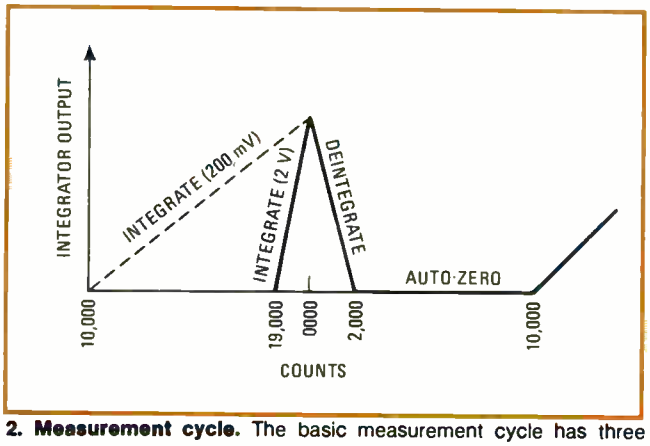
One basic choice facing buyers will be between those instruments that use light-emitting-diode readouts and thus require rechargeable batteries (such as the Simpson and Data Precision meters) and those that use the lower-power liquid-crystal displays and thus can use disposable batteries (such as the Fluke, Data Tech, and Dana meters). The rechargeable units give about six to eight hours of operation and then require overnight recharging. Alkaline batteries, however, generally can give more than 200 hours of operation before they must be replaced.

The Fluke unit has an exclusive feature—it can read conductance, thereby allowing resistance measurements up to 10,000 megohms, which would be useful in measuring leakage in capacitors, diodes, cables, and printed-circuit boards.

Stephen E. Scrupski



1. Converter chip. The C-MOS analog-to-digital converter chips, within the inner box, basically comprises the counter, display drivers, integrator, buffer amplifiers, and FET switches set by the analog control block during the automatic-zero, integrate, and deintegrate periods.



2. Measurement cycle. The basic measurement cycle has three periods. During auto-zero, offset is removed and the reference capacitor is charged. During integration, the unknown input is integrated for either 1,000 counts or 10,000 counts. During deintegration, the reference capacitor voltage is integrated until it causes the integrator to return to its threshold, and the count is displayed.

cause false readings because of the generally slow response time of the LCD. Rapid alternation between 6 and 7 might appear as an 8, for example.

Although clock frequency for the counter circuitry is 60 kilohertz, it is obtained from a 3.84-megahertz oscillator divided by 64 in an on-chip six-state counter. This high oscillator frequency allows use of the highly stable, low-cost AT-cut crystal, which is not available below 2 MHz. Also, crystals close to the television color-burst frequency (3.58 MHz) benefit from the very low production costs of this high-volume equipment.

C-MOS benefits

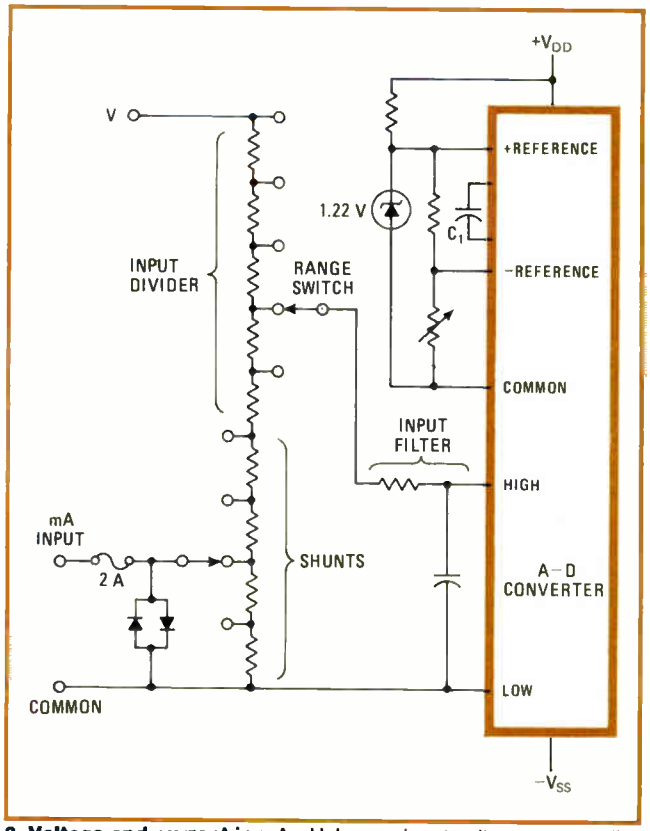
When Intersil was first asked to design the a-d chip, there was some question about the practicality of meeting some of the very stringent performance requirements. Three, in particular, stood out:

- Low power dissipation (less than 20 milliwatts).
- Input currents in the low-picoampere region.
- Very low noise (less than 30 microvolts peak-to-peak).

Intersil slightly modified its low-voltage C-MOS process to meet these requirements in a chip measuring 124 by 149 mils. The device is packaged in a 40-pin dual in-line package and operates at voltages down to 6 v from the single 9-v alkaline battery. Current drain is less than 1.5 milliamperes.

Low power dissipation is an inherent characteristic of C-MOS devices—unless the frequency of digital switching rises into the megahertz region. However, lowering the supply voltage will reduce the current. Since Fluke wanted to operate from a battery whose voltage might be anywhere from 6 to 10 v, the digital logic section was internally regulated to 5 v, while the analog circuits continue to operate at the full battery voltage. This low voltage for the digital section limited the current drain to 300 microamperes.

A zener diode buffered by a large p-channel MOS source follower supplies the digital logic with the 5 v. It also supplies the internal common voltage, which is divided down to 3 v from the positive supply. A buffer amplifier presents a low impedance at the common



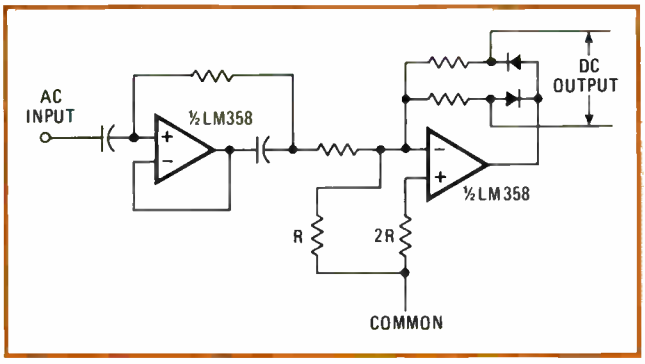
3. Voltage and current inputs. Unknown input voltages are applied across the divider string of resistors, while unknown currents are applied through a separate input jack, preventing damage to the shunts. For current measurements, the meter input may be connected to any switch position to pick up the voltage across the shunt, since unknown input currents do not flow through the divider.

terminal so that current may be drawn from the supply by circuits external to the chip.

The ohmmeter ranges of the 8020A require exceptionally low leakage currents at the input and reference terminals. The availability of field-effect transistors with negligible gate currents is another inherent advantage of C-MOS processing, but such circuits are susceptible to damage from static charges. Therefore, when the gate of a FET is brought out to an input pin, a small diode is added for static-charge protection—an important consideration in an instrument for field environments. Even with the diode, the leakage is typically less than 1 pA at operating voltage and room temperature. Low leakage is especially important in this system because any charge that the external capacitors lose through leakage will show up as an error in the instrument reading.

Reducing charge injection

Another way the capacitors can lose (or gain) charge is by charge injection from the switches. As the gate of a FET switch is driven off, its gate-to-drain capacitance injects a charge on any capacitor tied to it. This changes the voltage across the capacitor. However, in the C-MOS chip, each switch comprises an n-channel FET and a p-channel FET in parallel. If the gate-to-drain capacitances of the transistors are equal, the net charge injection will be zero, since the positive-going signal turning off the p-



4. Ac/dc converter. To measure ac input signals, the meter converts them to dc with a full-wave rectifier. Since both sides of the output are connected to one side of the amplifier, offset voltage is canceled, and, with the choice of resistors R and 2R to supply bias current, offset current is traded for offset voltage.

channel FET will exactly cancel the negative-going signal turning off the n-channel FET. Cancellation is not perfect, but capacitor voltage changes less than 2 μv.

If regular low-threshold (0.6-v) n- and p-channel transistors were used, the ones in the analog switches would have turned out to have too much leakage. This comes about because MOS transistors have exponential characteristics at low currents such that:

$$\text{Drain current} = a\,(e^{qV_{GS}/kTn} - 1)$$

where a = a constant, V_{GS} = the gate-to-source voltage (threshold—a negative quantity), q = the charge on an electron, k = Boltzmann's constant, T = device temperature on the absolute scale, n = 2 (a constant for Intersil's low-voltage process).

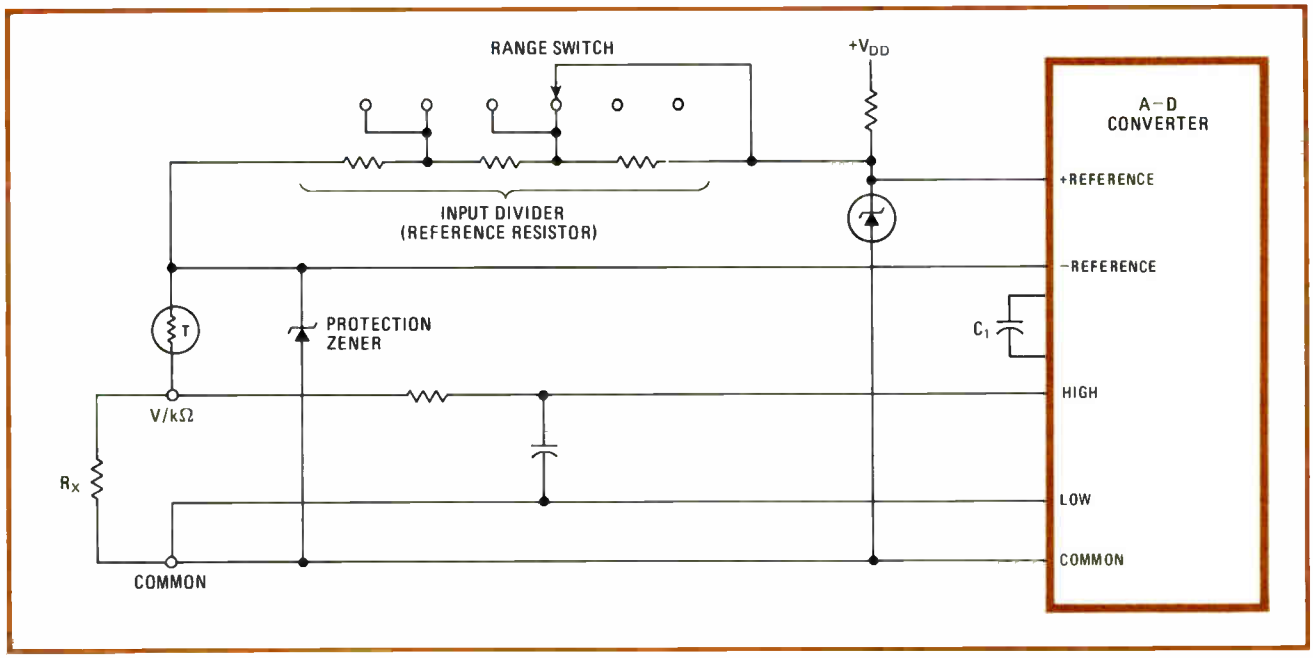
This equation shows that to reduce the drain current by a factor of 10 requires a 0.12-v change in threshold voltage. Thus raising the threshold voltage of the transistors in the analog switches to greater than 1 v means that under no signal conditions will leakage currents be significant. (The increase in threshold from the 0.6 v of the low-threshold transistors to 1 v reduces drain current about 1,000 times.) To achieve this drastically reduced threshold, an extra step of ion implantation is needed during fabrication of the transistors.

Cutting noise

The remaining problem was noise. Fluke wanted very low noise to avoid the problem of digit rattle so common on low-priced multimeters. Historically, C-MOS circuits have not been noted for low noise, and anxiety was amplified when preliminary samples of a competitor's C-MOS a-d converter showed 300 μv of noise referred to the input. This was 15 times greater than the 8020A requirement of 20 μv peak-to-peak.

Noise in C-MOS is caused by trapping sites that are filled and emptied at audio and subaudio frequencies. The chip's design attacked noise in two ways. First, a super-clean, gettered, and annealed process minimizes the number of trapping sites per unit area. Second, all FETs that serve noise-sensitive functions were made with very large gate areas. Because their instantaneous drain-to-source noise current is dependent on the percentage of trapping sites under the gate region that are filled at any one time, a large area gives more trapping sites over which to average and thus a smaller drain-to-source current variance (noise). Since the states of the trapping sites are independent of each other, the noise voltage is inversely proportional to the square root of the gate area.

With a big FET area, two other desirable features come free. The source-to-drain dimension (channel length) can be made greater than 2 mils, so that the output impedance is very high. This gives excellent common-mode rejection. Also, the device can be fabricated with a low



5. Ohmmeter circuit. For resistance measurements, the voltage input divider is used as a reference resistor. Its voltage is measured to determine the voltage across, and thus the value of, the unknown resistor. If the roles of the two resistors are reversed, the meter can measure conductance. The thermistor protects the reference resistor by increasing its resistance if the input signal level is too high.

In-step development

The development program for the 8020A portable digital multimeter was closely tied to the development schedule of the custom C-MOS analog-to-digital converter chip. While the chip was being designed, there was a lot of other work for the three-man design team to do: evaluate liquid-crystal displays from several vendors, figure out how to pack all the components into the hand-held enclosure, and design the circuitry that would protect the meter from all the mishandling and misapplications to which a portable DMM is subjected. However, it was not until the first chips from Intersil proved to work that the designers could be assured that they would complete their job on the schedule established about a year before.

The DMM team formed in October 1975 was headed by Stanley W. Jones (left in photo), who had been manager of test and manufacturing engineering. He broke down the design responsibilities in just about the most logical manner possible: analog and digital. Norman Strong (middle), a 13-year veteran with Fluke, handled the design of the analog portions of the meter, while Peter S. Duryee (right), nine years with Fluke, handled the digital design and the selection of the liquid-crystal display.

"We started out defining the performance requirements for the particular spot in the marketplace we wanted to hit with the 8020A," says Jones, "and then we started looking at Intersil and other semiconductor companies to determine the best LSI approach. We knew right from the beginning that we would have to develop our own chip, since there was nothing available at that time (nor is there now) that would meet all our requirements."

The early part of the project thus was dominated by the selection of the semiconductor process and the manufacturer. "Once that was tied down and we had a quote from Intersil as to how much it would cost and how long it would take, the rest of the project sort of revolved around that schedule," Jones says.

While the chip was in development, Duryee worked with Intersil's David Bingham while also checking on the LCD makers, and Strong worked with Intersil's Lee L. Evans. "We built quite a few breadboards using C-MOS op amps and even built some op amps out of discrete C-MOS transistors in an effort to determine the safest approach from a standpoint of noise and accuracy," Jones says.

"This was by far the smoothest chip development project that Fluke has ever been involved with," he says. That set the tone for the whole project. One of the high points, according to Jones, was when the first run of chips at Intersil actually worked. "The first die they put the probes on worked," he says. "We had some people in Europe at a sales meeting and we sent them a telegram—all we said was: 'The chip works.' That was all they needed to know, because it meant the schedule was realistic."

One of the major problems was maintaining adequate frequency response without many compensation adjustments. The small size and a requirement for no hand-soldered parts eliminated many alternatives. After many iterations of printed-circuit-board layout, a design was created with a compensation adjustment on only the 2-volt range. The solution was to move the first pole of the divider network beyond 35 kilohertz, which required less than 0.5 picofarad of capacitance across the input divider.

SES

bias current, and thus only a 0.3-v turn-on voltage is required. This increases the common-mode voltage range of the amplifiers, which also makes operation from a single 6-v supply possible.

LCD readout

The LCD also is essential to the meter's design, since it is the only type of display that would satisfy the power-drain requirements. However, examples from several vendors did have several problems for DMM applications:

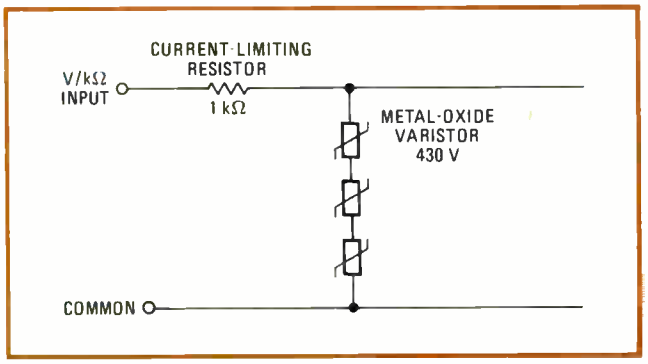
- Poor viewing angle.
- Slow operation at low temperatures.
- Serious degradation with humidity.
- Fragility of the thin glass plates.

The cooperation of engineers from Fluke and from several LCD vendors produced a display satisfying all the requirements originally set for the new multimeter.

By reducing the liquid-crystal thickness, both the speed at low temperatures and the viewing angle improved dramatically. An extra, protective laminate atop the polarizer material helped the display resist degradation for thousands of hours at high humidity.

The final problem was to protect the LCD from rough handling. Since the front is covered by a polarizing film, it seemed logical to protect it with a plastic lens with a mar-resistant surface. Unfortunately, the most mar-resistant plastic tends to shift the polarization of light, once again reducing the viewing angle (and making the display unreadable through Polaroid sunglasses). The solution to this was a special thermosetting plastic-rigid allyl diglycol carbonite inherently hard enough to provide mar resistance without special processing.

The signal conditioners, switches, and the all-important input-protection components extend the basic



6. Input protection. Three metal-oxide varistors are connected in series across the input. If the voltage applied is too high, the varistors will short-circuit to protect the internal circuitry of the meter.

circuitry to the outside world and make the device a multimeter. Figure 3 is a simplified representation of the input circuits, showing how the shunts and input divider are connected to the a-d chip to measure voltage and current. No switching is necessary to get from voltage to current; the user transfers a probe to the appropriate input jack. This helps protect the meter's shunts.

The input divider and the two shunts with the largest resistance are thick-film networks. Thick film was chosen over thin film because it is capable of withstanding severe transient overloads without damage. Even low-energy transients can cause sharp shifts in the value of a thin-film resistor. The low-value shunts are wirewound.

Ac/dc converter

Figure 4 is a simplified representation of the ac/dc converter used for ac measurements. The differential output to the a-d converter makes possible both full-wave output and direct coupling. Full-wave output doubles the ripple frequency, allowing much less filtering and resulting in a faster settling time. It also cancels the offset voltage of the amplifiers, since both sides of the output are connected to the same amplifier input.

Without proper corrective design, amplifier bias currents would flow through one of the diodes to only one side of the output, causing a voltage drop in that half of the circuit and an apparent offset. Placing a large resistor (2R) in series with one amplifier input and one half that value (R) in series with the other, means that the required two units of bias current are supplied through R. Therefore, offset current can be traded for offset voltage, to which the circuit is insensitive, and the error is cancelled. All resistors in the circuit are contained in a single low-cost network.

The ohmmeter

Figure 5 shows the 8020A connected to measure ohms. The input divider used for volts is also used as a reference resistor. Since the same current flows through it and the unknown resistor, the two voltage drops, which are the basis for the dual-integration measurement, are proportional to the respective resistances.

The voltage across the unknown resistance is integrated first, for 1,000 counts, and then the unknown voltage across the reference resistor is integrated downward until the zero crossing. The resulting accumulated count during the deintegrate period is proportional to the unknown voltage and thus to the unknown resistance. By changing reference resistors and a-d ranges, resistances from 0.1 ohms to 20 megohms can be measured by the new multimeter.

For higher resistances, the inverted range, referred to above, comes in. By integrating the voltage across the reference resistor first and using the unknown voltage as the reference during the deintegrate period, the 8020A will read the reciprocal of an unknown resistance—its conductance. This is the only practical means of measuring hundreds or thousands of megohms on a digital multimeter.

In this way, the 8020A can be used to read up to 10,000 MΩ. The scale is called 200 nanoSiemens (formerly known as the mho, the Siemens is the international unit of conductance). The conductance range extends the usefulness of the multimeter by three orders of magnitude without requiring the addition of a single component.

Electrical protection

A positive-temperature-coefficient thermistor protects the reference resistor, the most delicate component, against inadvertent high voltages across the input. This device maintains a low resistance of about 1 kilohm up to a critical temperature, at which point the resistance rises rapidly to thousands of times its original value. If an external overvoltage is applied to the input terminal, a high current flows through the zener clamp and the thermistor. The current heats the thermistor to its switching point, whereupon its resistance increases to protect the internal component. Although the thermistor is in series with the unknown and reference resistors, its voltage drop is not part of either of the independently measured input or reference voltages.

To protect against high-voltage transients, the 8020A has a string of metal-oxide varistors connected across the input in series with a current-limiting resistor (Fig. 6). The varistors look like an open circuit up to their rated voltage. At that point, their conductance increases exponentially, effectively short-circuiting the input pulses. The action is instantaneous and provides positive input protection.

Long-sustained overvoltages will, of course, destroy the varistors. They are designed to fail as short circuits, however, and the current-limiting resistor is designed to fail as an open circuit, so that protection remains positive. The milliampere input terminal is protected by a 2-ampere fuse and a pair of clamping diodes in the standard fashion.

The complete 8020A is built on a single printed-circuit board with fewer than 50 components, all wave-soldered at one time. The LCD display is mounted above the a-d converter chip, and the single 9-v transistor battery is connected to the pc-board by a flexible connector with snap-on terminals (the fuse holder is mounted on the battery connector). Battery life, using an alkaline battery, is over 200 hours. Calibration is an annual affair involving three adjustments; one for dc, one for ac, and one for ac frequency response. □

One-chip CPU packs power of general-purpose minicomputers

Evidence of the quickening pace in 16-bit microprocessors are two new devices that extend the range of these systems—one into the heart of minicomputer design and the other into low-cost controller designs. While both break new ground in 16-bit technology, the chips are as different as they possibly could be.

One of them is a high-performance minicomputer central processing unit built with integrated injection logic. Designed by Fairchild Camera and Instrument Corp., it is intended to implement general-purpose single-board minicomputers. The chip, part of Fairchild's 9400 microcomputer series, can execute the instructions of a well-established minicomputer family.

The other is an n-channel metal-oxide-semiconductor single-chip microcomputer that fits into the low end of Texas Instruments Inc.'s line of 9900 microcomputers. Containing all the processing, program memory, data storage, and input/output capability needed for control applications, the 9940 will serve as a dedicated stand-alone controller in high-volume equipment designs where a minimum of computation is required.

The two articles that follow, written by the designers of these devices, describe the technical details of the chips and how they can be used in data processing (Fairchild's) and control applications (Texas Instruments'). The Fairchild article starts in the next column and the Texas Instruments story begins on p. 118.

by Dan Wilnai and Peter W. J. Verhofstabt,
Fairchild Camera and Instrument Corp., Palo Alto, Calif.

☐ One of the new breed of 16-bit microprocessors, the Fairchild 9440 puts an entire minicomputer central processing unit on just one bipolar chip. Since all this power is packed in a single 40-pin package, a designer can now for the first time build a full-blown minicomputer on a board. Side by side with the 9440 go large-scale-integrated interface circuits and plenty of directly addressable memory—as much as 32,768 16-bit words that can be any combination of instructions and data.

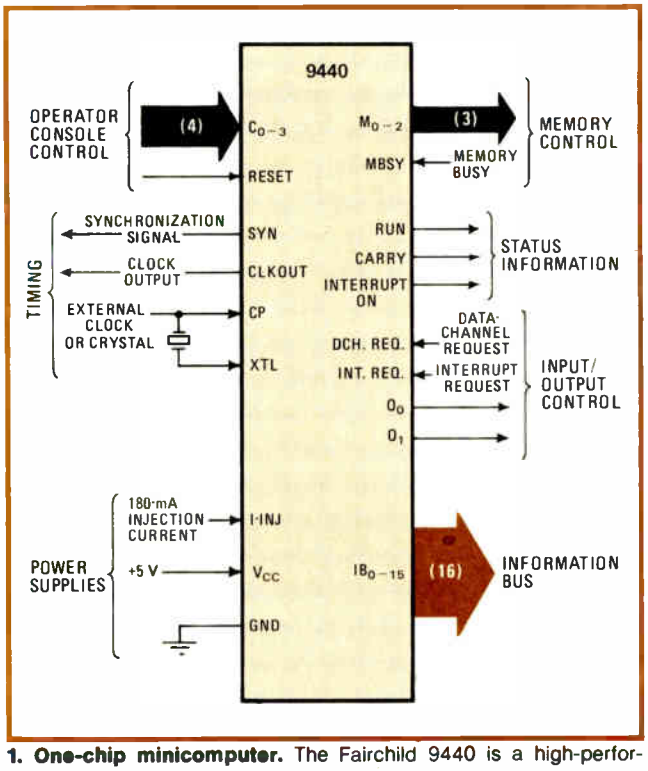
Rather than adding yet another instruction set to the already crowded repertoire, the new chip executes the same instruction set as the Nova series of general-purpose minicomputers built by Data General Corp. To fully utilize this instruction set, Fairchild provides its own complete software package that includes all the needed program development aids, as well as a full set of diagnostic programs and high-level languages.

Basic to all this capability is the Isoplanar integrated-injection-logic process, which Fairchild calls I^3L. The use of I^3L means that high density combines with high performance—160-microwatt consumption and 4-nanosecond propagation per gate—to yield a 16-bit microprocessor about the size of most 8-bit metal-oxide-semiconductor designs, but of course much more powerful. It also means that all the 9440's control lines, as well as its information bus, have low-power Schottky transistor-transistor logic. Power supply requirements for the chip are +5 volts and a 180-milliampere injection current.

The chip itself is modestly housed in the 40-pin package diagrammed in Fig. 1. Instructions as well as data are stored in homogeneous external memory, and a 16-bit-wide, three-state information bus carries both data and address between the microprocessor and the other computer elements.

The 9440 can directly service up to 63 peripheral input/output devices through programmed I/O as well as interrupt-driven I/O, and it also permits direct memory access. A single I/O instruction can at once control operation of the peripheral device and transfer a word between it and the 9440.

The interrupt system allows any peripheral device to interrupt the normal program flow on a priority basis. Device priority can be established off chip by daisy-chain connection of a serially propagated interrupt-priority signal. However, the processor can foil the inter-



1. One-chip minicomputer. The Fairchild 9440 is a high-performance 16-bit bipolar microprocessor built with Isoplanar integrated-injection-logic technology. It executes the same instruction set as Data General Corp.'s Nova series of general-purpose minicomputers.

rupt capability of any given I/O device by putting a mask bit on the information bus.

It is worth noting that the DMA arrangement is a true one in the sense that the I/O device is not under the control of the central processing unit but rather is communicating directly with memory over the information bus after the 9440 puts the latter into its floating or high-impedance state. This allows external circuitry to provide fast DMA at a rate limited only by memory or device speeds.

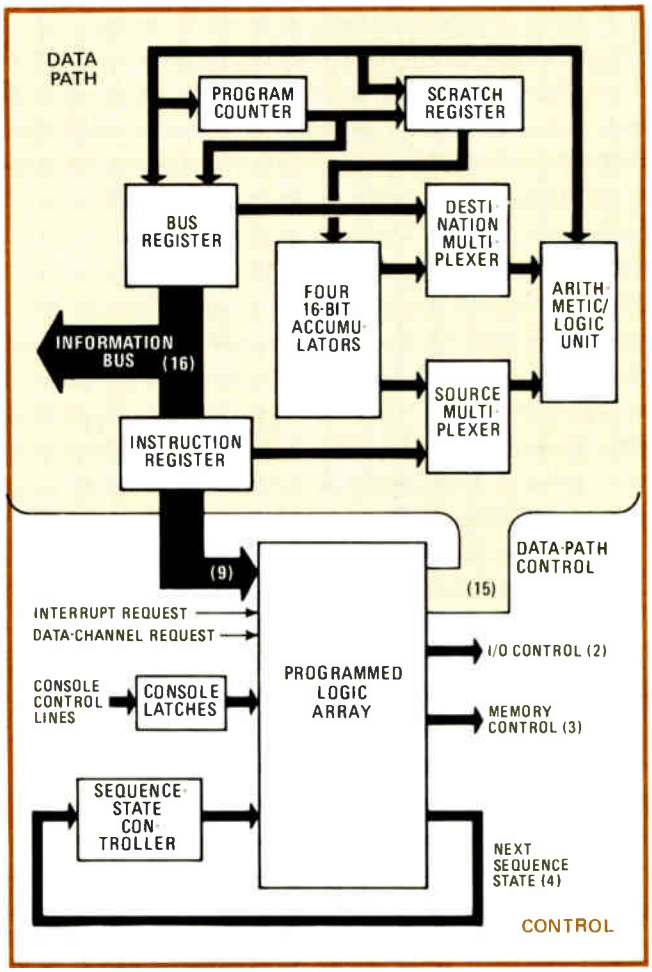
Internally, the processor is organized around four general-purpose accumulators and an arithmetic/logic unit. The ALU has two 4-bit-wide input ports and operates on two 16-bit words in four consecutive steps, taking one 4-bit "nibble" per step. Data can be moved in either direction between memory and any accumulator, and all I/O data transfers (except in the DMA mode) take place through the accumulators as well.

Architecture

The 9440 can be thought of as a collection of data paths and the controllers of these paths. The signal trafficking is shown in Fig. 2, where the upper portion depicts the data flow and the lower portion shows controller functions.

The data path portion of the processor includes an ALU, a bank of eight 16-bit registers, and two multiplexers, all linked by 4-bit-wide data paths.

Four of the registers serve as the general-purpose accumulators. Of these, accumulators AC_2 and AC_3 are also used as index registers, and AC_3 can also serve as a subroutine-linkage register during a jump instruction.



2. Architecture. Comprising a collection of data paths and the circuitry necessary to control those paths, the 9440 governs main memory and all peripheral I/O equipment, performs all arithmetic, logic, and data-handling operations, and sequences the program.

Specific data is delegated to the other four registers—the bus register, the instruction register, the program counter, and a scratch-pad register. The bus register, connected to the bidirectional information bus, can either supply or receive 16 bits of parallel data. The instruction register is loaded also with 16 bits in parallel, directly from the information bus during an instruction-fetch operation. The program counter is normally incremented to take instructions from consecutive memory locations. However, its contents can be incremented twice by the skip class of instructions or be changed entirely by the jump class of instructions. The scratch pad holds the data from the ALU for one cycle before putting it into the destination accumulator.

The destination and source multiplexers, handling the 16-bit words in groups of four nibbles each, are tied into all four accumulators and select source and destination registers for each operation. The multiplexers receive other inputs as well, from the bus and instruction registers, which permit the ALU to be used for effective-address calculations and other purposes.

The controller portion of the 9440 is structured around a 16-state microcode implemented with an internal mask-programmed logic array. For each of 72

possible data path operations, there is a corresponding 24-bit word in the logic array. Each word comprises the following signals:

- Data-path control signals—15 bits.
- Memory control lines M_{0-2}—3 bits.
- Input/output control lines O_{0-1}—2 bits.
- Pointer for next sequence state—4 bits.

The data-path control signals, which are internal to the 9440, handle the program counter and the bus and instruction registers, as well as the ALU, the four accumulators, and all multiplexing. The memory-control lines handle reading and writing, as well as loading of the memory-address register. The bits of I/O control tell the I/O devices what to do. The state pointer indicates the next one of the 16 states in the operating sequence of the logic array.

The particular 24-bit control word leaving the logic array is determined by an input word, 19 bits wide and carried on five signals, that address the logic array. The input signals are:

- Instruction register—9 bits.
- Operator console control lines C_{0-3}—4 bits.
- Sequence-state pointer—4 bits.
- Interrupt-request line—1 bit.
- Data-channel-request line—1 bit.

The instruction register is loaded directly from the instruction codes that are stored in the homogeneous external memory and conveyed to the register by the information bus. The console control lines C_{0-3} are encoded with information for the manual control, including functions such as run, step, halt, reset, and so on.

The sequence-state pointer keeps track of the current operating state of the PLA. The interrupt-request line is an input pin on the 9440 that is shared by all I/O devices. The data-channel-request line is also shared by all I/O devices and is used for requesting direct access to the 9440 memory.

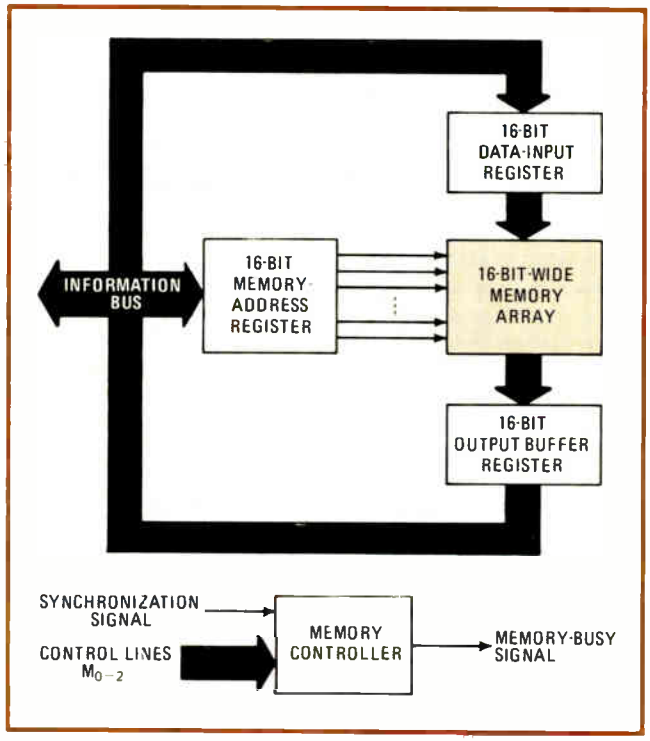
The instruction set of the 9440 processor divides up into four classes: two types of memory-reference instructions, arithmetic/logic instructions, and I/O instructions.

The first class of memory instructions consists of referencing without register (that is, not requiring use of the accumulators). They are used for modifying memory (such as increment- or decrement-and-skip-on-zero) and for branching (as in jump instructions).

The second class of memory instructions, referencing with register, moves 16-bit words between memory and the accumulators. This class comprises loading of the accumulators from memory and storing into memory from the accumulators.

The arithmetic/logic instructions, as the name implies, perform arithmetic (add, add complement, subtract, increment, and negate) or Boolean (AND, complement, and move) operations on the contents of two registers. The result of each operation, together with the carry bit, can be rotated right or left and tested for skip conditions as a part of the same instruction. After the shift, the result may also be loaded in the destination register if desired.

The final class of instructions is the I/O instructions, which move data between the 9440 accumulators and



3. Memory organization. The external memory system of the 9440 requires a 16-bit-wide memory array. The memory-address register defines an address in the array, the data-in register holds the data to be written, and the output buffer register holds the data read.

buffers (up to three) in the peripheral-device interface. The control functions, already mentioned as included in these instructions, comprise four commands: start, stop, clear, no operation. The instructions may also test the status flags in the I/O device and the central processor.

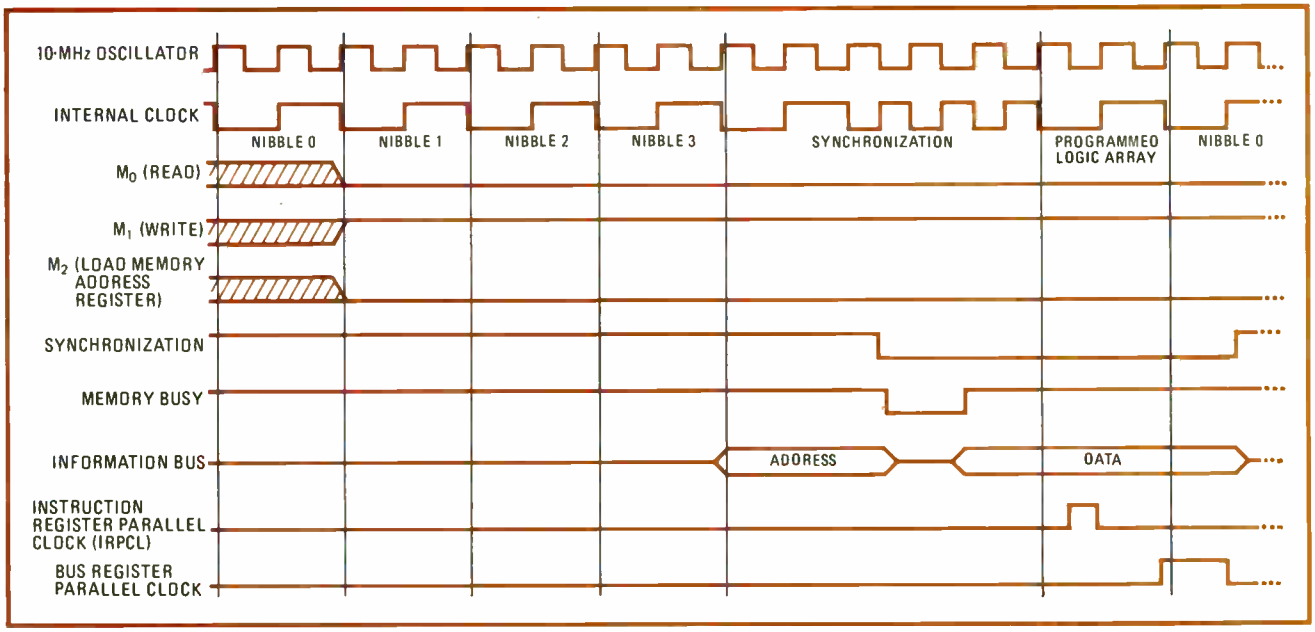
The 9440 has flexible memory-addressing structure that spans eight different modes. There are four different types of addressing—absolute addressing of page zero (the first 256 locations in memory), and relative addressing involving either of two accumulators or the program counter—and each type may either be direct or indirect, for a total of eight modes.

Relative addressing

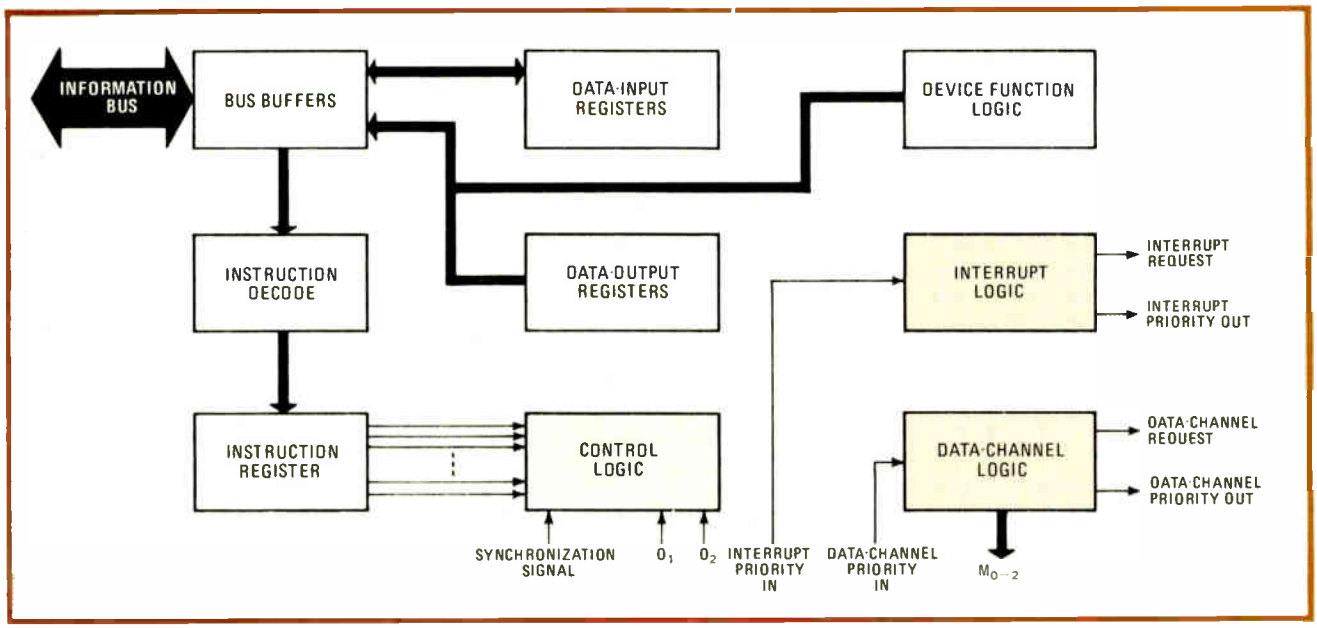
Relative addressing permits a variation of +127 or −128 locations about an index, which can be a location in accumulators AC_2 or AC_3 or the program counter. Relative addressing with an accumulator is useful for gathering consecutive entries from a table in memory, for example, where a displacement is added to an incremental index in the accumulator. Relative addressing with the program counter is useful for jumping to nearby locations when it is desirable to have a relocatable program.

In the case of direct addressing, the 15-bit computed value is the actual address used to read or store the operand. In the case of indirect addressing, the computed value is the address of an address; moreover, indirect addresses may be nested such that the data read from an indirectly addressed location may be another indirect address.

An auto-increment feature of the 9440 comes into



4. Read operation. In a memory-read operation, the address appears on the information bus at the end of the fourth 4-bit nibble. Once address information is latched into memory, reading begins and the 9440 receives a memory-busy signal that instructs it to remove the address from the information bus. After reading is completed, the memory applies its output buffer to the bus and stops the busy signal.



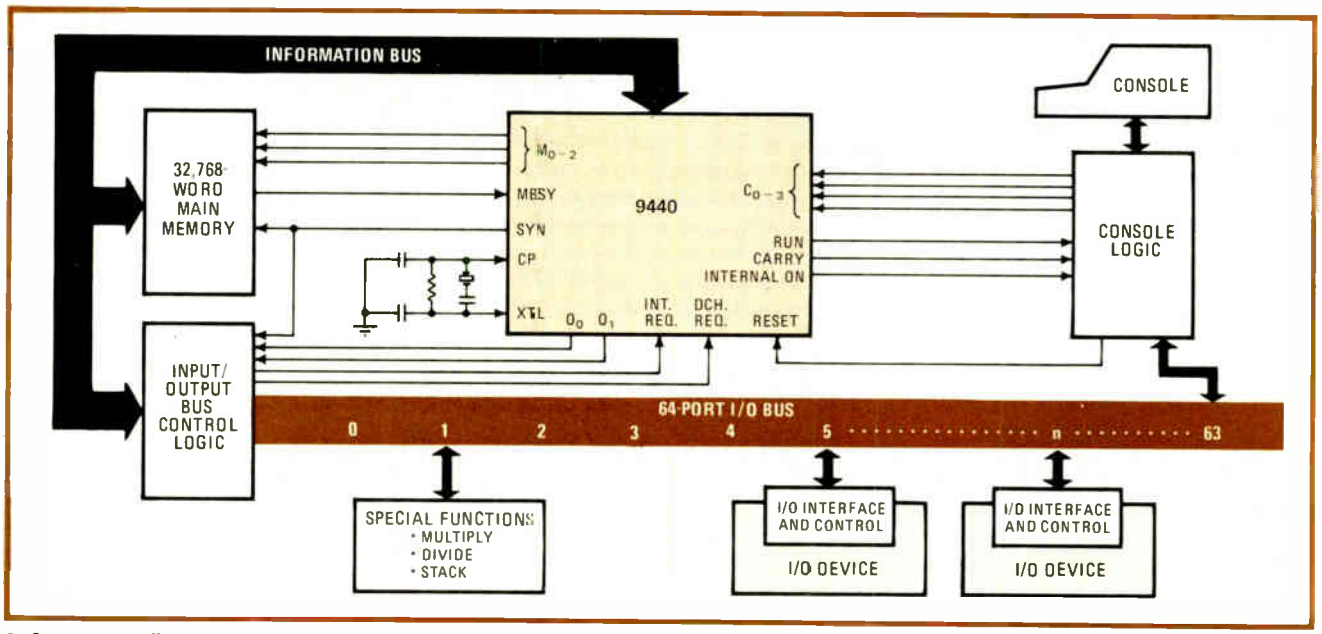
5. Interfacing I/O. The 9440 can directly address as many as 63 I/O devices. Peripheral devices interface under either program or interrupt control or by direct access to the main memory using the data-channel-request line. Lines M_{0-2} control the main memory, and lines O_{0-1} define the I/O function. Devices requesting interrupt (or data channel) at the same time are serviced by priority.

play when octal locations 20–27 are indirectly addressed—that is, whenever one of these locations is specified by a memory reference instruction in an indirect-address mode, the contents of the selected location are first incremented and then the new value is treated as the new address. The new address can again either be direct or indirect. In a similar fashion, a built-in auto-decrement feature can be used by indirect addressing of octal locations 30–37.

A typical external main-memory system, shown in Fig. 3, is organized around a 16-bit-wide memory array. A memory-address register defines an address in the array. Two other registers, the data-in register and the output buffer register, hold the data to be written into and the data to be read from main memory, respectively, and also interface with the information bus.

Memory operations are controlled by the M_{0-2} lines, which are common to the 9440 and to all I/O devices capable of direct memory access. Any device wanting to use the memory has to activate the appropriate control lines: M_0 is memory read, M_1 is memory write, and M_2 is load memory-address register.

Any operation on the memory must be specified for either read or write, and the location in the memory



6. System configuration. A typical computer system connects the 9440 as a central processing unit to main memory, peripheral devices, and an operator's console. Since it participates in the data transactions on the information bus, the console is treated as an I/O device and is connected to I/O port 63. Port 1 is reserved for special functions, such as hardware math and stack instructions.

array must be specified as well. Since the information bus in the 9440 is shared by both addresses and data, the information on the bus during each cycle must be clearly defined.

A memory-read cycle is shown in Fig. 4. At the beginning of the cycle, the 9440 asserts both M_0 (read) and M_2 (load memory-address register). The address is then put on the information bus at the end of the fourth nibble, and after a deskewing delay period, a synchronization signal is asserted.

Next, the memory latches the address into the memory-address register and sends the 9440 a memory-busy signal. The data stored in the accessed location is then read. When the 9440 receives the busy signal, it takes the address off the information bus. After the read operation is completed, the memory connects its output buffer to the information bus and terminates the busy signal. Finally, the 9440 loads the data read from the memory into the bus register or the instruction register and terminates the synchronization signal. Then the memory disables the output buffers.

A write operation is initiated in much the same way, except that a second cycle is required, at which time the 9440 asserts M_1 (write), and the data to be written into memory is then put on the information bus.

Interfacing with the outside

The structure of the I/O interface within the 9440 system is shown in Fig. 5. Peripheral devices communicate with the processor through the common information bus. To avoid conflicts on the bus, the devices are sent a synchronization signal. The function that the I/O device is to perform is conveyed over the information bus and on the O_0 and O_1 lines.

To allow the I/O devices to interface under program control, each should provide two signals as status indicators—one to indicate that the device is busy and another to signal that it is available. The 9440 can therefore probe the status of a given device by asking it to place its status signals on two lines (IB_0 and IB_1) of the information bus.

Since there may be several devices requesting interrupt simultaneously, device priority is established by a daisy-chained connection of an interrupt-priority signal. Each device has an interrupt-priority input line and an interrupt-priority output line. When there are no interrupt requests, the priority signal propagates serially throughout the chain. The first device requesting an interrupt breaks the chain by blocking the priority signal and receives first recognition by the 9440. It then answers the interrupt-acknowledge instruction received from the processor by placing its device code on the information bus. The 9440 can, however, disable the interrupt system in any I/O device by "masking" the particular device with an I/O instruction sent over the information bus.

For operation under direct memory access, three control lines similar to the interrupt control lines are available. The data-channel-request line, like the interrupt-request line, is common to all I/O devices. Priority under DMA can be established just as under interrupt control by data-channel-priority input and output lines, with a serially propagated priority signal daisy-chained between I/O devices.

A typical system configuration is shown in Fig. 6. The 9440 is connected to 32,768 bytes of main memory and to I/O bus control logic, as well as to operating console logic. All but two of the 64 ports on the I/O bus can be used for peripheral devices and can operate under program, interrupt, or DMA control. Port 1 is reserved for special functions such as hardware multiply/divide instructions and memory stack instructions. Port 63 is saved for special central-processing-unit instructions such as mask out or read switches from the console. □

16-bit microcomputer is seeking a big bite of low-cost controller tasks

by John D. Bryant and Rick Longley,
Texas Instruments Inc., Houston, Texas

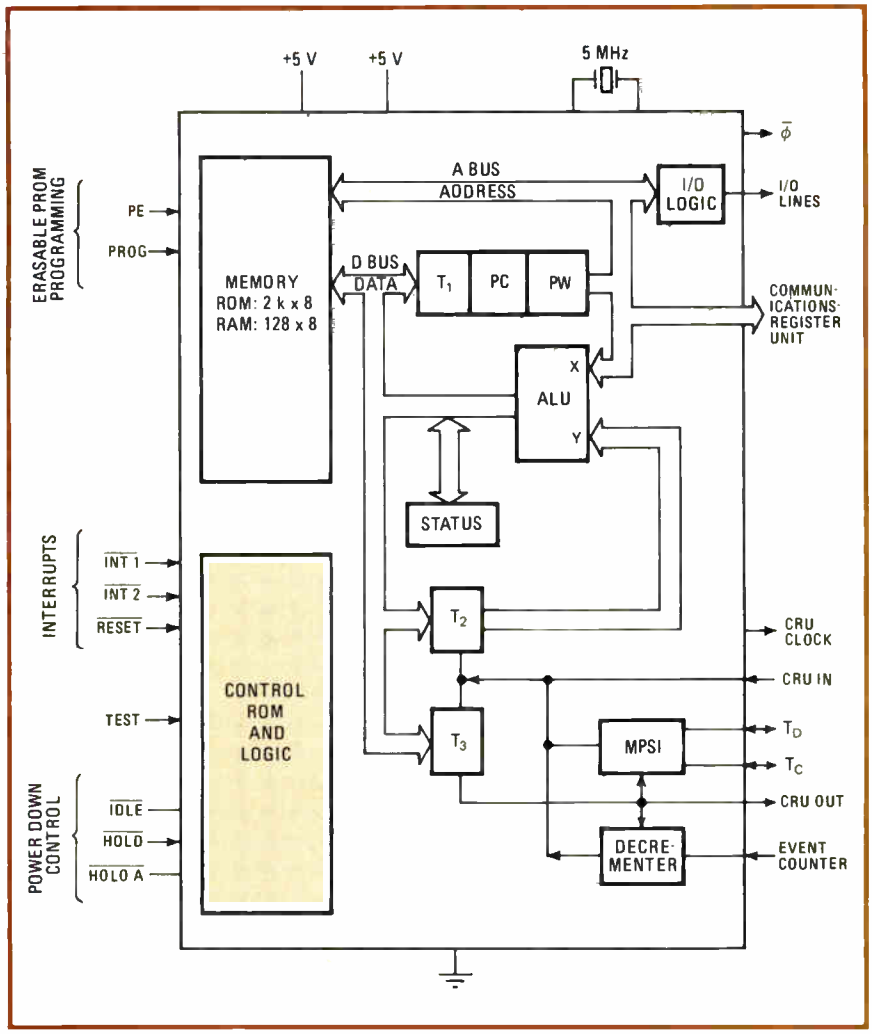
☐ One-chip microcomputers have staked out a claim to low-cost controller applications, and the device that is likely to grab a good share of the gold is the first 16-bit one-chip unit. The TMS 9940, the latest addition to the 9900 16-bit family, is a 5-volt stand-alone microcomputer containing all the necessary central processing and control logic, memory, and input/output capability needed for many low-cost controller applications.

The on-chip memory consists of 128 bytes of read/write random-access memory and 2,048 bytes of either mask-programmable read-only memory or (as an option) reprogrammable ROM. The total capacity exceeds most 8-bit one-chip devices.

The 9940 can address 32 bits of general-purpose I/O devices and can be expanded to 256 additional bits of I/O, or three to five times more than the smaller one-chip microcomputers. Equally important, processing 16-bit words makes it inherently faster than 4-bit and 8-bit microcomputer chips. The longer words also make it better at controlling equipment requiring higher precision—12 bits and up, for example, in an analog-to-digital conversion.

What's more, the 9940 is the only one-chip unit with an architecture and instruction repertory identical to a well-established microcomputer family. A user can move directly from it into the higher-performing multichip 8- and 16-bit members of the 9900 family with no additional expense in basic software development.

Like all members of its family, the new chip (Fig. 1) processes data over two independent, parallel data and



1. The big one-chipper. This 16-bit one-chip microcomputer has all the processing blocks for handling a wide range of control applications. On-chip memory consists of 128 bytes of RAM and 2,048 bytes of ROM. The 9940 can address 32 bits of I/O, expandable by another 256 bits.

instruction bus lines under the direction of a 4,000-bit microprogrammable control ROM (tinted in the figure). [For details of this organization, which follows popular minicomputer architecture, see *Electronics*, May 27, 1976, p. 99.]

How it's organized

The 9940's central processing unit sends a memory address to the on-chip memory over the bus labeled A and sends or receives data over the bus labeled D. Temporary 16-bit registers, T_1, T_2, and T_3, store intermediate addresses and operands, while another 16-bit hardware register called the program counter (PC) stores the value of the address of the next instruction to be executed. An 11-bit hardware register, called the workspace pointer (WP), stores the value of the memory address of the beginning of the register file.

For handling program instructions, the arithmetic/logic unit accepts two independent 8-bit inputs and puts out the 8-bit result on the D bus. It uses high-level techniques called pipelining (starting one operation before completing the previous one) to allow the ALU to rapidly process two bytes of data automatically. The pipelining feature boosts the 9940's throughput two to three times higher than other commercially available one-chip microcomputers.

The program memory is addressable in 8-bit bytes, with a word being defined as two consecutive bytes. The chip employs an advanced memory-to-memory architecture (just as in the TMS 9900 CPU). Blocks of memory, designated workspace register files, replace dedicated hardware registers like the ones used in microprocessor designs such as the 8080 or 6800. This setup makes the chip extremely flexible, since the workspace register files contain 16 contiguous memory words that can function as operand registers, accumulators, address registers, or index registers.

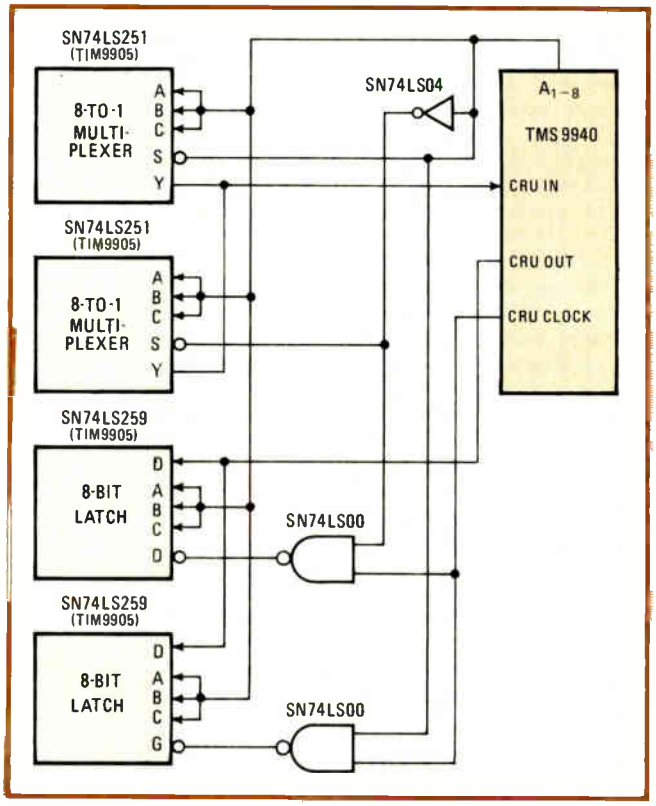
The workspace arrangement is particularly valuable during operations that require a context switch, such as an interrupt or subroutine call. Such an operation in a microprocessor with a conventional multiregister arrangement requires that at least part of the contents of the register file be stored and reloaded. The 9940, on the other hand, can accomplish a context switch with a simple exchange of values in the status register, the PC register, and the WP register.

Easy to interrupt

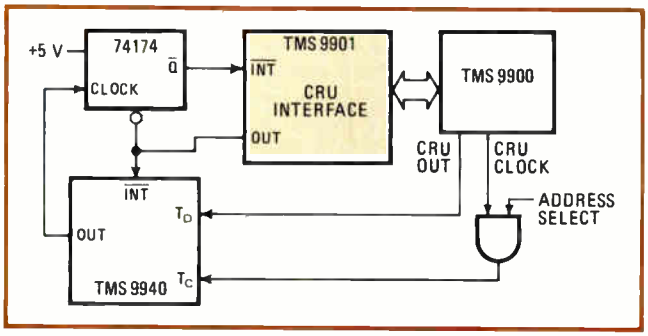
Another big advantage of the 9940 over the 4- and 8-bit one-chip devices is its ability to handle many varied interrupts. The chip can implement four hardware interrupt levels, with the highest priority being reserved for the reset function, followed by the decrementer and the two user-defined external interrupts.

In interrupt routines, the value of the highest active interrupt level is continuously compared with the interrupt mask in the status register. When the level of a pending interrupt is of higher priority than the mask value, the CPU recognizes the interrupt and performs a context switch.

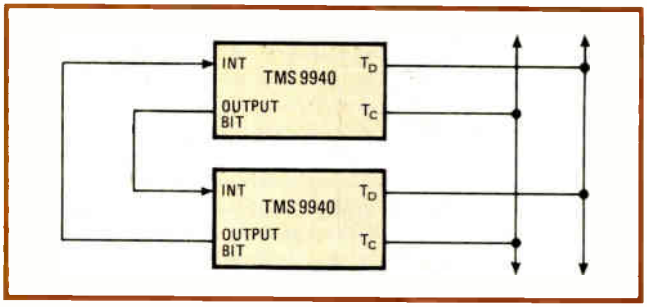
The context switch is done by fetching the next PC and WP context values from the interrupt vector location,



2. Expanding. This I/O configuration, which is a 16-bit input and 16-bit output register, requires only a few easily available parts: two 8-to-1 multiplexers, two 8-bit latches, and some gates. The 9940's I/O capability can be expanded to handle 16 of these registers.



3. Peripheral processing. The 9940 makes a good peripheral processor in large multiprocessor systems. In this setup, the 9940 can execute peripheral instructions from a 9900-based system simply by executing the off-loaded instructions sent to its RAM.



4. Communicating. Two 9940s in a multiple processor system communicate through ports T_C and T_D. The protocol for multiple systems—additional chips can be included by wire-ORing MPSI signals—treats all devices as receivers except when transmitting.

How the 9940 measures up

There are two principal competitors to the 9940 available: the 8048 and 3870 8-bit one-chip microcomputers. While benchmark results often depend on the routine performed and therefore could be misleading, the standard method of evaluating such devices is to exercise them through several unrelated routines and compare the results.

The comparison shown in the table is for six routines, each carried out by the 9940, the 8048, and the 3870. The results are formulated using three measures: program steps—reflecting the power of the instruction set and the nonrecurring software development costs—memory bytes—the smaller needed to do the job, the better, especially in restricted memory systems such as single-chip microcomputers—and execution speed. In each category the 9940 won. It required fewer program steps, less memory, and did the jobs quicker.

The routines are defined as follows:

1. Increment a four-digit binary-coded-decimal counter and compare to a limit. Four BCD digits are stored in random-access memory as a software counter. The counter is incremented and the result is compared with a RAM-resident limit.
2. Process I/O data. The manipulations required of this routine are: (a) input byte A from port 1. (b) input byte B from port 2. (c) compare A to B and then act as follows: (1) A = B; set flag and exit. (2) A > B; output A, reset flag, and exit. (3) A < B; output B, reset flag, and exit.
3. 16-digit BCD add. Sixteen decimal digits are in RAM for each of two numbers, A and B. The sum A + B is computed in BCD and placed in 16-digit location C.
4. 8-bit binary multiply. The 16-bit product of two 8-bit binary quantities defined in RAM is computed and stored.
5. Interrupt context switch. This routine reflects the overhead involved in saving a set of working registers before processing an interrupt and restoring them afterward.
6. String search. A block of 15 bytes is defined in RAM and is searched for a string of three contiguous bytes. Two partial finds occur before a match is found. When the match is found, a flag is set and the string's starting address is returned.

Routine	Program steps			Memory bytes (8-bit)			Execution time (μs)		
	9940	8048	3870	9940	8048	3870	9940	8048	3870
1) Increment/compare 4-digit BCD counter	10	20	17	20	26	25	30.4	60	62
2) Process I/O data	13	18	19	26	23	28	44.2	47.5	61
3) 16-digit BCD add	8	11	24	18	15	27	163.2	177.5	478
4) 8-bit binary multiply	1	14	25	2	17	28	32.4	185	373
5) Interrupt context switch	1	5	17	2	5	17	11.6	20	68
6) String search	20	39	48	40	46	58	380.8	815	969
Total	53	107	150	108	132	183	662.6	1,305	2,011

while storing the previous PC, WP, and status-register context values in the reserved registers (13, 14, and 15) of the new workspace file.

Meanwhile, the routine loads the interrupt mask with a value that is one less than the interrupt level being serviced—a step that automatically masks out all lower-priority interrupts. Of course, if a higher-priority interrupt becomes active during a service routine, a second context switch occurs to service it. When the higher-priority routine is complete, a return instruction (RTWP) restores the previous service-routine parameters to the processor, completing processing of the lower-priority interrupt.

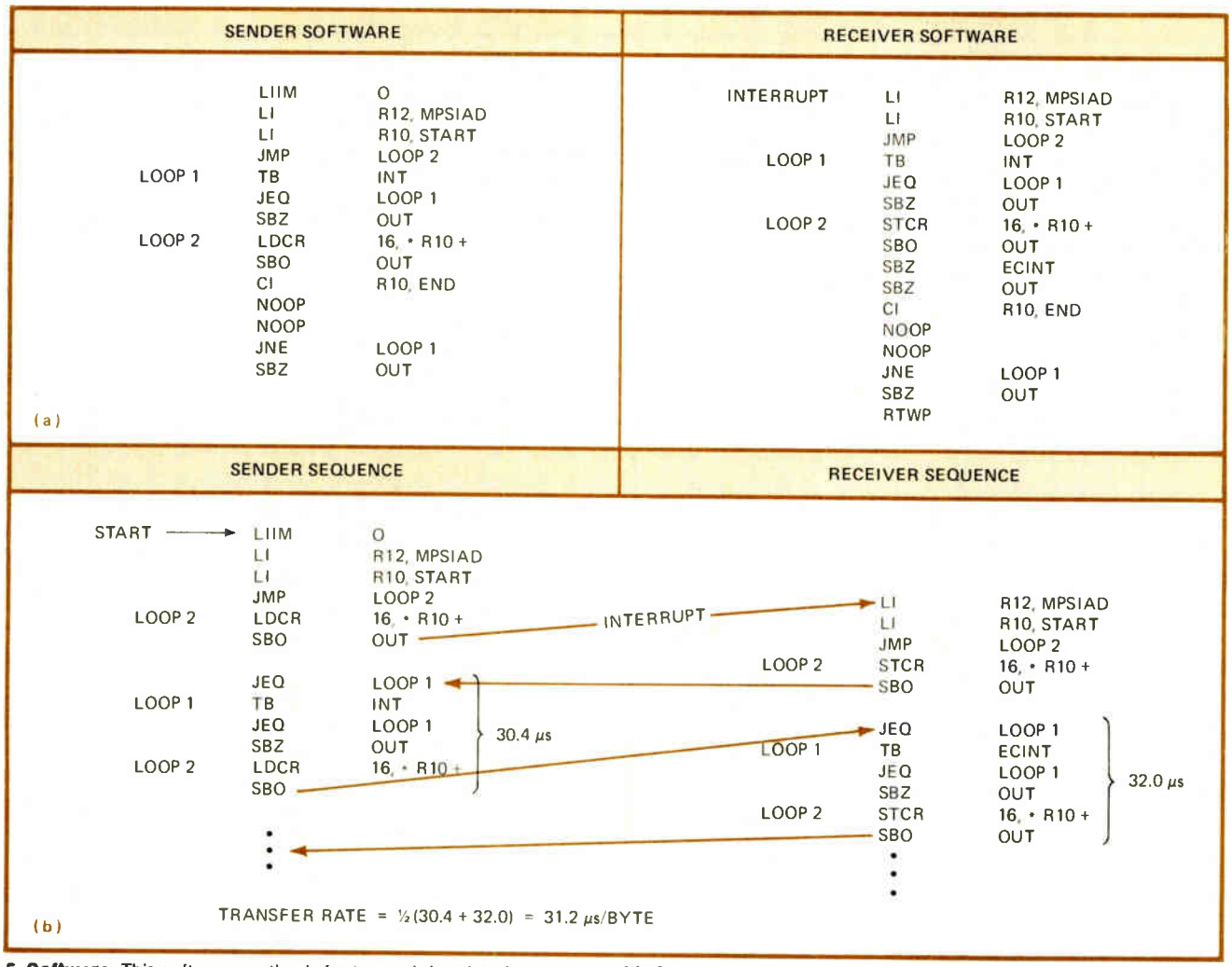
Plenty of I/O too

The 9940 I/O configuration consists of three separate interfaces: the general-purpose on-chip I/O, the I/O expansion, and the multiprocessor system interface. As in the 9900 parent chip, I/O data communication with the outside world is through the communications register unit, a versatile bit-oriented interface. The CRU makes I/O bits accessible in fields of 1 to 16 (specified via CRU instructions), with each bit specified by an address present on the A bus. The processor instructions that drive the CRU interface can set, reset, or test any bit in the array, or move data between memory and I/O.

The general-purpose on-chip I/O consists of 32 lines that can be independently programmed to be input or output ports, with each port consisting of 1 to 16 lines. The lines can be set, reset, tested, read, or written through the CRU interface. Simple software instructions accomplish direction programming, which can be changed in real time.

A nice feature of the 9940 is its direct expandability to as many as 256 bits of additional I/O lines simply by using standard transistor-transistor-logic components. Figure 2 illustrates the configuration for implementing a 16-bit input and 16-bit output register expansion: two 8-to-1 multiplexers, two 8-bit latches, and a few gates. The CRU addresses can be decoded as needed to implement as many as 16 such interface registers. But in any given system application, only the exact number of interface bits needed to interface the specific peripheral devices must be provided. In other words, it is not necessary to have a 16-bit interface register to interface an 8-bit device.

The 9940 instruction set, a subset of the 9900-family instruction repertory, contains 58 instructions. The use



5. Software. This software routine is for transmitting data between two 9940s. The sender starts the transfer by loading the first 16-bit word to the MPSI and issuing a command to interrupt the receiver. The program shown here takes 31.2 μs per byte of data.

of the 16-bit operation code field allows individual instructions to implement powerful operations, such as multiply and divide, with data being specified by multiple addressing modes. The 16-bit architecture also allows a programmer to use unrestricted, indexed, and indirect addressing procedures, while the 8-bit orientation ensures program efficiency.

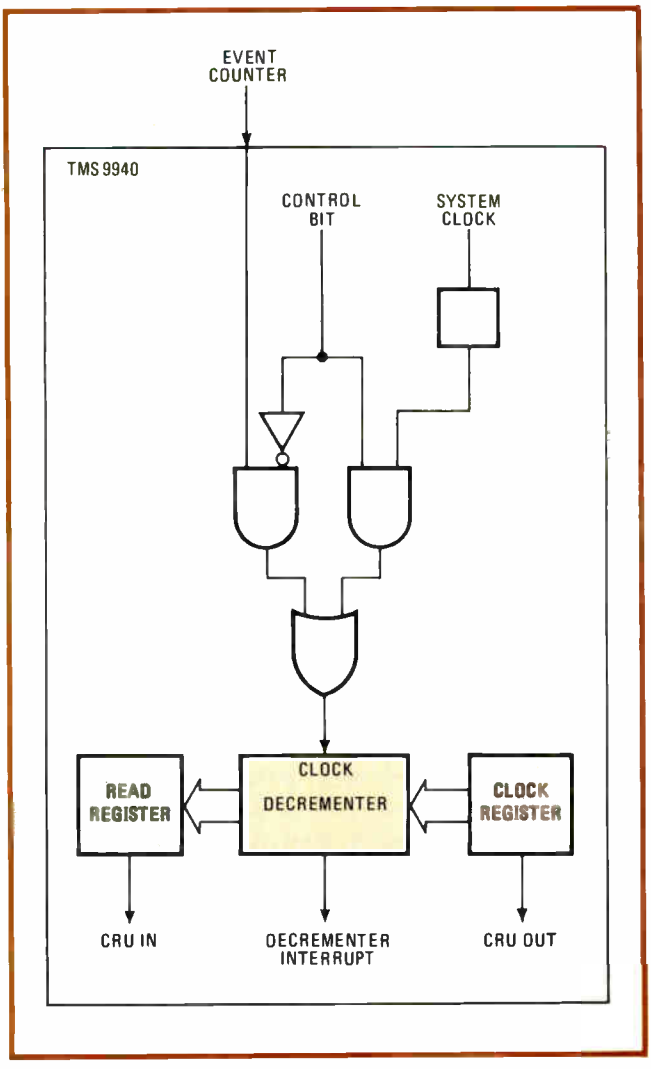
Included in the instruction set are those that perform such complex functions as arithmetic operations on word, byte, and immediate data; multiply; divide; decimal add and subtract; branches and conditional jumps; logical operations; and multibit (1 to 16 shifts). Moreover, the instruction repertory contains a variety of available modes for addressing random-memory data (e.g., program parameters and flags) or formatted memory data (character strings, data lists, etc.). The set also includes 11 conditional jumps that make use of the five conditional status-register bits.

Multiprocessing systems.

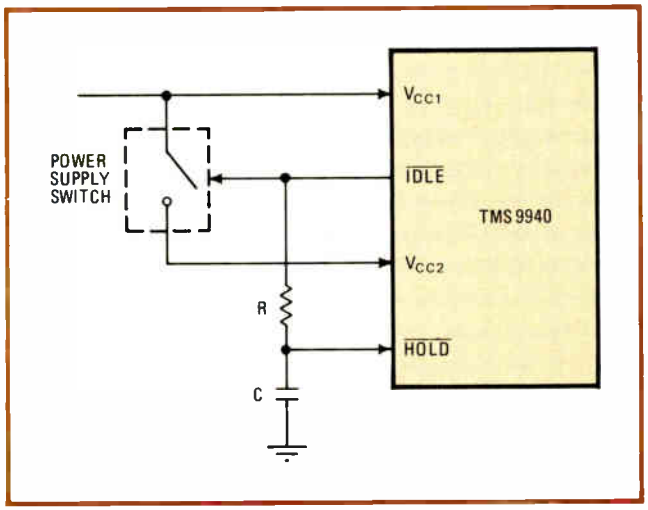
Interfacing 9940s with each other or with a more powerful microprocessor such as the 9900 is eased by the multiprocessor-system-interface port. The MPSI is a CRU-compatible two-wire interface for transferring data in a multiprocessor system. In a 9900/9940 multiple-processing system such as that of Fig. 3, the MPSI allows a system designer to off-load instructions from the 9900 to the 9940's memory for execution by the latter chip. Making the scheme possible is the 9940's ability to execute instructions directly out of its RAM. The MPSI can also be used to transfer data between processors in master-slave configurations, with the master processor distributing tasks to the 9940 slaves.

The T_C and T_D ports of the new chip ease communications between these chips in multiple processing systems, as shown in Fig. 4 where two are interconnected. Additional chips can be connected simply by wire-ORing MPSI signals.

The protocol of such a system treats all devices as receivers—except when, actually transmitting data, they are in the sender mode. The T_D input signal feeds an internal 16-bit shift register. The T_C input clocks the shift register to allow 16 bits of data to be shifted into the register in a manner completely transparent to the rest of the CPU's operation. The sender interrupts the receiver (through a normal interrupt input), so that the latter can execute an STCR instruction (store CRU bits in memory) to input the former's MPSI data.



6. Multipurpose. The 9940's decrementer register can also be used as a programmable interval timer, programmable event timer, or programmable event counter. As an event counter, the positive edge transition of the EC signal initiates the count.



7. Powering down. The 9940 has a convenient power-down mode, accomplished when the IDLE instruction is executed and a low value is output on $\overline{\text{IDLE}}$. That opens the power supply switch. The switch is closed with an interrupt forcing the chip into $\overline{\text{IDLE}}$ high.

To become a sender, the 9940 executes an LDCR instruction (load memory bits on CRU) to the dedicated MPSI addresses. The T_D signal then automatically switches to the output mode to send data, and the T_C signal sends out the CRU clock strobe. After completion of the instruction, T_D and T_C revert to the input mode to switch the device back to receiver status.

The software required for each communication between two 9940s is shown in Fig. 5a, and the software sequence during a transfer is shown in Fig. 5b. The sender starts the transfer by loading the first word to the MPSI and issuing an output command to interrupt the receiver. The receiver takes in the MPSI data, acknowledges receipt to the sender, and checks to see if the transfer is complete. If incomplete, the receiver enters a wait loop to wait for the next word to be sent.

Once receipt has been acknowledged, the sender sends the next word, checks for completion of transfer, and enters a wait loop to wait for the next acknowledgment. When the transfer is finally complete, the receiver executes a return instruction to return it to its original program. The transfer rate consists of the sum of the sender and receiver sequences and is 31.2 microseconds per byte, as shown in Fig. 5b.

A useful feature of the 9940 is the 14-bit decrementing register (Fig. 6), which can also be programmed as a programmable interval timer, an external-event timer, or an external-event counter. The decrementer functions as an interval timer simply by using the proper start value. It will then issue interrupts at the chosen interval.

It functions as an event timer by reading the timer values at the start and stop points of the event of interest and comparing the two values. The difference will be a direct measurement of the elapsed time.

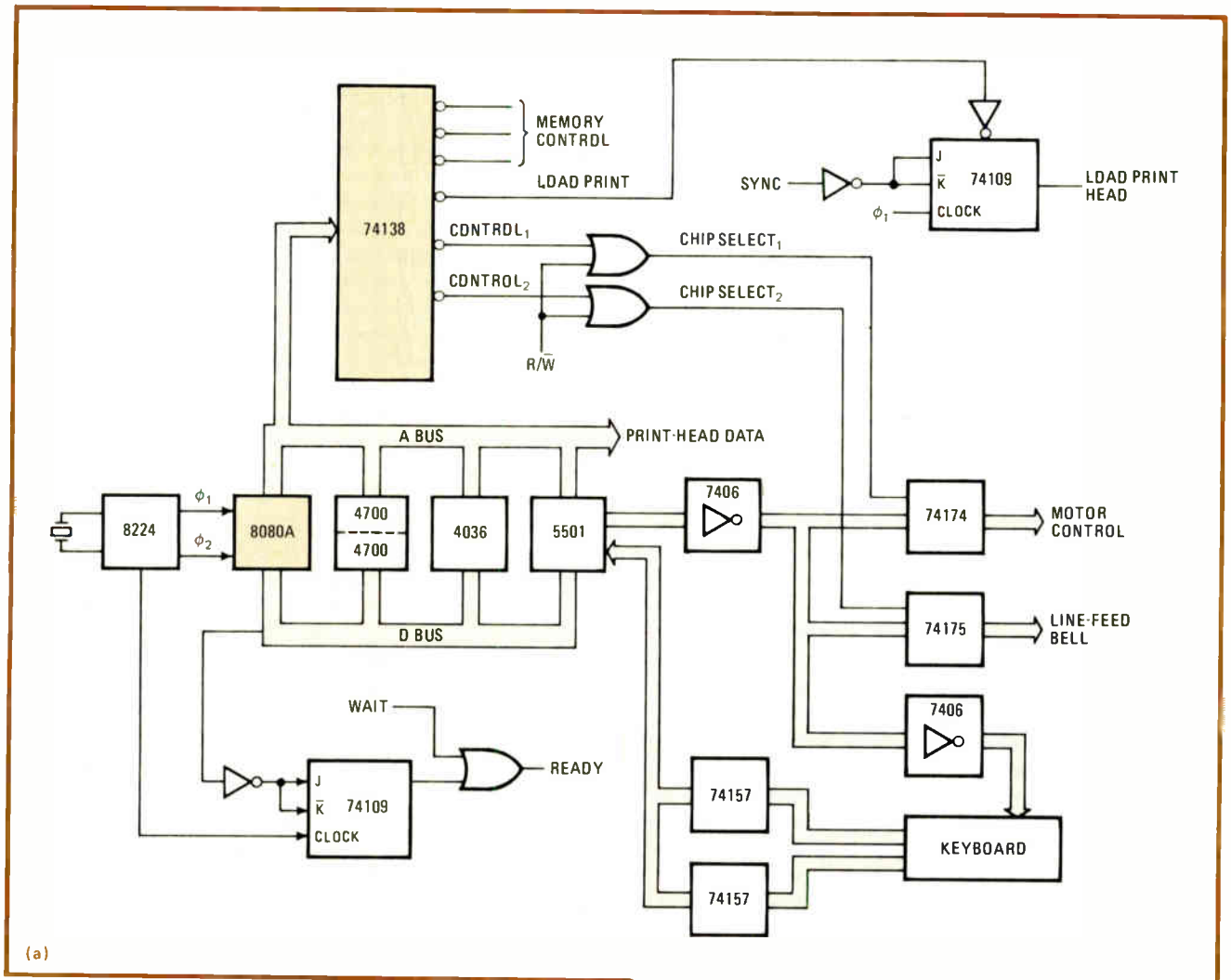
When programmed as an event counter, the decrementer functions as it does for event timing, except that the event-counter pin (EC) replaces the system clock as the clock input. A positive edge transition on EC will decrement the count. When the count reaches zero, the decrementer is reloaded with the programmed start value and an interrupt is issued. The EC pin can also function as a positive-edge-triggered interrupt by loading a start value of one.

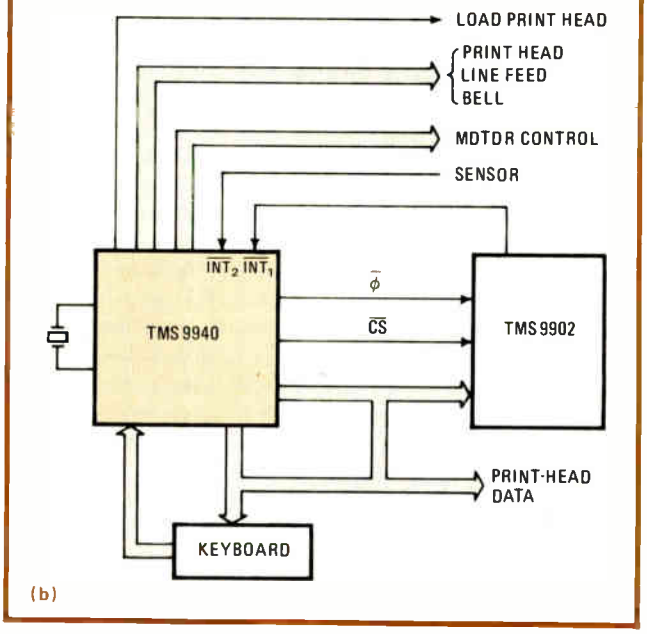
Power down

Applications that have low duty cycles (like those that interact with human beings) or require low power dissipation can make use of the 9940's convenient power-down capability. The chip is powered by two separate power supplies: V_{CC1}, which powers the RAM, decrementer, and interrupt logic; and V_{CC2}, which powers the rest of the circuitry (Fig. 7).

Power down is accomplished when the IDLE instruction is executed and a low value goes out on $\overline{\text{IDLE}}$ to open the power-supply switch. Sending an interrupt into the CPU forces the processor out of its IDLE mode and puts out a high value on $\overline{\text{IDLE}}$ that closes the switch and powers up the rest of the circuitry. The $\overline{\text{HOLD}}$ input is a Schmitt-trigger input that will keep the CPU stopped until V_{CC2} has settled.

A system designer can build prototypes using the 9940



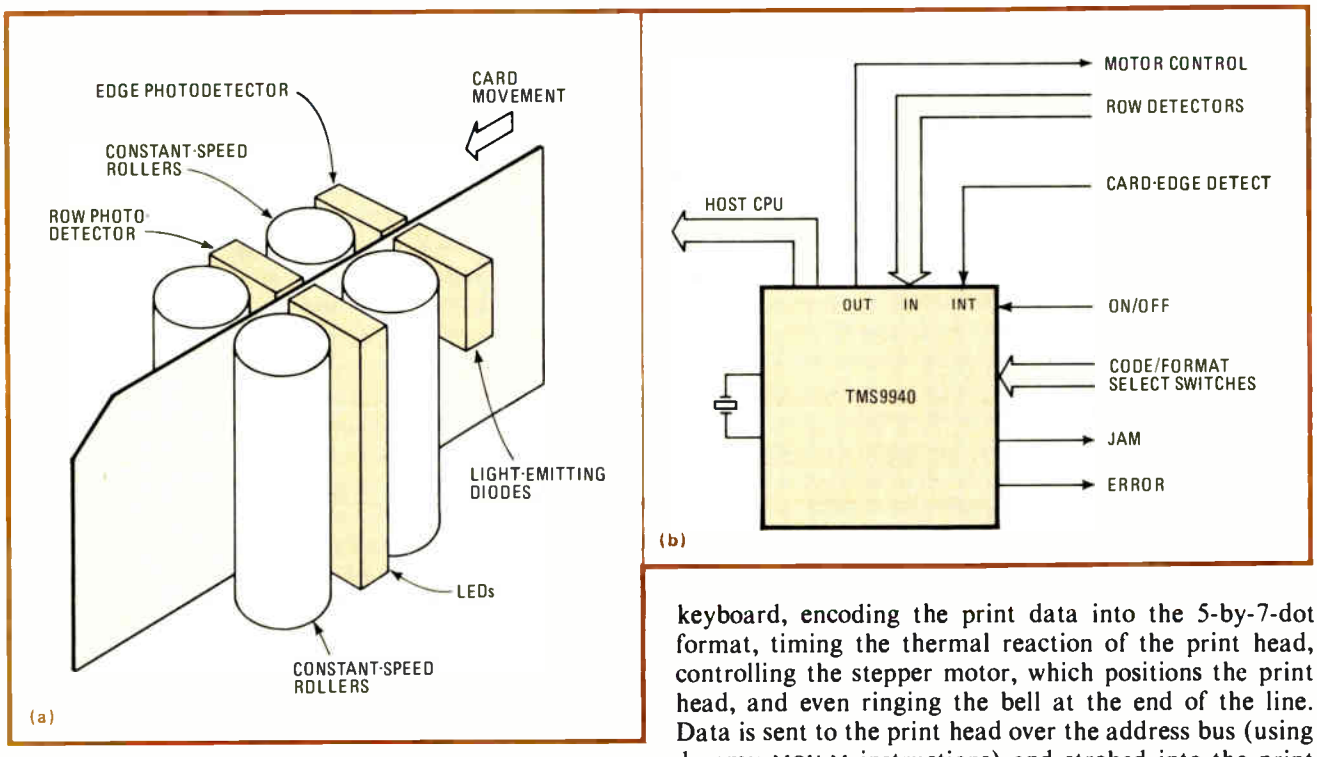


by several methods. Other family members (such as the TMS 9900 and TMS 9980 CPUs) can be used for software development. The 9900 microcomputer board also makes a good starting point for this development.

The 9940 implements three additional instructions (decimal add, decimal subtract, and load immediate data to interrupt mask), which are not in the basic 9900 instruction set. These instructions are defined by operational codes corresponding to those for XOP 10 to XOP 12 (internal software interrupts) of the 9900 (only XOP 0 to XOP 7 are implemented as general XOPs on the 9940). Executing one of these operational codes in a 9900 system will force a context switch to allow software emulation of the operation directly performed in the 9940. In this way, the two machines will maintain in-line machine-code compatibility.

Another alternative uses a microprocessor prototyping laboratory that is available to support all members of the 9900 family. The MPL provides real-time emulators that minimize hardware development. In addition, it has trace/analyzer functions to give to the system developer the capability of real-time monitoring and debugging. Pertinent data and control signals may be sampled and saved in a host RAM until occurrence of a user-specified event. The target microprocessor may be single-stepped

8. Terminal design. Using a 9940 instead of an 8080 to build terminals saves money. This TI 745 terminal requires 17 ICs (a) when an 8080 does the job and only two (b) with the 9940. Besides the processor, all that is needed is a 9902 communication controller.



9. Very smart. By itself, the 9940 can implement an intelligent card reader for the IBM standard 12-row, 80-column card. The chip goes into action when the front edge of the card passes the edge detector, generating an interrupt that allows it to synchronize itself to the card.

through its program so that internal registers and target memory can be examined and altered.

As the prototype progresses into hardware, the microcomputer board or the MPL CPU can be replaced by the reprogrammable-ROM version of the chip (9940E). For volume production, the mask-ROM version (994ON) would be the most cost-effective solution.

Applications abound

Microprocessors have proven valuable in data terminals, such as the Texas Instruments 745 portable terminal. This unit is a low-cost, light-weight terminal offering such features as selectable print speeds (10 and 30 characters per second) on a thermal print head with a 5-by-7-dot matrix. It has a built-in acoustic coupler and can provide switch-selectable half- or full-duplex operation from an ASCII standard keyboard. The hardware required to implement this terminal with an 8080A microprocessor is shown in Fig. 8a, and the hardware when built with a 9940 is shown in Fig. 8b.

With the 8080A, the microcomputer portion of the 745 design requires 17 integrated circuits. The memory consists of 2 kilobytes of ROM program memory (two 4700s) and 64 bytes of RAM (one 4036). Moreover, the peripheral interface chip, the 5501, contains a universal asynchronous receiver/transmitter, programmable interval timers, interrupt control, an 8-bit input port, and an 8-bit output port. The remaining circuitry is used for I/O buffering and expansion where needed and for general system overhead duties.

The 8080A controls all operations of the terminal, including scanning, debouncing, and encoding the keyboard, encoding the print data into the 5-by-7-dot format, timing the thermal reaction of the print head, controlling the stepper motor, which positions the print head, and even ringing the bell at the end of the line. Data is sent to the print head over the address bus (using dummy MOV M instructions) and strobed into the print latch by the LD PRINT HD signal.

The design is much simpler with a 9940 microcomputer. In fact, it takes only that chip and a 9902 asynchronous communications controller. Software multiplexes 12 of the 32 I/O lines on the microcomputer among the 9902 interface, the keyboard scan, and print-head data output. The remaining 20 I/O lines are used to interface to the rest of the system requirements.

The 9940 also makes handy work of intelligent peripherals designs, such as the card reader for the standard 12-row, 80-column card. A card-reading mechanism (Fig. 9a) is equipped with rollers that move the card at a constant rate. The front edge of the card is detected by the edge detector to synchronize the reader to the card. Photodetectors are then sampled at appropriate intervals to determine the column code punched on the card.

The 9940 is a one-chip solution to this application (Fig. 9b). The on/off control is an input bit, which is sampled to determine if the card reader is being used. When an on condition is detected, the chip sends a signal that turns on the roller motors and activates the light-emitting diodes. When the front edge of the card passes the edge detector, an interrupt is generated to allow the 9940 to synchronize itself to the card. The chip's interval timer measures the appropriate time intervals for the data as each column passes through the photodetector.

As each column is read, the chip can make the appropriate conversion from the switch-specified card code to the specified format (e.g., Hollerith to ASCII). Before transferring the data, the chip can process it to perform such functions as deleting extraneous characters, prescaling or normalizing numerical data, checking for special characters and issuing appropriate commands, and verifying data via use of check summations. The data then goes to the host processor through the MPSI or through an external asynchronous interface chip. □

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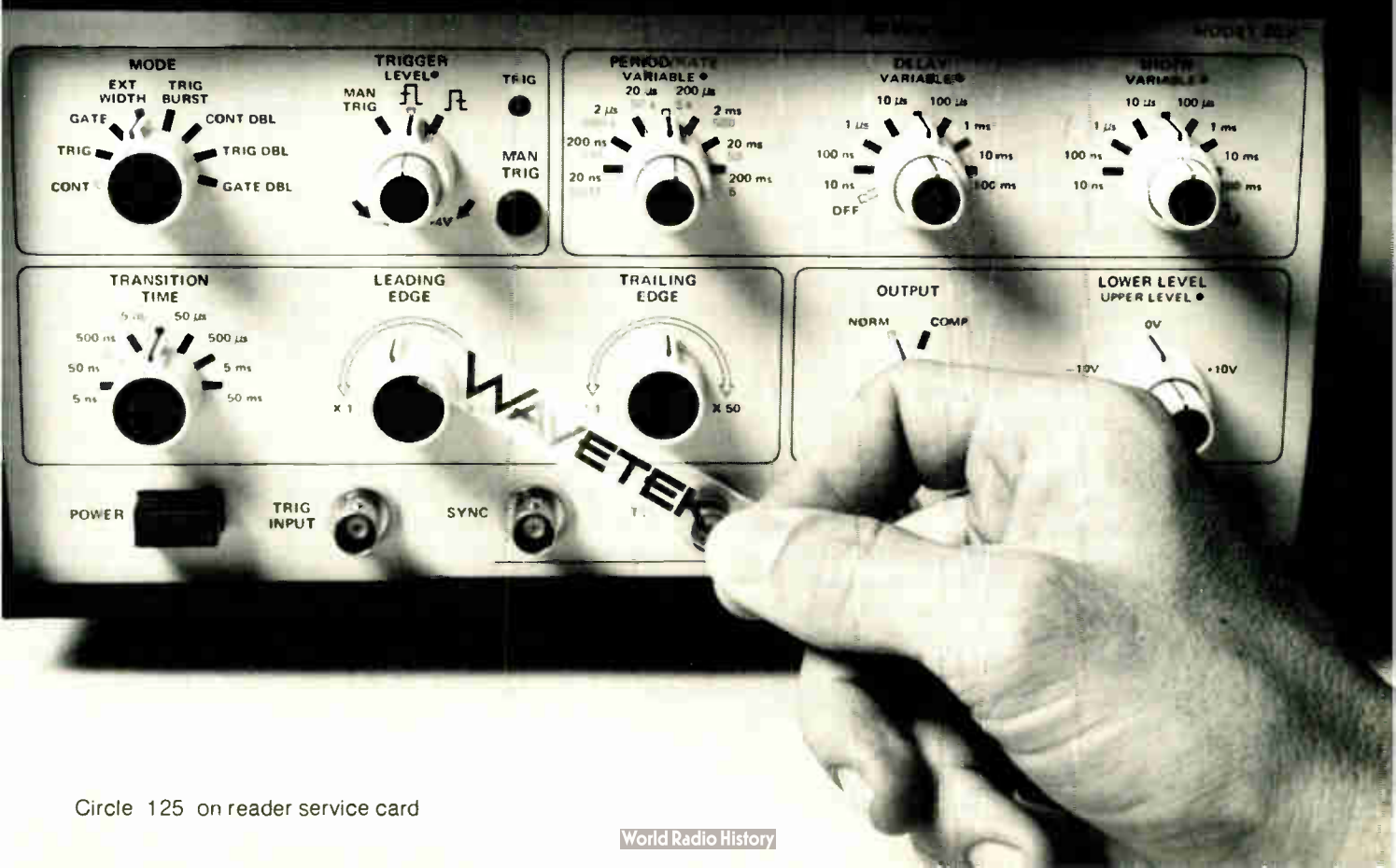


Circle 125 on reader service card

Single C-MOS IC forms pulse-width modulator

by Mark E. Anglin
Novar Electronics, Barberton, Calif.

A pulse-width modulator can be constructed with a single complementary-metal-oxide-semiconductor integrated circuit if the IC's field-effect transistors control the duty cycle of a free-running oscillator. The output resistance of the FET varies almost linearly with input voltage over portions of its characteristic curve, permitting the circuit to be used for applications in switching power supplies and analog conversion in data-communications systems.

This circuit uses a CD4007 dual complementary pair plus an inverter device, which comprises three n-channel and three p-channel enhancement-type MOS transistors. As shown in the figure, inverters I_1 and I_2, each formed by two gates in the 4007, themselves form an astable multivibrator in conjunction with resistor R and capacitor C. The frequency of oscillation of the multivibrator is given by:

$$f = 1/1.4\,RC$$

The 1-megohm resistor, left in the figure, limits the feedback current into I_1. This prevents the input circuit from burnout and the inverter from switching prematurely and affecting the desired frequency of operation.

The two remaining gates in the 4007, one n-channel and one p-channel gate, are connected across the output of I_1 and R. This network is designed to modify R and thus control switching times t_1 and t_2.

The oscillation (switching) times for this device may be expressed by two equations:

$$t_1 = RC \ln [(V_{dd} - V_{tr})V_{dd}]$$

and

$$t_2 = RC \ln (V_{tr}/V_{dd})$$

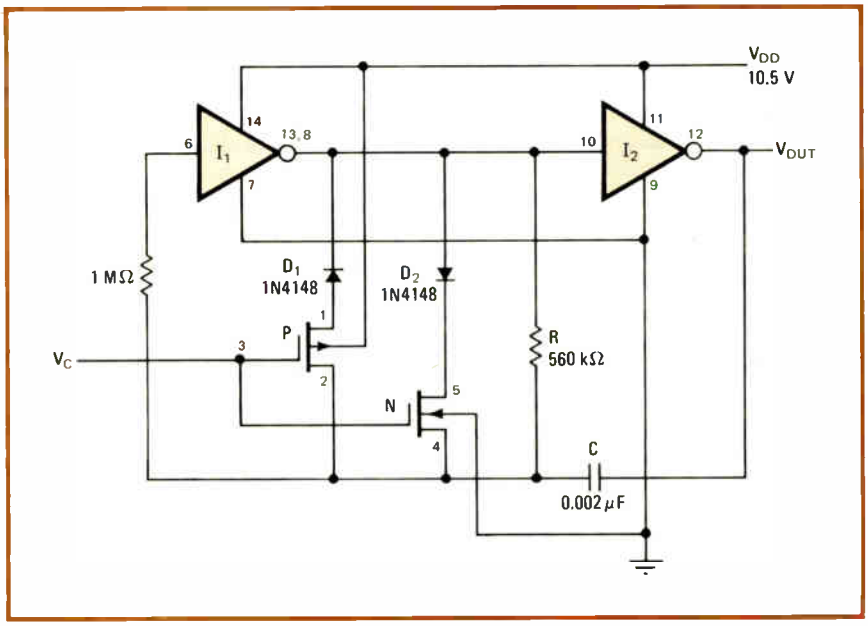
where t_1 is the on time and t_2 is the off time of the oscillator, V_{tr} is the threshold voltage at the gate's input, and V_{dd} is the supply voltage.

When the oscillator's output is high, diode D_1 may conduct. The p-channel output resistance will be in parallel with R, neglecting the diode's forward resistance. The p-channel gate's output resistance will decrease as V_c decreases.

Similarly, when the oscillator's output is low, D_2 may conduct, and the n-channel output is placed in parallel with R. The n-channel's resistance will decrease as V_c increases. The duty cycle of the oscillations (in other words, control of the on and off times) is variable from 1% to 99% of the operating frequency. The duty cycle is directly proportional to the amplitude of the control voltage V_c.

The component values in the figure yield an oscillation frequency of 1 kilohertz. The change in oscillation frequency as a function of duty cycle is minimal; although the basic frequency of oscillation is modified by the FETs across I_1, the output impedance of one always increases, and the other's decreases proportionately, for any value of control voltage V_c. Thus, the average resistance shunted across R during a cycle is constant. □

Designer's casebook is a regular feature in *Electronics*. We invite readers to submit original and unpublished circuit ideas and solutions to design problems. Explain briefly but thoroughly the circuit's operating principle and purpose. We'll pay $50 for each item published.



Single IC modulator. Pulse-width modulation is achieved by varying duty cycle of free-running oscillator in accordance with input voltage V_c. Output impedance of FETs shunts switching-time element R, permitting adjustable duty cycle.

Comparators replace mechanical set-point meter

by Louis A. Perretta
HNU Systems Inc., Newton, Mass.

A standard ammeter and a simple comparator circuit can replace the expensive and bulky mechanical dual-set-point meters used for most process control applications. This electronic circuit provides higher efficiency at low cost and can be built on a printed-circuit card. With a slight modification to the basic circuit, a double high set point and a double low set point may be established—a feature that is not available from the mechanical meter.

The mechanical meter used for industrial purposes contains internal relays and a 115-volt power supply to drive them, as well as a meter that triggers when its pointer or indicating device comes into contact with the high or low set points on the meter dial.

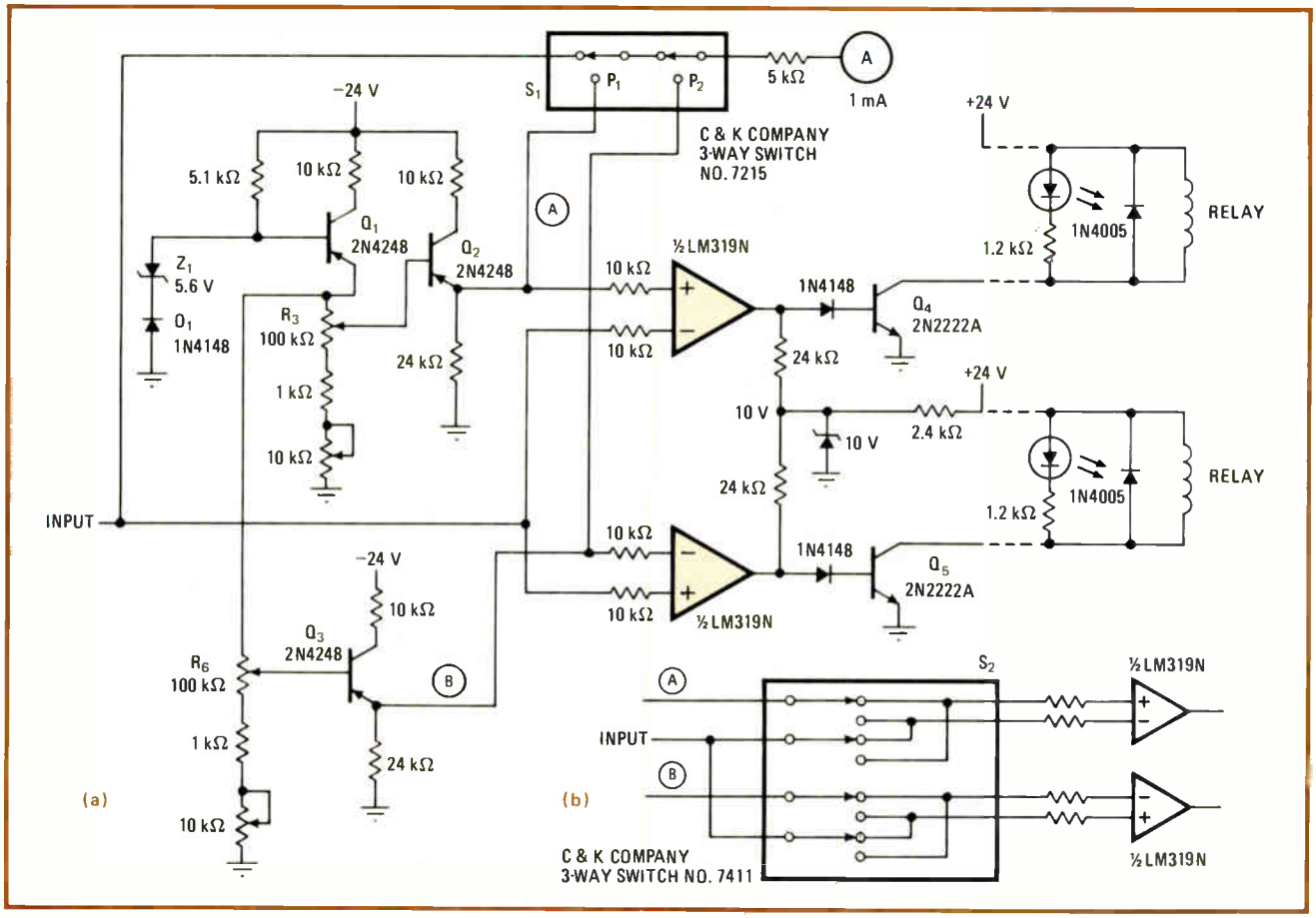
In the electronic circuit shown in the figure, the mechanical set control is replaced by two potentiometers, transistors Q_1 through Q_5, and the LM319 operational amplifier. A 1-milliampere meter indicates conditions at the output of the monitored circuit. The meter is no longer part of the relay triggering circuit, and the relays no longer need a power supply. If the circuit is to control heavy loads, relays must be employed, but they draw only little power from output transistors Q_4 and Q_5 and can be placed far from the metering circuit.

In normal operation, an input signal is applied to each of the two op amps in the LM319, which compares it to a previously set (high- and low-point) reference. In the circuit, the reference voltages are adjustable from 0 to −5.6 v. This is made possible by the biasing arrangement at Q_1, in which diodes Z_1 and D_1 are configured to supply a constant −5.6 v at its emitter. The voltage across potentiometers R_3 and R_6 thus may vary between two references, one at −5.6 v and the other at −0.6 v, so that the input to the comparator can vary between −5 v and ground.

When the input voltage, as set by the meter, exceeds the high or low reference, the appropriate output of the LM319 fires and switches either transistor Q_4 or Q_5, which closes the proper relay.

The high and low reference points may be set by using the meter. Switching switch S_1 to P_1 removes the metering circuit from the input signal, and the meter then displays the high-point reference voltage, which can be adjusted by R_3. With S_1 moved to position P_2, the desired low-level voltage may be adjusted with potentiometer R_6.

The voltage drop across zener diode Z_1 and the



Mechanical to electrical conversion. Implementation of dual-set-point meter using standard meter and comparator circuits (a) is low-cost and reliable. When a three-way switch is added to circuit (b), double high and low set points can be set.

TI's new 16K EPROM programmed here.

Texas Instruments has a new EPROM, the 16k TMS-2716.

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The TMS-2716 is an enlarged version of the popular 2708, and programs exactly the same. Because of its pin compatibility with the 2708, the new TMS-2716 allows users to double memory size without extensive circuit revisions and thus add creative innovations to their products. Its erasability means quicker turnaround on design and program corrections.

The TMS-2716 EPROM is priced at $54.75 in 100-unit quantities.

Pro-Log's TMS-2716/2708 Personality Module, when used with Pro-Log's stand-alone Series 90 PROM Programmer master control unit, will program, list, duplicate and verify not only the TMS-2716 but the 2708/L08 as well. The dual TMS-2716/2708 Personality Module can also be used with Pro-Log's single button Series 92 Peripheral PROM Programmer/Duplicator master control unit.

The TMS-2716/2708 Personality Module utilizes Pro-Log's innovative programming technique whereby blocks of from one to sixteen words can be programmed in as little as 2.5 seconds after keying is complete.

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A TMS-2716/2708 Personality Module (PM9053) costs $450. Courtesy of TI, Pro-Log will supply a free TMS-2716 EPROM with each of the first 100 modules purchased.

A Series 90 master control unit costs $1,800.

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PROM Programmer options include TTY, paper tape reader, parallel I/O, RS232 and CMOS RAM buffer.

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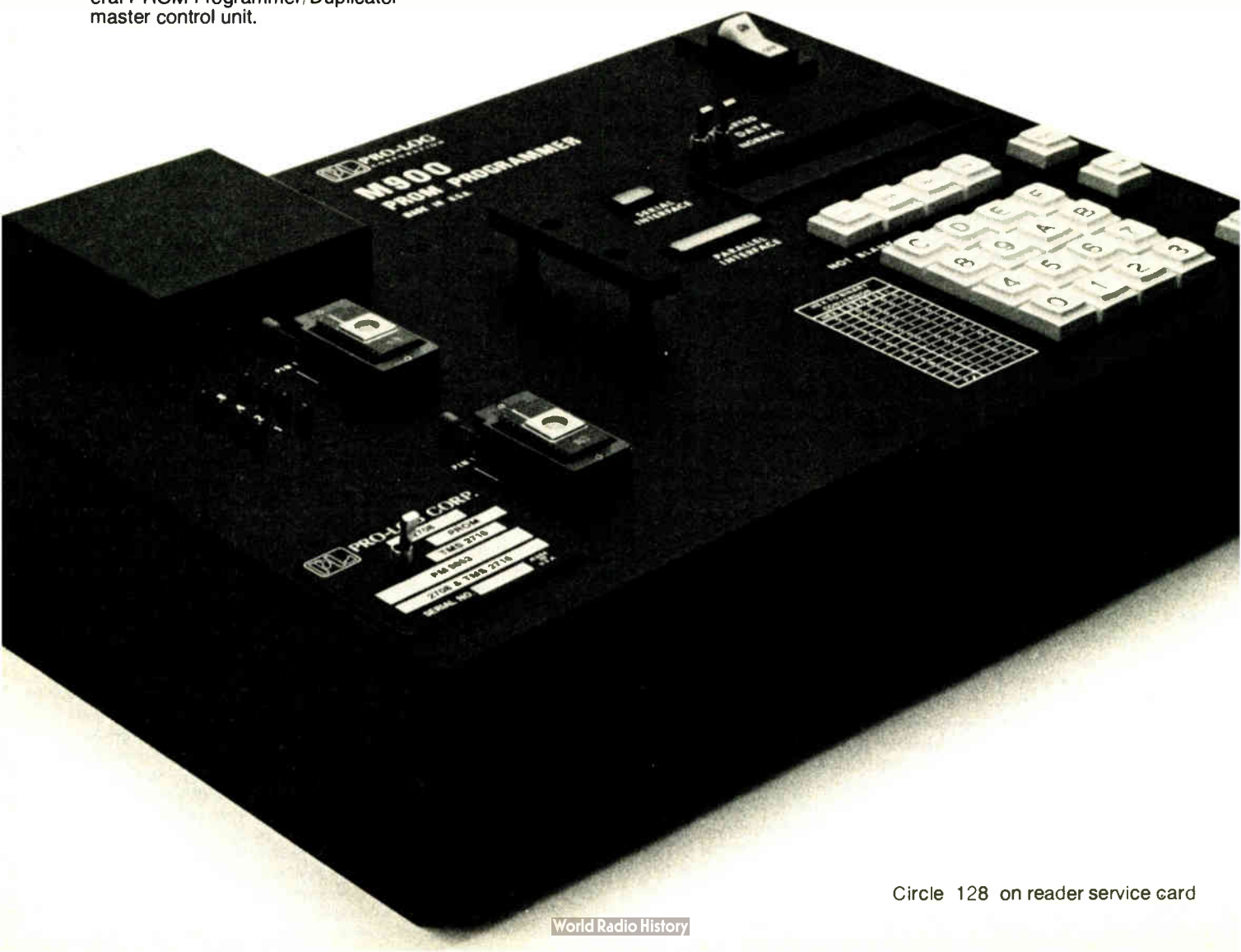


Circle 128 on reader service card

number of standard diodes (D_1) determines the range of reference voltages possible. Reversing diode polarities and changing Q_1, Q_2, and Q_3 to npn devices produces positive reference voltages.

To establish double high set and low set points, a four-pole, three-way toggle switch is placed in the path of transistors Q_2 and Q_3 and the input of the op amp, as the lower part of the figure shows. □

High-impedance op amp extends 555 timer's range

by Ronald Zane
University of California, Los Angeles, Calif.

The period of oscillation of the 555 timer can be increased 20 times or more if the timing components are replaced by a feedback loop containing a transistor and a very-high-impedance input operational amplifier configured as an integrator. The circuit is an inexpensive way of generating timing periods of hours or days to control industrial processes, to turn on lights in the home for burglar protection, and for like applications.

As shown in the figure, resistor R_5 and capacitor C combine with the CA3140T op amp to make the integrator that controls the period of oscillation in the 555. The very low offset current of this op amp (typically 3 picoamperes but no greater than 30 pA) permits accurate integration of very low input currents (100 pA). Thus it ensures excellent control over the actual oscillation times.

The timer, operating in its astable-multivibrator mode, produces a change of state at pins 3 and 7 each time the input signal requirements are met at the threshold and trigger ports of the device. The output moves low when the input at the threshold terminal is greater than two thirds the supply voltage V_s. It stays low until the trigger input detects decay of the input signal's voltage to less than one third of V_s. Then the output assumes a high state.

Transistor Q_1 switches in accordance with pin 7 of the 555; point E_1 will be at ground when Q_1 is on, and at $V_s/2$ when Q_1 is off, because of the voltage divider made up of R_1 and R_2. The voltage at E_2, $V_s/4$, is determined by the divider made up of R_6 and R_7 (R_1, R_3, and R_4 in series hardly affect the calculation).

When Q_1 is on, the current through R_5 at the inverting input of the op amp is thus:

$$I = \frac{(V_s/2 - V_s/4)\,R_4}{R_5(R_3+R_4)} = \frac{V_s\,R_4}{4R_5\,(R_3+R_4)}$$

and when it is off, the current is:

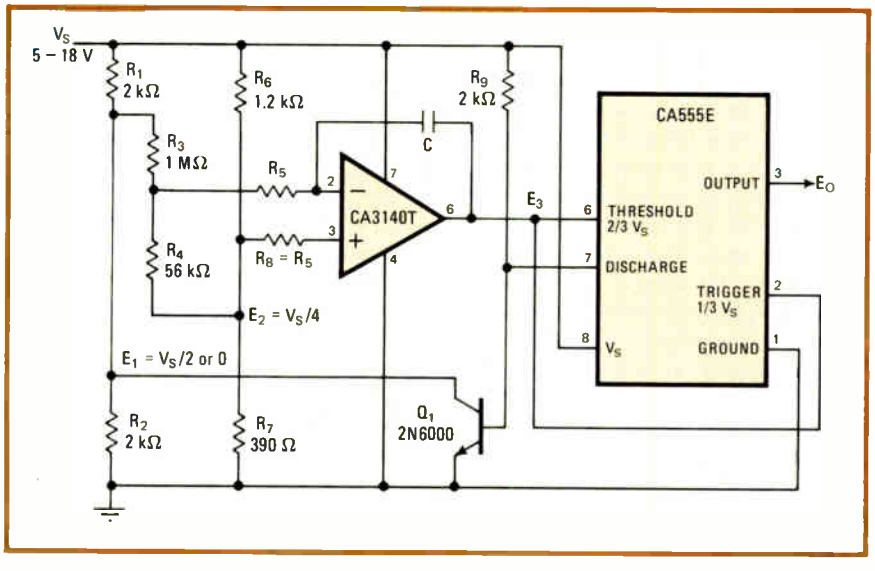
$$I = \frac{(0 - V_s/4)\,R_4}{R_5\,(R_3+R_4)} = \frac{-V_s\,R_4}{4\,R_5\,(R_3+R_4)}$$

The magnitudes of these currents are the same. The integrator then operates on this input current. Because its output is $E_3 = dV_s/dt = I/C$ by definition, and because E_3 switches between one third and two thirds of the supply voltage each cycle, the oscillator's period is:

$$t = \int_{1/3}^{2/3} \frac{C}{I}\,dV_s \frac{8(R_3+R_4)\,R_5C}{3R_4} = 50\,R_5C$$

The low offset current of the op amp allows R_5 to assume values in the hundreds of megohms. Even when R_5 equals 110 MΩ, the current through it is 1.8 nanoamperes, far exceeding the op amp's offset current.

If R_5 is 110 MΩ and C is 1 microfarad, the 555's period is 5,500 seconds. Since R_5 and C can be increased, periods of 10 hours or more may be realized with inexpensive components. If a 510-MΩ resistor and a 10-μF capacitor is used in the integrator, the oscillation period will be 70 hours. The bare 555, which may use a maximum timing resistance of 20 MΩ, coupled with a 10-μF capacitor for its timing capacitance, would have an oscillation time of only 280 seconds. □



Time-magnification. Oscillation frequency of a 555 may be lowered 20 times or more if a low-input-current, integrating op amp is used to replace timing components. One oscillation every few days is possible if a high-value capacitor, C, is used in integrator.

Analog output chips shrink a-d conversion software

When microprocessor systems use the new devices, it becomes easier to create a low-cost program for analog-to-digital conversion

by Andrij Mrozowski, *Burr-Brown Research Corp., Tucson, Ariz.*

☐ The most economical way of digitizing analog inputs to a microprocessor-based data system is not always the easiest. For example, when software can be used for the conversion logic, it keeps hardware costs attractively low but is often discouragingly extensive. Still, even designers with little programming know-how can adopt the approach if they use either of two new microprocessor output units that shrink the software to manageable proportions.

Of course, putting the conversion logic into software is practical only under two conditions. The analog inputs to the data system must be few, and its conversion speed must be relatively slow.

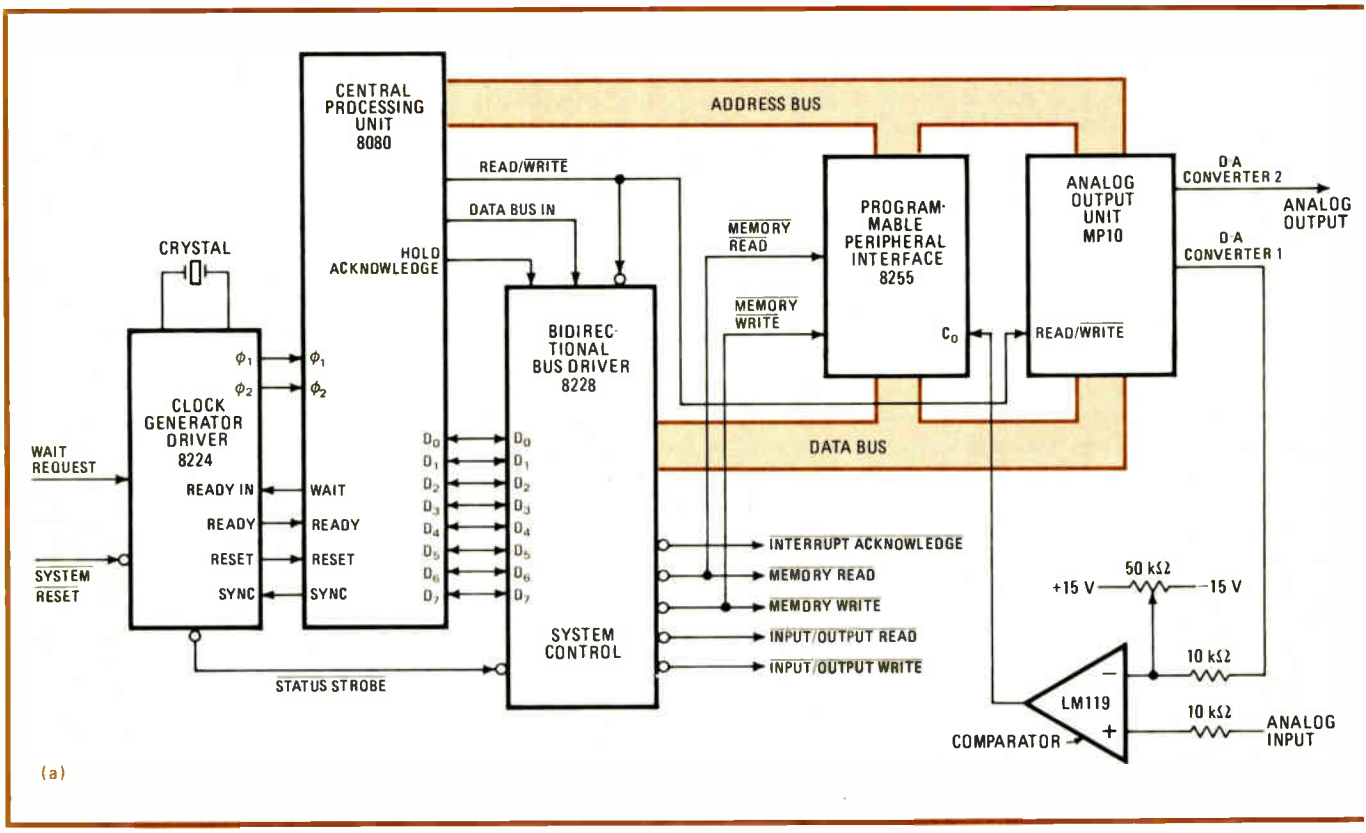
The MP10/11 analog output units work with most of the popular microprocessor chips [*Electronics*, May 26, p. 106]. Completely self-contained, they incorporate a pair of 8-bit digital-to-analog converters, address decoding, and control logic.

Simple hookups for the 8080 and 6800

Under microprocessor control, either unit may be made to perform simultaneously as both a d-a converter and a successive-approximation a-d converter. For this kind of operation, one of the device's two channels provides its normal analog output, while the other channel, in conjunction with a comparator, handles the analog input data.

Figure 1 shows the hardware implementation for the

1. Trimming hardware costs. Implementing a successive-approximation routine in software saves the expense of an analog-to-digital converter in microcomputer data systems. With minimal software, a single two-channel analog output unit (the MP10 or MP11) simultaneously delivers analog output data and converts analog input data for Intel's 8080 (a) or Motorola's 6800 (b) microprocessor family of chips.



MP10 with the 8080 (a) and the MP11 with the 6800 (b). In each case, the successive-approximation logic for the a-d conversion is done in the software.

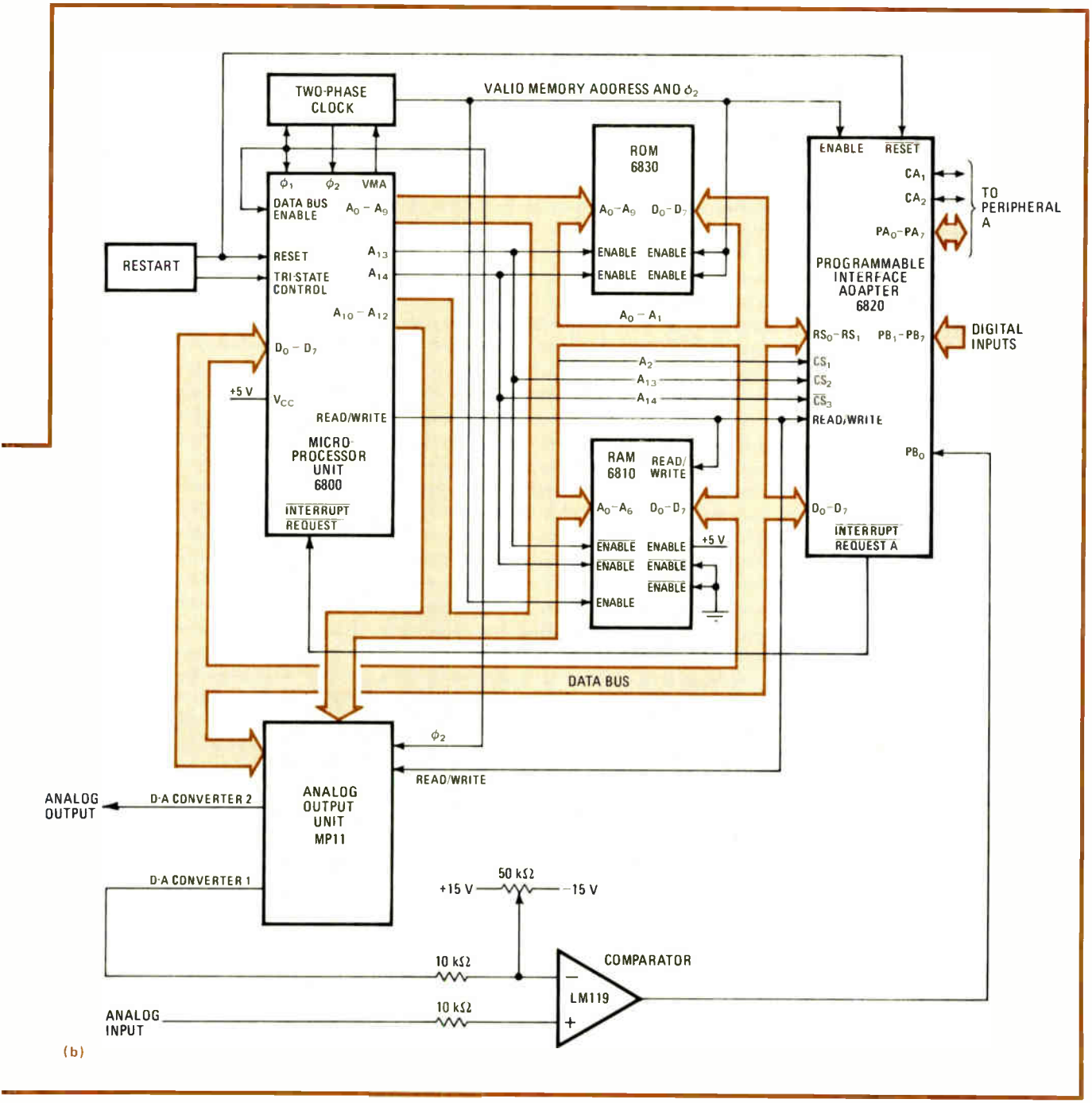
Essentially, this is how it works. In a successive-approximation a-d conversion, the analog input is compared to known outputs of a d-a converter. To do this, the microcomputer first turns on the most significant bit of the digital data, then waits for the outputs of the d-a converter and comparator to settle, and lastly reads the status of the comparator output.

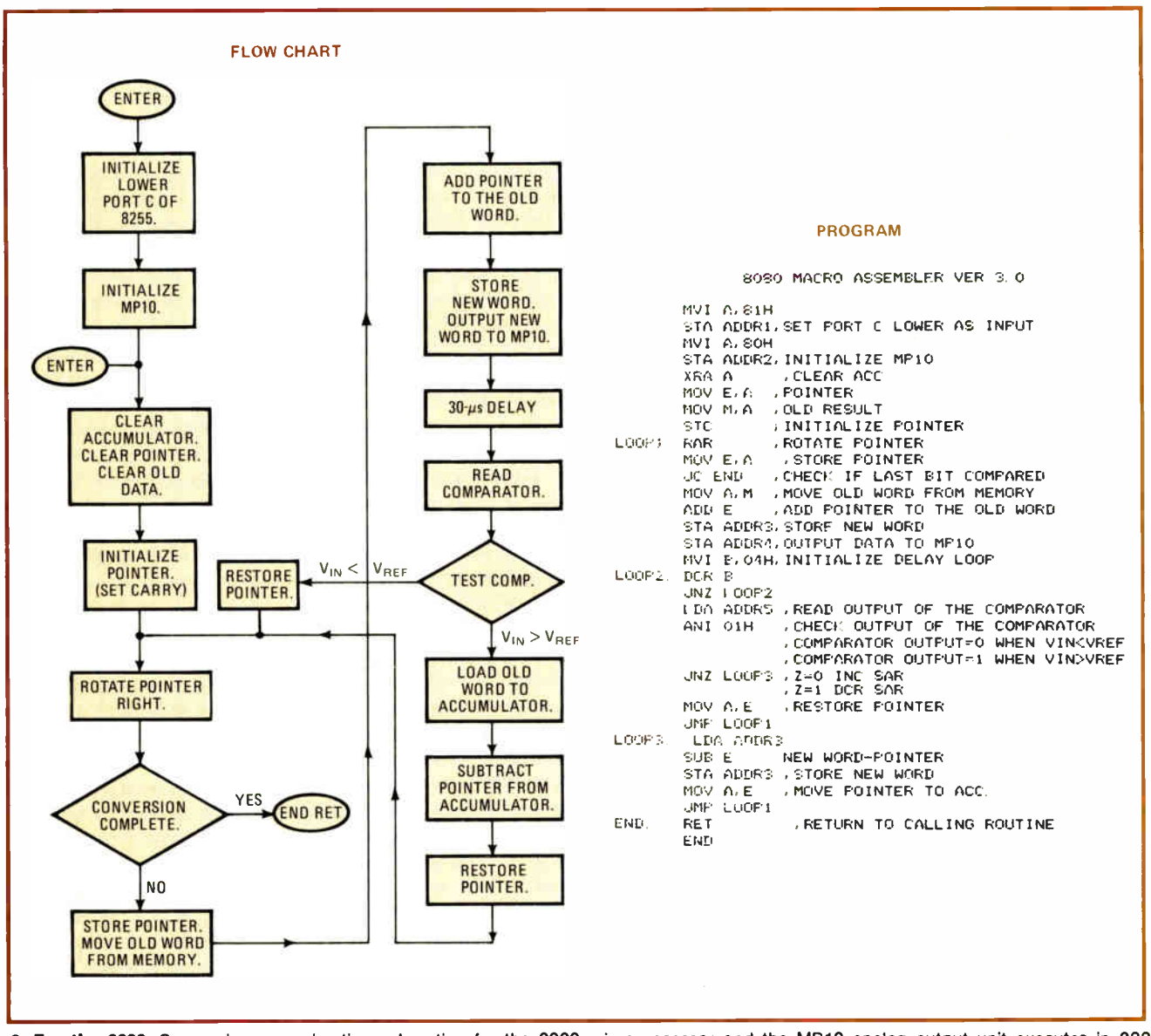
If the comparator indicates that the MSB voltage is smaller than the analog input, the MSB input to the d-a converter stays on, and the microcomputer turns on the next MSB. If the comparator indicates that the MSB value is larger than the analog input, the microcomputer turns this MSB off and the next MSB on. The cycle repeats until all 8 bits of the d-a converter have been tested.

When the conversion is complete, the input to the d-a converter will be a digital representation of the analog input signal. Also, the microprocessor stores this digital value in its accumulator register.

Minimal software necessary

The program (Fig. 2) for the MP10 working with the 8080 is intended to be used as a subroutine. It is 51 bytes long and executes in under 90 microseconds if the microprocessor cycle time is 500 nanoseconds. Before employing this subroutine program, the user must





2. For the 8080. Successive-approximation subroutine for the 8080 microprocessor and the MP10 analog output unit executes in 833 microseconds. The user may reduce this by about 20 μs by moving the initialization to the microprocessor's monitor program.

specify the following mine program instructions:

- ADDR1, the initialization address of the programmable peripheral interface—one bit of this device's lower port C may be dedicated as an input to read the output from the comparator.
- ADDR2, the initialization address of the MP10.
- ADDR3, the memory location where the final result is stored.
- ADDR4, the address of the MP10's d-a converter to be used in the successive-approximation routine.
- ADDR5, the address of the lower port C of the programmable peripheral interface.
- Loop 1, a JUMP address.
- Loop 2, a JUMP address.
- Loop 3, a JUMP address.
- END, the address of the return (RET) instruction.

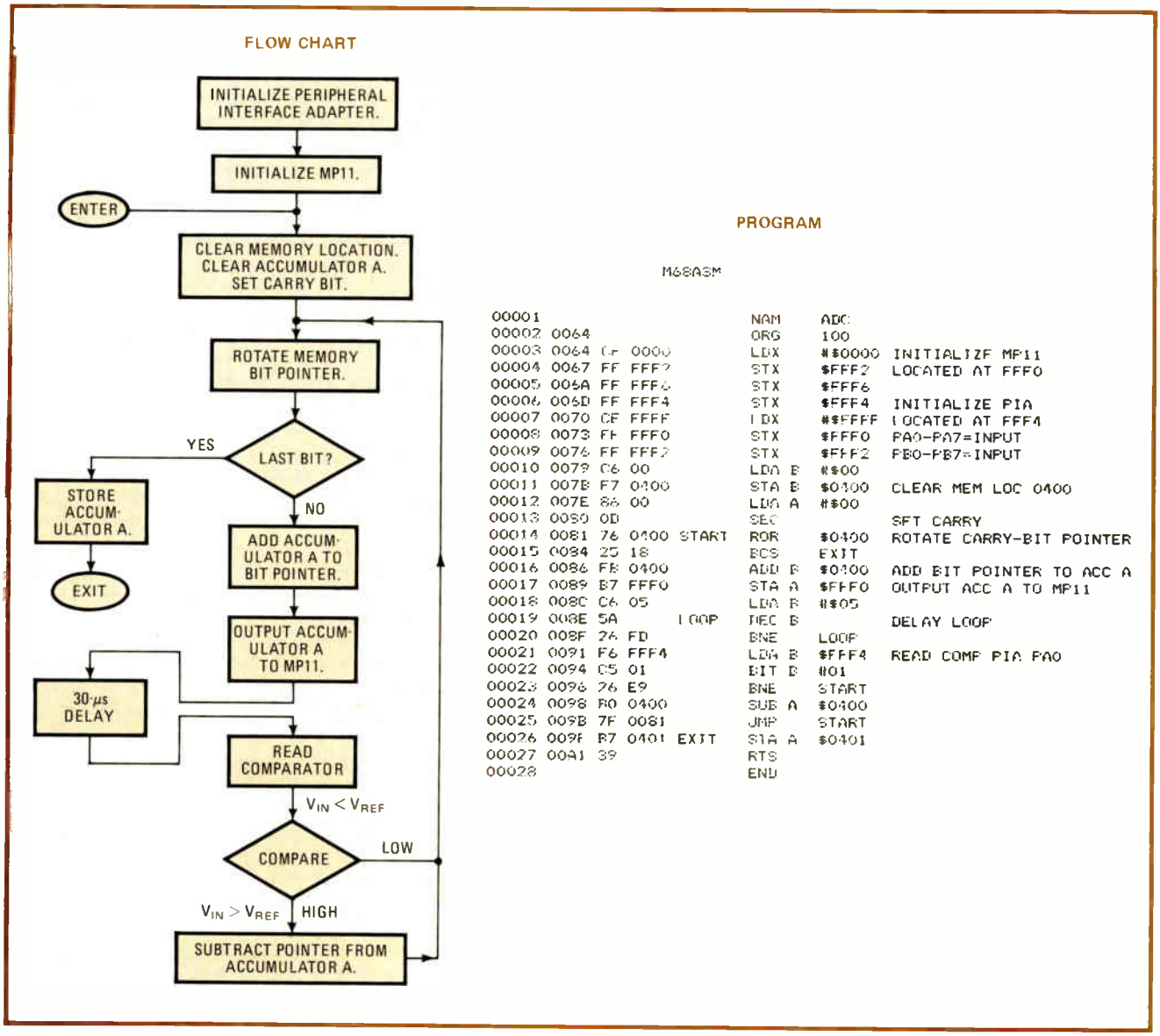
Of course, the positions of the JUMP addresses depend on where the program is stored. The user may remove the initialization portion of the subroutine and store it in the microprocessor's monitor program, so that the programmable peripheral interface and the MP10 need not be initialized every time the subroutine is executed. This will save about 20 μs of execution time.

Delay time depends on comparator speed

The comparator should have a slew rate of at least 6 volts/μs in order to work with the 30-μs delay called for in the program. If the comparator is slower, the user may easily modify the delay routine by changing the value of N in the MVI B instruction. N, which is set equal to 4 in this example and stored in the 8080's register B, indicates how many times the delay loop must be iterated for all signals to settle properly. For the MP10 program:

$$N = \frac{(25\ \mu s) + (\text{comparator slew rate})}{7.5\ \mu s}$$

The delay time, then, is simply:



3. For the 6800. Subroutine dubbed ADC acts as successive-approximation register for the 6800 microprocessor and the MP11 analog output unit. Execution time, which is about 630 microseconds for this program, may be decreased by 36 μs if the MP11 is initialized on power-up.

$$T_{delay} = (7.5\ \mu s) \times N$$

Then the total conversion time becomes:

$$\text{total conversion time} = (593\ \mu s) + (8 \times T_{delay})$$

Therefore, extending the delay from 30 to 50 μs will increase the execution time from 833 to 993 μs, permitting a comparator with a slew rate of 1 v/μs to be used.

Working with the 6800

Similarly, the program for the MP11 and the 6800 (Fig. 3) is also intended to be used as a subroutine—one named ADC and stored at memory location 0100. Here, the microcomputer's programmable interface adapter is located at address FFF4, while the MP11 is at FFF0. Memory location 0400 stores a bit pointer, and memory location 0401 will contain the final result.

If the MP11 does not have to be initialized every time subroutine ADC is called, execution time may be reduced by 36 μs. Otherwise, execution time may be calculated from:

$$\text{total conversion time} = (390\ \mu s) + (8 \times T_{delay})$$

where:

$$T_{delay} = (6\ \mu s) \times N$$

As in the MP10 program, the value of N depends on the speed of the comparator and is stored in register B of the microprocessor. However, for the MP11 program, N may be computed from:

$$N = \frac{(25\ \mu s) + (\text{comparator slew rate})}{6\ \mu s}$$

To sum up, then, in a small system where only one analog input is needed and where conversion time is not critical, the MP10/11 analog output units can make it much simpler to realize a software successive-approximation register. □

Transistor sensors provide reliable temperature control

by M. W. S. Thomas
Hydraulics Research Station, Wallingford, Oxon., England

The known voltage-to-temperature relationship at a transistor pn junction allows it to be used as a low-cost sensing element for temperature-control circuits. With constant current through the transistor, the base-to-emitter voltage, V_{be}, varies linearly with temperature. Because the thermodynamic relation for energy transfer between two or more bodies also is linear in this case, an easy design procedure using these simple equations can be developed for heat-transfer applications.

The method is best explained by an example that shows how a circuit may be designed for temperature monitoring and control in a central heating system. A boiler initially operating at 82°C (T_b) is to maintain a room temperature (T_r) of 21°C when the outside temperature (T_a) is 0°C. Thus the heat lost by the room to the outside must be transferred to the room by the boiler. This leads to the heat equation:

$$T_b - T_r = K(T_r - T_a) \quad (1)$$

where K is defined as the system constant. Substituting the initial temperature values, the value of K is determined to be approximately 3, and the equation becomes:

$$T_b - 4T_r + 3T_a = 0 \quad (2)$$

Although the constant was determined by the initial temperatures, this equation is valid for an infinite number of temperature combinations of T_a, T_b, and T_r.

It is necessary to transform the heat equation to an electrical equation. This can be accomplished if equal and opposite terms are added to (2), T_b, T_a, and T_r are set equal to each other—permissible from (2)—and T_c is defined as the desired room temperature. This yields the equation:

$$8T_c - T_b - 4T_r - 3T_a = 0 \quad (3)$$

This equation can be solved electronically by an inverting summing amplifier, as shown in the figure, if all temperatures at the transistor pn junctions can eventually be expressed by their corresponding voltages. Since this relationship is known, the equation to be solved is of the form:

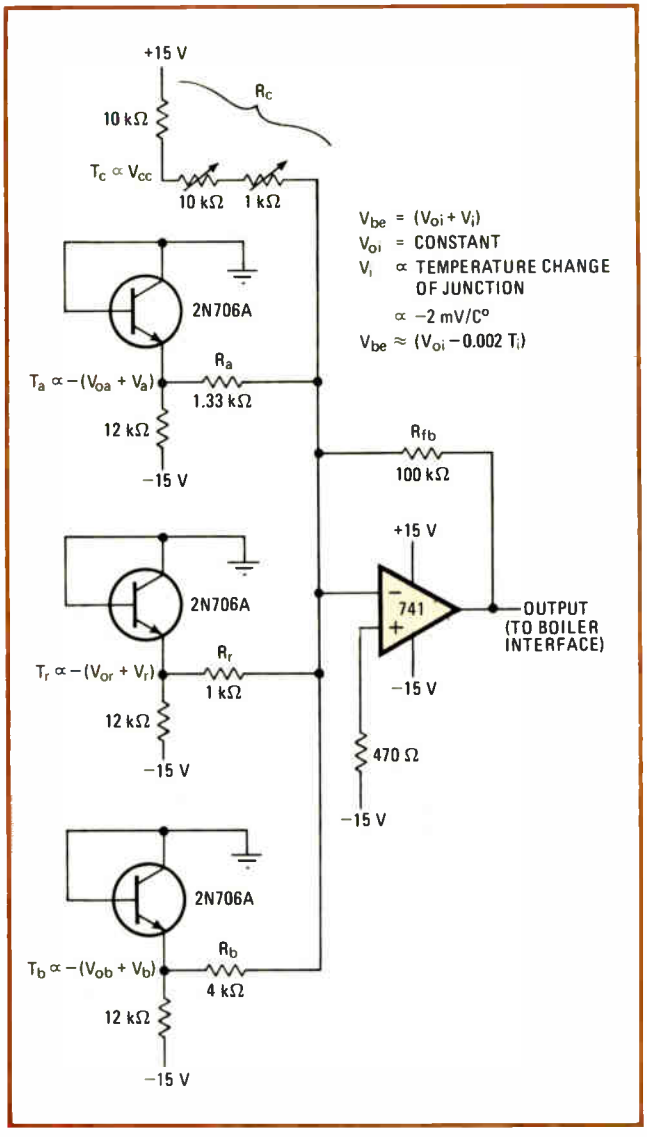
$$V_o = K_1(8T_c - T_b - 4T_r - 3T_a) \quad (4)$$

where V_o is zero volts at thermal equilibrium and K_1 is a constant. The summing amplifier's output voltage is:

$$V_o = -R_{fb}\left[\frac{V_{cc}}{R_c} - \frac{V_{ob}+V_b}{R_b} - \frac{V_{or}+V_r}{R_r} - \frac{V_{oa}+V_a}{R_a}\right] \quad (5)$$

Neglecting the amplification factor, it is necessary to match the coefficients of all terms in (4) and (5), as both are equal to V_o, to find the value of the gain-controlling resistance elements R_{fb}, R_a, R_b, and R_r. This may be done by grouping the constant and the temperature-dependent terms of (5) together. This yields:

$$V_o = -R_{fb}\left[\left(\frac{V_{cc}}{R_c} - \frac{V_{ob}}{R_b} - \frac{V_{or}}{R_r} - \frac{V_{oa}}{R_a}\right) - \left(\frac{V_b}{R_b} + \frac{V_r}{R_r} + \frac{V_a}{R_a}\right)\right] \quad (6)$$



Summing thermostat. Operational amplifier output reflects sum total of changes in T_a, T_b, T_c, and T_r, informs boiler to increase temperature of room when necessary. System is linear over T_c range of 4°C to 27°C. Accuracy of system is not appreciably affected by op amp temperature or distances separating sensors.

If R_{fb} = 100 kilohms, R_a = 1.33 kΩ, R_b = 4 kΩ, and R_r = 1 kΩ for a V_{cc} of 15 v, the final equation is:

$$V_o = -25\left(\frac{4C}{R_c} - V_b - 4V_r - 3V_a\right) \quad (7)$$

where C is a constant. The coefficients of (7) and (4) match and the heat equation is now equivalent to the electrical equation.

The circuit must now be calibrated to ignore the constant term. This is done by placing the three monitoring transistors in a container of pure water at the desired temperature (for example, 21°C), placing the 1-kΩ room-control potentiometer in R_c at the center of its range, and adjusting the 10-kΩ trimmer (also part of R_c) for zero output voltage. The temperature of the bath may be changed to another temperature, say 15°C, and the 1-kΩ control adjusted for zero output again.

In both cases, the position of the pot is noted so that a dial may be calibrated for it. Each transistor is then placed in contact with the boiler, the room temperature, or the outside, depending on its monitoring function. The op amp should be placed in an area that will not undergo major short-term variations in temperature. The temperatures T_a, T_b, T_c, and T_r, once determined, are constant for a reltively short time because of environmental changes that may affect personal preferences. Once calibrated, the circuit will maintain T_c for any variance in any variable including the only truly independent variable in the system, T_a.

The output of the op amp will be zero when $T_c = T_r$ for any boiler or outside temperature. When T_c is greater than T_r, the output of the op amp should be positive, and the boiler should turn on, raising its temperature. A suitable interface will be needed to drive the boiler solenoid, which should not respond when the output voltage is negative. □

Pulsed low-power source energizes solenoids and relays

by Tom Rogers
United Telecommunications Inc., Shawnee Mission, Kan.

Simultaneously activating the track switches of a model railroad from just its standard low-voltage power supply is a neat hobbyist's trick. But the circuit that makes it possible also can serve in any application where low-power sources must supply tremendous currents for activating mechanical-latch solenoids and relay coils. The circuit stores the source's energy and releases it in a burst through those devices.

The source—in this case a 20-volt supply—is stored on a capacitor and then discharged instantaneously through a low-resistance inductor. The unit's operation is analogous to that of a strobe circuit, where a blinding light is produced by storing a small voltage on a capacitor and quickly discharging it to form a pulse of energy.

The supply typically provides only 6 volt-amperes—barely enough to supply the required current to one switch, and certainly not enough to operate larger switches. But, with capacitor C_1 included as shown in the figure, large currents may be produced. The 20-v ac or dc input from the accessory terminals of the power supply charges C_1 through lamp L_1 and diode D_1 in the half-wave rectifier circuit.

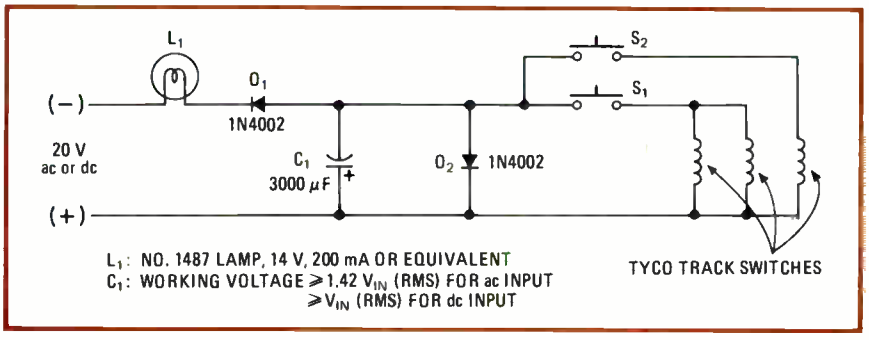
The lamp resistance limits the charging current to approximately 120 milliamperes and is also used as a charging indicator. When the capacitor voltage is approximately equal to the peak value of the input voltage, the lamp is extinguished. The energy stored in the capacitor at this time is about 3.5 joules.

One of the external momentary-contact push buttons may now be depressed. The capacitor will discharge through the appropriate low-resistance relay coil. The instantaneous current through the coil will be very great for a few microseconds, enough to switch the relay but not long enough to damage its coil. Diode D_2 provides protection for the capacitor by preventing the coil's counter-electromotive force from appearing across it.

The energy stored by the capacitor may, of course, be increased by raising the value of capacitance or input voltage ($E = CV^2$). The current produced as the capacitor discharges will be directly proportional to the energy stored.

Recharging the capacitor is accomplished in three seconds or so. Charging currents, and thus charging times, are easily changed by substitution of appropriately rated lamps for the one used in this circuit. If the charging current is kept low enough, other devices connected to the power supply will not be affected by this circuit's operation.

The circuit also suits applications where it is necessary



High-current pulser. Energy in low-power source is stored on capacitor, then released to provide latch-type relays with high-current pulse. Lamp is charging indicator and limits current to relays in applications where small continuous current is necessary.

to keep the external switches closed after the initial switching pulse has been applied. The holding current will be much less than the initial current, and the current supplied continuously will be a function of the lamp, coil, and diode (forward) resistances. The limited current should not overheat the transformer or the coil might be damaged. Holding currents for the particular solenoid can be supplied by the manufacturer. □

Pulsed-voltage measurements check LED quality

by Terence Klein
Xciton, Latham, N.Y.

The suitability of a light-emitting diode for high-pulse-current applications can be easily determined by a test that measures the voltage drop across the LED at high currents. The use of a pulsed constant-current source to drive the diode and determine its high-current capacity subjects neither it nor the user to the "smoke test," yet the resulting voltage drop across the LED may point up the existence of an internal fault, such as a high-resistance pn junction, a substrate fracture, or a shunt path around the junction. The results of the measurement are independent of LED optical properties.

As shown in the figure, a Darlington amplifier using a MPSU95 device provides a current to a test LED through the AD7510DIKN quad analog switch. The current source is adjustable from 0 to 100 milliamperes. A 555 timer configured as an astable multivibrator drives a second timer, and the combination provides adjustable duration time and repetition rates for switching all analog gates simultaneously.

The outputs of three of the analog gates, each having an on resistance of 75 ohms, are tied together to reduce the equivalent impedance to 25 Ω, to minimize the voltage drop across the gates during conduction. Capacitor C_1 is connected across the LED when the gates are on; thus the voltage across the capacitor is the peak voltage of the diode under test.

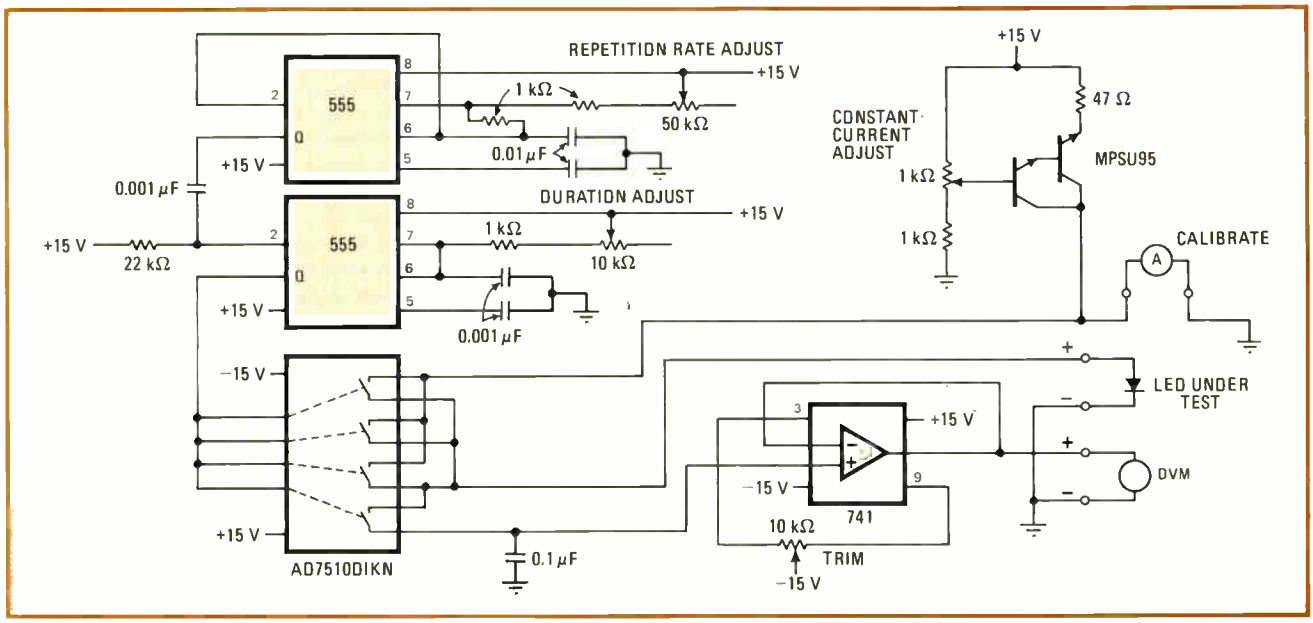
This voltage is applied to the noninverting input of the 741 operational amplifier. The op amp is a unity-gain buffer, so that even low-impedance voltmeters may be placed across its output for measuring the LED's voltage (a digital voltmeter is preferable, however).

Once the user knows the test specifications of the diode, he makes a one-time adjustment of the duration time and repetition rate with an oscilloscope (for many tests, this could be 30 microseconds at 1 kilohertz). The next step is to calibrate the current source by placing an ammeter in series with the calibrating terminals. The resultant voltage across the LED can be measured with a DVM set at its fastest sampling mode.

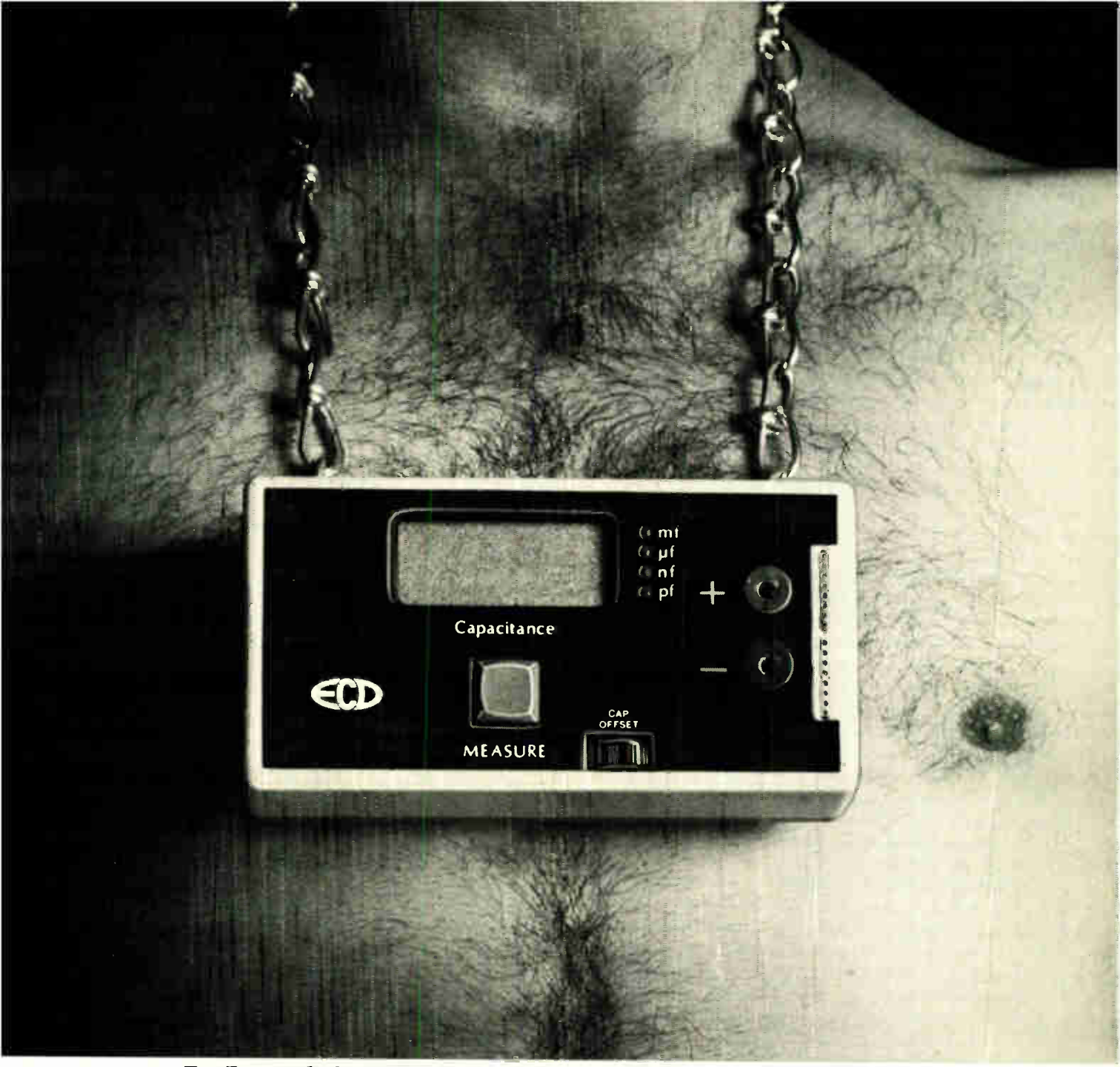
Diodes likely to fail in an actual circuit from high resistance, substrate fracture, or die-casting faults might produce much higher voltages than expected. Low voltage drops across the LED for a specified current could be the result of shunt paths surrounding the pn junction.

If care is taken in minimizing circuit ground-point differences, and if the 741's output voltage is trimmed to zero after shorting the op amp's socket terminals during pulsed measurements (to zero out the effects of lead drop), this method of measuring the voltage across an LED easily yields an accuracy greater than 1%. □

Engineer's notebook is a regular feature in *Electronics*. We invite readers to submit original design shortcuts, calculation aids, measurement and test techniques, and other ideas for saving engineering time or cost. We'll pay $50 for each item published.



Fast and accurate. Quality-control determination is obtained at low cost by observing DVM directly in lieu of time-wasting oscilloscope measurements, which are subject to errors of judgment by the observer. DVM reading may indicate faults in diode's pn junction.



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Circle 137 on reader service card 137

Engineer's newsletter

A couple of meters can find shorts in pc gate inputs

Why remove integrated circuits or, worse, cut etched connections from a printed-circuit card when trying to determine which of a number of paralleled gate inputs has a short to ground? **It's faster and nondestructive if you use a volt-ohmmeter and digital voltmeter to measure the small voltage drop associated with the short,** says Martin Ewing of the California Institute of Technology in Pasadena, Calif. (An ohmmeter alone won't do, of course, because of the low impedances involved.)

Set a volt-ohmmeter, such as the Simpson 260, to its R × 1 scale, and connect it between the node in question and ground, providing a constant current of about 100 milliamperes. Then use the DVM (say, an HP3476) in its millivolt range to probe the etched wiring and pinpoint the defective gate input. **You simply note the location of increased voltage drop brought about by high current through the portion of the etched wiring adjacent to the shorted gate.** Typical etched connections produce a voltage drop of about 1 mV per inch with these currents, so useful results can also be obtained with partial shorts up to nearly 100 ohms.

Bargain basement for GaAs FETs—well, almost

Now that gallium-arsenide X-band power field-effect transistors at 1 watt and above are available from multiple sources, **prices of these costly devices are starting to come down.** One supplier, Texas Instruments Inc., plans to cut prices by 75% on its 1-W 8-gigahertz GaAs FETs. For example, the TI MSX 803, a device selling for $1,000 in small quantities, will be slashed to $250. Other manufacturers of 1-W and above devices—RCA Corp., Microwave Semiconductor Corp., and Japan's Nippon Electric Corp. and Fujitsu Ltd.—all plan to follow suit.

Signal-driven exclusive-OR gate detects state changes

An exclusive-OR gate can detect a change in state of a logic signal more conveniently than can a one-shot, says N. Ghani of the Computer Laboratory at Newcastle University, Newcastle-upon-Tyne, England. A one-shot can directly sense state changes in only one direction, so additional circuitry is needed to handle both positive and negative changes. **But a quad 7486 exclusive-OR gate, driven by the signal and its delayed version, can sense both types of changes,** Ghani says.

Three of the gates can be used as inverters producing a delay. The fourth is in the exclusive-OR mode, taking in the signal and its delayed counterpart. Whenever the input changes state—whether it is positive- or negative-going—the 7486 will produce a narrow negative pulse with a width equal to the delay. If no inverters are used in producing the delay, then a positive pulse will be generated.

Don't raise the bridge; lower the river

A roadblock to wider usage of film-carrier packaging of integrated circuits is that IC houses have not produced chips with the input/output pads required for bonding to the tape's copper interconnects. One solution is to **put the metallic bumps on the tape,** along the lines of a Pactel Corp. process. But the Westlake Village, Calif., firm could only supply the tape in strips, not in the large reels needed for IC assembly.

However, the Dyna Tape division of National Semiconductor's subsidiary Dyna-Craft Inc. will be able to deliver reels of a bumped film carrier by the year's end. There's no isolation between lead frames, so on-tape Testing is impossible. But in 1978, the Santa Clara, Calif., company will supply isolated lead-frame tapes on reels. **Stephen E. Scrupski**

NATIONAL ANTHEM

A Review of New Products and Literature from National Semiconductor

LM140/340: Better Specs At The Same Price

Our LM140 series of three-terminal voltage regulators now offers a combination of features that gives you a higher-performance part, but with no increase in its price.

For example, our LM140 boasts superb low-frequency ripple rejection under load—to 80 dB, typ., depending on the output voltage level; excellent high-current load regulation at high input voltages—0.60%/A; line regulation, 0.06%/V; output current capability in excess of 1 A (with an adequate heat sink for the TO-3 package); and very low thermal feedback effects. Of course, internal thermal overload protection, internal short-circuit current limiting, and output transistor safe area protection are also included.

Now look at our brand new LM340. We're the first manufacturer to offer this commercial part with line and load regulations identical to the MIL version, yet priced the same as competing, less-tightly-spec'd devices.

And we've made both the LM140 and the LM340 very easy to use—they need very few external components, and are available in a wide range of fixed outputs between 5 V and 24 V. Ask too, about our LM140A and LM340A; these feature tighter output voltage tolerances and even better line/load regulation than the LM140/340.

Protected CD4000's

Not all CD4020/40/60 CMOS counters have Schmitt triggers on the clock inputs. Ours do. And these Schmitts eliminate the problems commonly encountered on clock inputs in the competition's devices.

The CD4020B and CD4060B are 14-stage ripple-carry binary counters; the CD4040B is a 12-stage version. All advance one count on the negative transition of each clock pulse, reset to the zero state with a logical '1' at the Reset input (independent of the clock), operate between 3 V and 15 V, run at 8 MHz (at V_{DD} = 10 V), and are low-power-TTL compatible (fan-out of 2 driving 74L, of 1 driving 74LS).

Support Circuits, Faster 8080A's Added

Less than one year ago we entered the 8080A marketplace with our INS8080A—a pin-for-pin, function-for-function replacement for you-know-who's MPU. But that was only the start: Since then we've added two more versions of that microprocessor, as well as a complete family of support circuits.

The new versions of our original 2-μs cycle time INS8080A are the INS8080A-1, which has a 1.3-μs cycle time, and the INS8080A-2, with a 1.5-μs cycle time.

In addition to the faster 8080A's, we now offer ten types of interface circuits to support 8080A system design.

- DP8212 is an 8-bit I/O port that you can use to implement all major peripheral and MPU I/O system functions.
- INS8255 is a programmable peripheral I/O interface that features direct bit set/reset capability.
- DP8301 is a microprocessor interface latch element (MILE) with on-chip status flags for 'handshake' control and interrupt generation. It drives TTL, NMOS, PMOS, and CMOS circuitry.
- DP8224 is a crystal-controlled clock generator and driver, which also provides a status strobe and oscillator outputs for external circuits.
- DP8228/8238 are system controller and bus driver circuits that generate all needed read/write control signals, provide drive and isolation for the 8080A's bidirectional data bus, and a user-selected single-level interrupt vector.
- DP8304 is an 8-bit bidirectional bus transceiver with high active outputs to both ports, a Tri-State® chip enable control, and transmit/receive control.
- INS8251 is a universal communications interface (USART) for data communication in 8080A and other bus-structured systems. (Available in April.)
- DP8216/8226 are I/O buffer drivers (4-bit parallel transceivers) suited to both 8080A and general MPU applications. (Available in April.)

Video Modulator for Display, Game Systems

Our LM1889 lets you display video information—from VTR's, games, test equipment, etc.—on any standard black-and-white or color television receiver, and also lets you encode composite video. In addition, the LM1889 together with our MM57100 and MM53104 form a complete video game system.

Consisting of sound and chroma subcarrier oscillators, quadrature chroma modulators, rf oscillators and modulators for any two low-band vhf TV channels, the LM1889 interfaces audio, color difference, and luminance signals to a TV receiver's antenna terminals.

The LM1889 features dc channel switching, a wide range of operating voltages, excellent oscillator stabilities, low intermodulation, and a 5-$V_{pk\text{-}pk}$ chroma reference signal.

Not Just Another Pretty Shift Register

We've added two National-proprietary circuits to our line of digital products—the DM86LS52 and DM86LS62 shift registers. But if you're thinking, "Ho hum, just another shift register," you're wrong. For in each 18-pin package there are two registers—an 8-bit serial type in parallel with an 8-bit I/O type.

Such a device is called an 8-bit dual-rank shift register. And what that means is that each package gives you a bidirectional circuit designed to interface parallel and serial bus lines. Thus, you can transfer 8-bits-wide parallel data to a serial line, and vice versa.

The DM86LS52 lets you synchronously clear the registers, while the DM86LS62 lets you simultaneously transfer data between the serial and parallel registers.

To duplicate such functions with standard components would require about 13 packages; a single DM86LS52 or 62 does it all, and at about half the cost.

Specifics of these new bus-oriented registers include edge triggering on the positive transistions of the clock; pnp transistor inputs; input disable dominant over output disable; Tri-State® buffered, 8-bit common I/O pins; n-bit cascadability; 36-MHz (typ.) shift frequency; and 305 mW (typ.) power dissipation.

Second-Source 8-Bit D/A Converters

Our LMDAC08 and LM1508/LM1408 monolithic D/A converters are direct replacements for the DAC-08 and MC1508/MC1408, respectively, and carry very low prices in 100-up quantities.

These current-output D/A's feature high-speed operation (typical settling times to within ±½ LSB are 100 ns for the LMDAC08 and 150 ns for the LM1508/LM1408); full-scale current matching to ±1 LSB; and typical full-scale drifts of ±10 ppm/°C (LMDAC08) and ±20 ppm°C (LM1508/LM1408). Excellent reference-to-full-scale current matching eliminates current trims.

Both the LMDAC08 and LM1508/LM1408 interface directly with DTL, TTL, CMOS, etc., logic levels. They operate between ±4.5 V and ±18 V, and dissipate only 33 mW, typical, at ±5 V.

8-Bit-Wide Tri-Safe™ PROMs Increase Memory Density

The DM74S470 (open collector) and DM74S471 (Tri-State®) PROMS are Schotty-clamped, 2048-bit memories organized 256 x 8. The DM74S472 (Tri-State) and DM74S473 (open collector) PROMS are also Schottky clamped, but are 4096-bit parts organized 512 x 8.

Although the word width is 8 bits—which, by the way, is ideal for MPU applications—these memories are housed in 20-pin DIPS only 0.3-inch wide. And this means that you get the increased memory density of 0.6-inch-wide designs, but at the better packing density of older, 4-bit-word designs in 0.3-inch-wide packages.

The combination of National's Tri-Safe™ programming and advanced, low-voltage titanium-tungsten fusing assures you of extremely high programming yields and the most reliable long-term stability you can buy.

The DM74S470/471 feature address access times of 60 ns (max.), while the DM74S472/473 have address access times of 65 ns (max.). The enable access time for all these parts is 30 ns, maximum.

BI-FET™, Integrating A/D Analog Building Block

BI-FET technology — an IC process pioneered and introduced by National Semiconductor more than a year ago (see *National Anthem*, January 1976)—combines JFET and bipolar transistors on the same chip. For our LF13300, BI-FET technology provides a unity-gain, high-input-impedance (>1000 MΩ) buffer, a comparator and integrator, and nine rugged JFET analog switches.

As a result, the LF13300's accuracy is sufficient for use in DPMs of up to 4½ digits, or in data acquisition systems of up to 14 bits plus sign. The LF13300 is in fact ideal for use with our ADB4500P BCD digital and ADB1200P 12-bit binary building blocks. (You're more familiar with these ADB parts per their older numbers—MM5330 and MM5863, respectively.)

In general, the LF13300 eliminates many discrete components and reduces system complexity. In particular, the LF13300 features automatic offset correction, an analog input range of ±11 V with ±15-V supplies, a supply range of ±5 V to ±18 V, and TTL- and CMOS-compatible logic.

APPLICATIONS CORNER

How to Build a Digital Thermometer

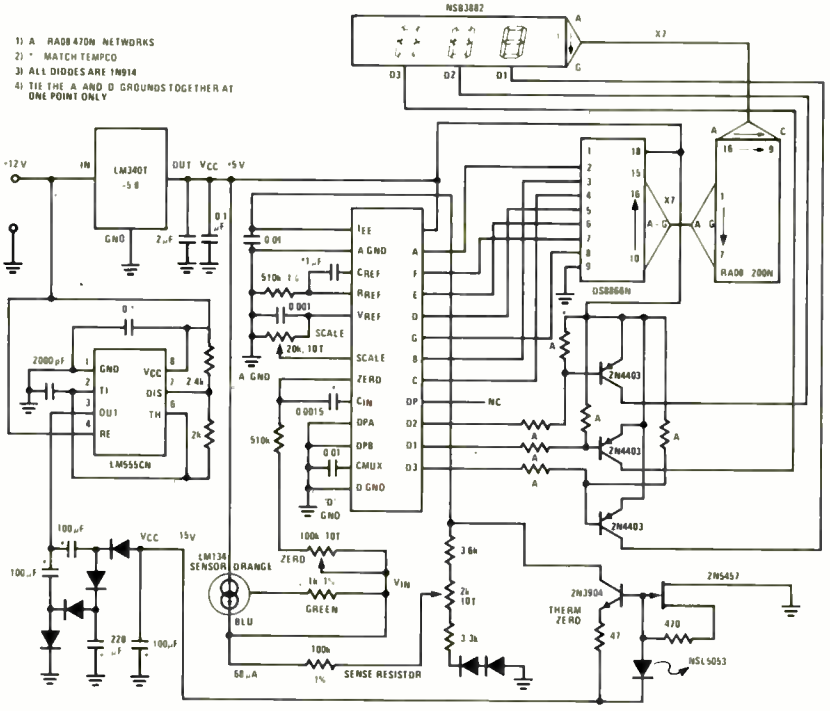
Analog electronic thermometers have been available for some time, but they are generally difficult to read and, besides, are relatively fragile. Digital thermometers, on the other hand, are both easy to read and rugged.

The digital thermometer described here uses a ADD2500 2½-digit DPM chip for A/D conversion and display decoding. The LM134 programmable current source operates here as the temperature sensor, and the LM555 timer as a dc/dc converter. The DS8866 and the pnp transistors drive the NSB3882 display.

The LM134 makes an excellent temperature sensor: it has a constant temperature coefficient of +0.30%/°C (0.167%/°F); and its noise immunity and current programmability make it ideal for remote sensing use. Output-current flow through a sense resistor scales the LM134's output voltage—in this case, to 10 mV/°F, which is one count of the DPM or 1°F displayed.

Besides a +5 V input, the ADD2500 draws 18 mA from a negative supply. This comes from the dc/dc converter (at −15 V) as a regulated current via the 2N5457 FET, the LED, and the 2N3904. The negative supply of the ADD2500 is internally Zener regulated; it, together with the two diodes and the resistor string between ground and I_{EE}, establish a low-drift offset voltage for the LM134's sense resistor.

The finished thermometer requires only a single, unregulated +12 V supply, and operates from −29°C to +60°C (−20°F to +140°F).



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Our new *Transducer Features Chart* shows you, at a glance, what's available in our line of IC pressure transducers.

The chart lists basic product type numbers on a vertical axis, and package options, etc., on a horizontal axis. At the projected intersection of the basic part number and the number of the option, the chart shows you the complete model number of the combination you've selected. Conversely, the absence of a number indicates that the combination you've selected is not a standard part.

So if you're working with pressure transducers, the *Transducer Features Chart* is a handy short-form guide to National's pressure transducer products. Just ask for a copy, and it's yours.

A Review of New Products and Literature from National Semiconductor

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SC/MP Applications Handbook

Simple to use . . . cost effective . . . applications oriented. These terms are all descriptive of SC/MP—National's very popular single-chip 8-bit microprocessor. In support of such descriptors, National now offers the *SC/MP Microprocessor Applications Handbook*, which, in its 145 pages with 68 illustrations, defines SC/MP's internal architecture, pin-outs, and interfacing techniques—from an applications point of view.

The text also addresses the concepts, principles, hook-up details, and general implementation procedures that relate to the many applications for which SC/MP is so well suited.

The information is organized in capsule form so that the reader can use it to expand, modify, or customize a given application. Those applications within the text are organized by class —A/D and D/A systems, keyboard/display systems, multiprocessor systems, and so on.

A great amount of general design data are also included, and the material covers the instruction set, addressing modes, I/O capabilities, interrupt structures, and other applications-related features.

The *SC/MP Microprocessor Applications Handbook* costs $5.00 per copy. Send your check or money order—no cash, please—to Marketing Services M/S 520, National Semiconductor Corp., 2900 Semiconductor Drive, Santa Clara, CA 95051. (California residents add 6% sales tax, please; San Francisco Bay Area residents, 6.5%.)

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Our new *LED Short Form Catalog* details our line of LED lamps and numeric displays.

The page headings of the ten-page catalog describe its content: Special Feature Lamps (constant current, side view, and high-lens types); Panel Indicators (red, green, and yellow); General Purpose Lamps; Numeric Displays; and Watch Display Die. For each lamp grouping the catalog shows appropriate application areas, lamp features, and the technical specifications for each lamp.

There's also a LED lamp locator that charts lens type versus lamp size, which lets you quickly locate the part number of the lamp suited to your specific needs; mounting clip information for panels and PC boards; and two pages of drawings of various mounting techniques, which name the sources of connectors and other mounting hardware. The catalog closes with a listing of National's LED segment and digit drivers, which shows, for each driver, its input compatibility, V_{out}, I_{out}, input code, and so on.

Our *LED Short Form Catalog* is free for the asking. Simply check the box on this issue's VIP card.

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A Review of New Products and Literature from National Semiconductor D

Low-cost ICs convert light to current

Monolithic optoelectronic circuits combine low-temperature diffusion and ion implantation to boost gain and blue sensitivity

by Bernard Cole, San Francisco bureau manager

Combining an advanced low-temperature diffusion process with a new ion-implanted photodiode fabrication technique, National Semiconductor Corp. has developed a new family of linearized-output bipolar optoelectronic integrated circuits aimed at replacing discrete phototransistors and hybrid arrays in numerous applications.

The first three parts in the new family, available in sample quantities next month, include the LM1890, a light-to-current converter with an on-chip voltage reference and light-biased comparator; the LM1891, a gain-programmable light-to-current converter, and the LM1892, a two-terminal light-to-current converter with a claimed leakage current of zero in darkness.

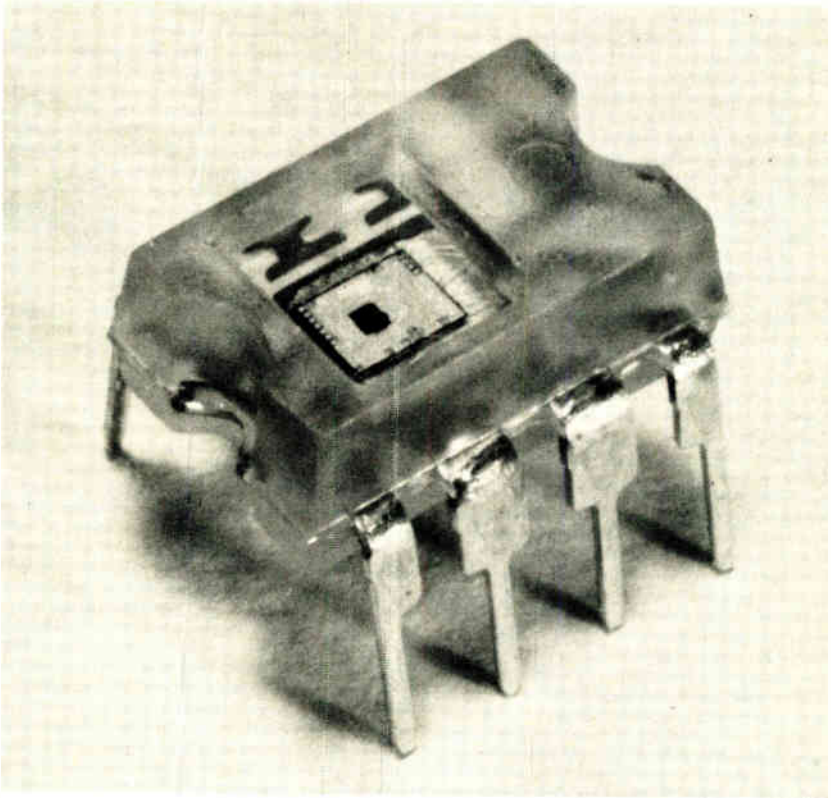
Designed as single-chip solutions for problems that up to now have required several discrete phototransistors and peripheral circuits or hybrid combinations costing as much as $50, the new linear opto ICs will cost only 50 cents to $1 in volume—scarcely more than does a single phototransistor.

Typical applications will include light meters, camera controls, electronic flash controls, smoke detectors, modulator/demodulators in infrared links or in audio systems for home movie projectors, linear optoisolators, optical servo loops, wheel position sensing, headlight dimmers, light threshold detectors, color sorting, and fluid density measurements.

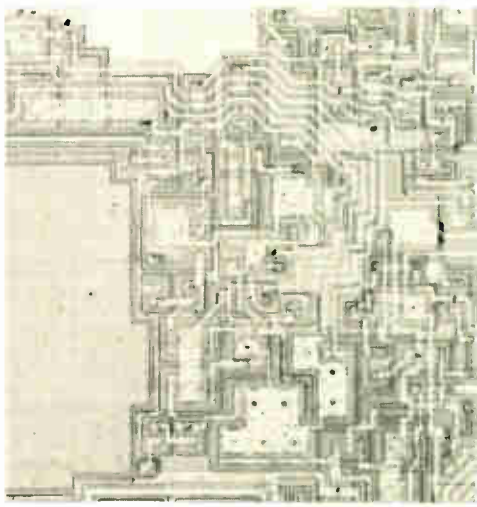
Features of the new all-monolithic family, says design engineer Dennis Monticelli, include convenient low-cost eight-pin dual in-line clear plastic packages, blue-enhanced photodiode spectral response, and nominal conversion gain of about 8 microamperes per foot-candle at 2,865 K. What's more, the line boasts accurate absolute conversion gain from on-chip trimming, linear conversion gain over several decades of light intensity, high-impedance cascoded current-source outputs with wide compliance down to 1 volt, a dark current of less than 1 nanoampere, and high supply rejection. The design has been optimized for battery operation—at +2.5 v for the LM1890-91 and +1 v for the LM1892.

In addition, the use of an on-chip comparator on the LM1890 with adaptive biasing insures the bias current is only 1% of the output, independent of light level. Dynamic range of the gain-programmable LM1891 is 40 decibels. Operating as a light-controlled oscillator, the LM1892 has a dynamic range of over 5 decades, from 1 hertz to 100 kilohertz.

Each die is calibrated during wafer sorting using a reference light source and a computer-controlled metal-link blowing technique, Monticello says. The chips are mounted in DIPs molded using a proprietary clear compound, rather than inserted in TO-5, TO-18 or TO-92 metal packages with glass windows as is the common practice. A small recess



New products



is formed in the package to allow a light filter to be conveniently inserted if needed, thereby reducing the infrared response. A second layer of aluminum is used on the die to shield the low-level control circuitry from incident light.

Special processing was developed to provide the blue-enhanced photodiodes (left portion of chip, above) and pnp and npn transistors with common-emitter forward-current gain ratios substantial enough to handle the low-level currents, Monticelli says. The use of ion implantation allows the fabrication of a shallow photodiode junction close enough to the surface to boost the normalized conversion efficiency to 60% in the visible light range and to increase the sensitivity in the blue portion of the spectrum.

Low-temperature diffusion processing and the use of a graded 1- to 5-micrometer epitaxial layer provide good forward-current gain ratios, while holding junction leakages to less than 1 picoampere at room temperature. Comparisons between photocurrent and various reference currents take place at levels as low as 2 nA, using a reference-current generator that is free from the problem of compounding leakage and current gain errors. Using a reinjector current-division chain to provide a ratio of 5,000:1 avoids this problem, Monticelli says.

National Semiconductor Corp., 2900 Semiconductor Drive, Santa Clara, Calif. 95051 [338]

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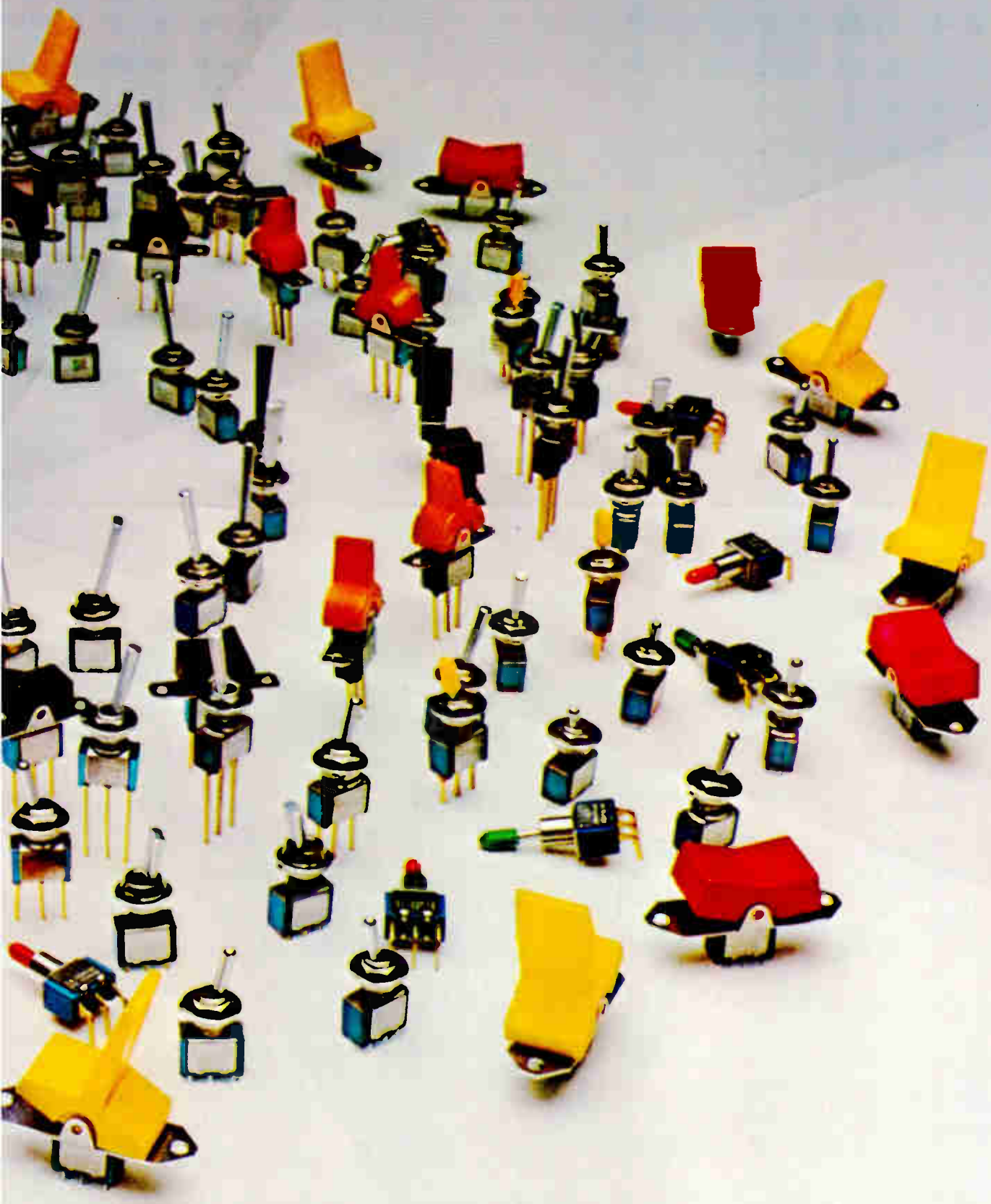

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Semiconductors

V-f converter is highly linear

Low-cost monolithic unit has maximum nonlinearity of 0.01% at 10 kilohertz

In the last few months, the performance of monolithic voltage-to-frequency converters has improved appreciably, yet prices have remained attractively low. Now, from Burr-Brown, an established leader in hybrid technology, comes an impressive v-f chip with a maximum guaranteed nonlinearity of 0.01% at 10 kilohertz and with the capability to operate at frequencies of up to 0.5 megahertz. Pricing starts at a low $6.10 each for 100-unit lots.

Designated the VFC32, the device may be used as either a v-f converter or an f-v converter. It has a six-decade dynamic range, spanning 0.5 hertz to 0.5 MHz. At the top frequency, maximum nonlinearity is 0.2%, tightening to 0.05% at 100 kilohertz.

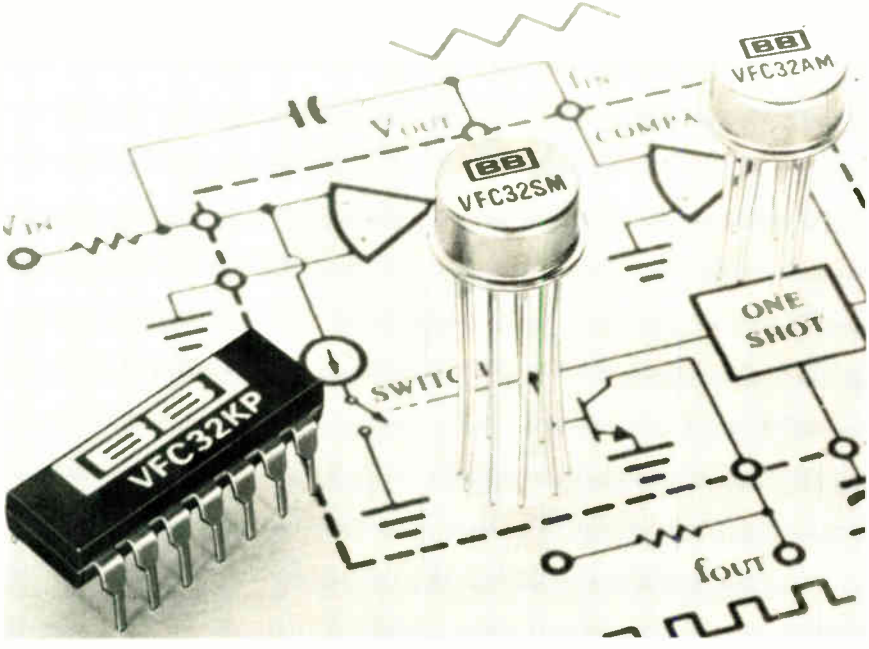
The unit accepts voltage inputs of 0 to +10 volts or 0 to −10 v, and positive current inputs of up to 0.25 milliampere. Its output is an open collector, so the VFC32 is compatible with a number of logic families, including diode-transistor logic, transistor-transistor logic, and complementary metal-oxide-semiconductor logic.

The number of external components required is minimal—just an RC network for setting up the full-scale frequency, a pull-up resistor, and a one-shot capacitor. Stability is adequate for most applications—maximum drift of the full-scale frequency is 100 ppm/°C and the input offset voltage drift is less than 2 ppm/°C.

In all, three models and two package configurations are available. The lowest-cost version, the VFC32KP, is in a 14-pin epoxy dual in-line package; it operates from 0°C to 70°C. The BM and SM versions are packaged in hermetically sealed TO-100 metal cans, with the VFC32BM operating over the temperature range of −25°C to +85°C and the VFC32SM operating from −55°C to +125°C.

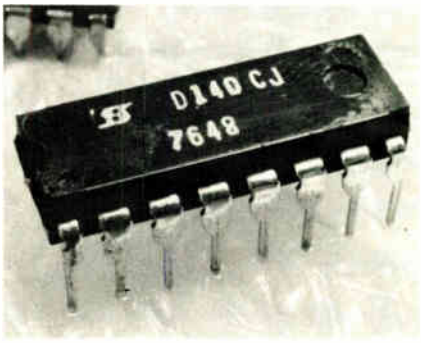
Price for the VFC32KP is $10.20 each for less than 10, dropping to $6.10 for quantities of 100 to 249. Similarly, the BM model sells for $13.90 singly or $8 for 100 to 249. The full military-range device, the VFC32SM, is $19 each for less than 10 or $11.70 for 100 to 249.

Burr-Brown Research Corp., International Airport Industrial Park, Tucson, Ariz. 85734 Phone (602) 294-1431 [411]



Hex digit driver interfaces MOS circuits with LED loads

Designed to interface low-voltage metal-oxide-semiconductor integrated circuits with high-current loads, such as light-emitting-diode displays, the D140 hex digit driver is able to work from a supply voltage as low as 3 volts. The monolithic bipolar circuit contains six independent drivers, each of which includes a high-gain Darlington stage and a current-limiting resistor network. Each of the device's six drivers can sink up to 90 milliamperes at a 3-v supply voltage. In small quantities the D140 sells for $2.24; in hundreds, the price drops to $1.56. Delivery is from stock.

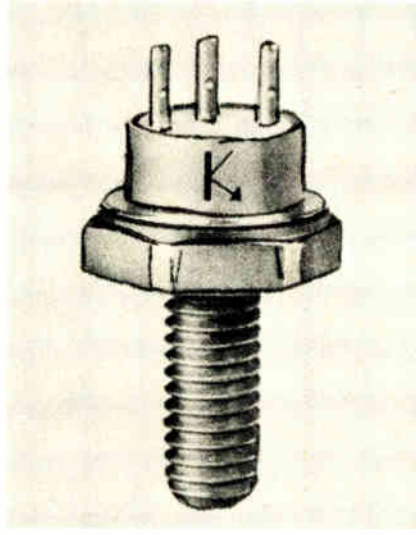


Siliconix Inc., 2201 Laurelwood Road, Santa Clara, Calif. 95054. Phone Jim Graham at (408) 246-8000 [414]

Transistor has cut-off frequency of 300 MHz

When biased at a collector current of 500 milliamperes and a collector voltage of 5 volts dc, the KS6038 has a cut-off frequency of 300 megahertz. A companion unit, the KS6039, has an F_t of 200 MHz under the same bias conditions. In addition to serving as class A amplifiers, both units can be used as fast switches. In

this latter mode, they are both capable of turning a collector current of 1 ampere on and off in a total switching time of 200 nanoseconds—a turn-on time (delay time plus rise time) of 50 ns, a storage time of 125 ns, and a fall time of less than 25 ns.



Both transistors are bonded with gold eutectic solder in a TO-60 isolated package. All internal leads are aluminum and are ultrasonically bonded. For quantities of 100 to 999 pieces, the KS6038 sells for $3.50 each, while the KS6039 is priced at $3.10 each for the same quantities. Production quantities are available from stock.

Kerton Inc., 7516 Central Industrial Drive, Riviera Beach, Fla. 33404. Phone George Reiland at (305) 848-9606 [413]

Four-quadrant multiplier is accurate to within 0.25%

The AD534L is a laser-trimmed monolithic four-quadrant multiplier with a maximum multiplication error of 0.25% at 25°C. Other versions are the AD534K and AD534J with maximum errors of 0.5% and 1%, respectively. For operation over the military temperature range from −55°C to 125°C there are the S and T versions with maximum errors of 2% and 1%, respectively. The units are all offered in an hermetic TO-100 can and are available from stock. Prices, in hundreds, are $16, $24, $36, $45, and $60 for the J, K, L, S, and T versions, respectively.

Analog Devices Inc., P.O. Box 280, Norwood, Mass. 02062. Phone (617) 329-4700 [415]

Circuit controls automobile ignition

A monolithic circuit, the MC3333, forms the basis of an advanced automotive ignition system that utilizes a flux-averaging sensor instead of the conventional points and condenser. Flexible enough to be used in a variety of configurations, the circuit needs only one external active component—a Darlington driver transistor (MJ10012) to supply the current to the primary winding of a high-energy spark coil.

The MC3333 can operate with battery voltages from 4 to 24 v dc. Called a Vari-Dwell ignition circuit, it is supplied in a 14-pin plastic dual in-line package at a price of $2.25 each in hundreds. The device is also available in standard chip and flip-chip forms.

Motorola Semiconductor Products Inc., P. O. Box 20912, Phoenix, Ariz. 85036. Phone (602) 244-6900 [417]

TOPICS

Semiconductors

Motorola Semiconductor Products Inc., Phoenix, Ariz., has developed a series of uhf power transistors for use in the 100-to-500-megahertz range. The five units in the series range from the MRF321, which puts out 10 watts at a gain of 12 decibels, to the MRF327, which puts out 80 W at a gain of 7.3 dB. . . . **Texas Instruments Inc., Dallas, Texas,** is second-sourcing several products originated by National Semiconductor Corp. Among them are the LM193, LM293, LM393, and LM2903 dual differential comparators. TI is also second-sourcing National's LM117, LM217, and LM317 three-terminal regulators.

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AC Input Power: 98 Vac-132 Vac, 187 Vac-250 Vac. Frequency: 47-63 Hz single phase. 360-440 Hz (double rms Ripple spec.) *No derating.* Voltage selectable by a single link on the front panel.

Voltage Regulation: Line: 0.03% over full AC input range. Load: 0.03% for zero to full load.

Voltage Ripple: Typical 2m V rms, 20mV pk-pk (20Hz to 20 MHz). Max. 5mV rms, 50mV pk-pk (20Hz to 20MHz).

Temperature Coefficient: 0.01% max. per °C.

Stability: 0.05% max. for 24 hours after warm-up.

Transient Response Time: Output voltage returns to within 1% in less than 1.2 ms following a step-load change from either 50% to 100% or 100% to 50% of full load.

Overshoot: No overshoot at turn-on, turn-off or power failure.

Hold-Up Time: Full regulated voltage holds up for 40ms after removal of power at full load, and nominal input and output voltages (80ms for half load).

Overvoltage Protection: Built-in adjustable overvoltage protection standard on all models.

Efficiency: Up to 78%.

Remote Sensing: Voltage drops can be compensated for up to the max. specified terminal voltage.

Paralleling: May be directly paralleled without derating.

Soft-Start: In-rush current is limited by soft start circuit.

Model No.	Nominal Voltage	Output Voltage Range (Vdc)		Output Current				Price
		min.	max.	@40°C	@50°C	@60°C	@71°C	
SSD2-30	2	1.8	3.0	30.0	27.0	22.5	15.0	$295
SSD5-30	5	4.7	6.5	30.0	27.0	22.5	15.0	295
SSD9-20	9	6.5	9.5	20.0	18.0	15.0	10.0	295
SSD12-15	12	9.5	13.0	15.0	13.5	11.2	7.5	295
SSD15-12	15	13.0	17.0	12.0	10.8	9.0	6.0	295
SSD18-10.5	18	16.0	21.0	10.5	9.4	7.8	5.2	295
SSD24-8.5	24	20.0	26.0	8.5	7.6	6.3	4.2	295
SSD28-7	28	25.0	33.0	7.0	6.3	5.2	3.5	295
SSD36-5	36	32.0	43.0	5.0	4.5	3.7	2.5	295
SSD48-4	48	42.0	56.0	4.0	3.6	3.0	2.0	295

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With the success of their Athena 2000 home sewing machine, today we may look even better.

This revolutionary new machine by Singer can sew 25 different stitch patterns at the touch of a button. And it's entirely controlled by a single MOS circuit made by AMI.

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One company can cut keyboard costs. Even when their keyboards cost more.

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Or maybe customize integrated circuits to provide you more logic for less money.

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It all adds up to quality you can put your fingers on every time.

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Circle 154 on reader service card

Instruments

600-MHz counter sells for $595

Portable unit uses building-block approach for low cost, high flexibility

Small companies looking to carve a niche out of a market dominated by the industry's giants often turn to custom circuitry to provide some price or performance edge. But when engineers at Aero Marine Electronics Inc. of Delran, N. J., focused their sights on the high-frequency counter field, they also saw that custom chips can be very expensive for a small company and could cause the firm to lose flexibility in designing other counters.

Therefore the three-year-old firm's engineers did some comparison shopping of standard devices. After finding what they felt were "the best available off-the-shelf parts for the job," says executive vice president Neal Mumbert, "we applied them to achieve performance value, portability, small size and weight, and low price." The result is an 8-digit 600-megahertz frequency counter, the FC600A, that Aero Marine is about to begin selling for $595, including a telescoping antenna, regulated ac power converter, and attaché carrying case. Initial deliveries are set for September.

The unit's sensitivity is 10 millivolts root mean square from 6 to 100 hertz, 25 mV rms to 500 MHz, and 50 mV rms to 600 MHz. Weighing only 1.5 pounds, the portable counter is intended for service, maintenance, and calibration applications in aircraft, marine, two-way radio and television broadcast markets, as well as on production lines and in laboratories, says marketing director Jack Taylor.

The FC600A consists of three building blocks—counter, oscillator, and front-end—and a 0.4-inch light-emitting-diode display. The heart of the counter building block is the LS 7031, an off-the-shelf six-decade up counter with an eight-decade latch and multiplexer in a 40-pin dual in-line package from LSI Computer Systems Inc. of Melville, N. Y.

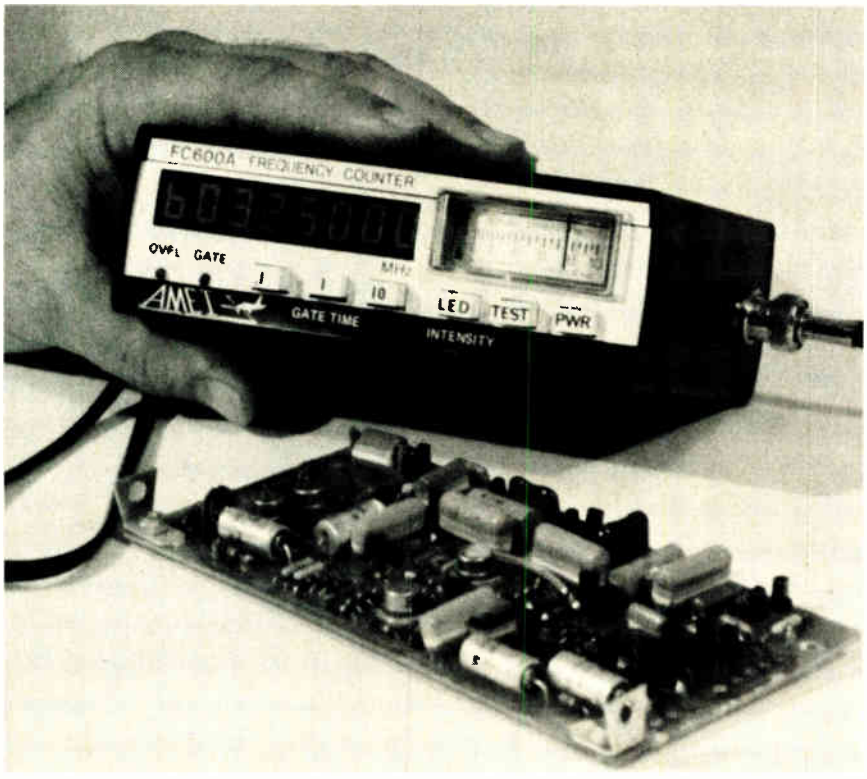
The counter's oscillator has an aging rate of 3 parts per million per year and is accurate to within 5 ppm over the full operating range of 0°C to 55°C after a 15-minute warm-up. An optional temperature-compensated crystal oscillator ($150) has an aging rate of 1 ppm/year and is accurate to within less than 0.1 ppm over specific ranges but 1 ppm over the full temperature range.

The counter consumes less than 4 watts, drawing 300 milliamperes from a 12-volt dc source. It also can be powered from line voltage with the ac converter and, for true portable operation for up to four hours continuous, from three 9-v transistor-radio-type alkaline batteries.

Some unique front-panel features of the FC600A are an analog field-strength meter for use in peaking and nulling transmitters, a "super-bright" button that gives a 100% increase in LED display intensity for use under high ambient light conditions, and a test button to check the counter's calibration.

In keeping with its approach of using "the best available off-the-shelf parts for the job," Aero Marine is packaging the FC600A in the 5.5-by-3.75-by-1.75-inch case that has been popularized in the digital multimeter line offered by Data Precision Corp. of Wakefield, Mass. But Mumbert hopes the similarities won't stop there. "What Data Precision did in the digital multimeter field," he says, "we intend to do in the counter market."

Aero Marine Electronics Inc., 1819 Underwood Blvd., Delran, N. J. 08075 [351]



100-MHz scope resolves time intervals to 0.002%

Capable of making time-interval measurements quickly and easily with a resolution of 0.002%, a 100-megahertz dual-channel oscilloscope also provides third-channel trigger viewing and automatic trace overlapping. The model 1743A uses an averaging technique to improve its

accuracy and resolution over previous delta-time scopes. It also allows measurement of events close to the trigger by permitting the measured interval to begin simultaneously with the trigger.

The scope contains a five-digit light-emitting-diode display with 300% overrange. For time intervals of 5 microseconds or longer, measurement resolution is 0.002%; shorter intervals are measured to 100 picoseconds. The new scope sells for $3,300.

Inquiries Manager, Hewlett-Packard Co., 1501 Page Mill Road, Palo Alto, California 94304 [353]

DPM is small in size, power consumption, and price

The model AN2575 panel meter is a 3½-digit instrument that combines small size and low power consumption with high accuracy and a one-piece price of only $69 ($49 each in hundreds). The meter takes up only 7.2 cubic inches of space behind the panel and weighs less than 5 ounces. Power consumption is a low 800 milliwatts from a single 5-volt supply, while an extra-cost option is available to reduce power consumption to 350 mw.

The meter has a maximum absolute error of 0.05% of reading plus 1 count, with a temperature coefficient of 50 ppm of reading/°C. To make

the most of its accuracy, the AN2575 has a bipolar differential input with a maximum bias current of 100 picoamperes and an input resistance in excess of 1,000 megohms. The meter is offered with full-scale ranges of 199.9 millivolts and 1.999 volts. Latched and buffered parallel binary-coded-decimal outputs and provision for three-wire ratiometric operation are offered as options. The meter is available from stock.

Analogic Corp., Audubon Road, Wakefield, Mass. 01880. Phone (617) 246-0300 [356]

Scope calibrator provides digital display of error

A three-in-one instrument for calibrating oscilloscopes, the model 6125B time and amplitude calibrator includes a 3½-digit readout for displaying deviations up to ±10%. The unit's three main functions are calibrating amplitude, sweep and delay time, and rise time.

The amplitude and sweep-and-delay time functions can be used in two modes: as a source of accurate

signals for the calibration of oscilloscopes (and other instruments) and as a source of variable signals of which the deviation is accurately known—for checking to see if the instrument under test meets its specifications. In the second mode, a vernier control on the 6125B is adjusted until the signal on the oscilloscope screen covers the proper number of divisions. The percentage deviation, if any, is then displayed on the meter.

As a rise-time calibrator, the instrument simply puts out a clean signal with a rise time of 1 nanosecond. It also puts out 200-megahertz and 500-MHz sine waves. It sells for $1,875 and has a delivery time of 60 days.

Ballantine Laboratories Inc., P. O. Box 97, Boonton, N. J. 07005. [354]

Unit displays four logic signals on one-channel scope

A portable hand-held instrument, the 45-B logic analyzer gives the user the ability to display four channels of digital logic waveforms simultaneously on a single-trace oscilloscope. The unit is intended to help both designers and field-service personnel observe the complex timing relationships that exist among digital signals. Capable of operating from the ac line or with a 9-volt battery, the 45-B sells for $149.95 including a battery and an ac adapter. It handles a wide range of logic families without adjustment.

Digital Broadcast Systems Inc., 4306 Governors Drive, Huntsville, Ala. 35805. Phone (205) 837-2183 [358]

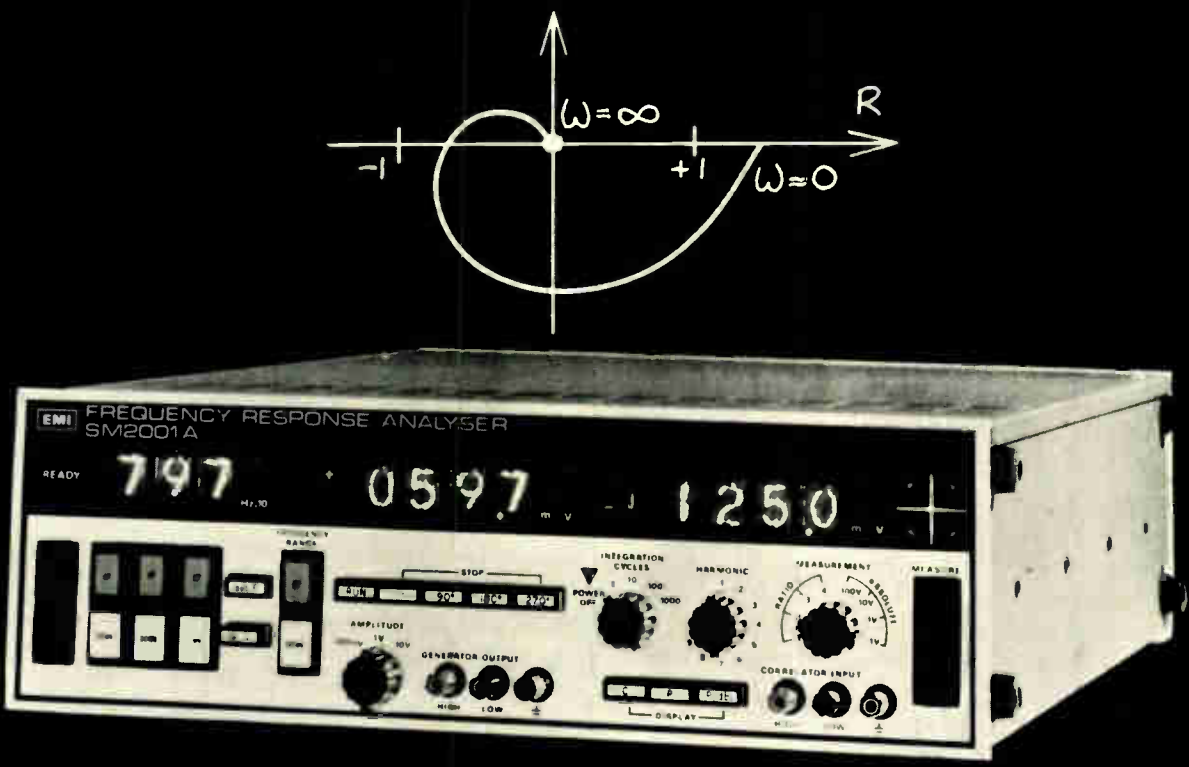
Compact 15-MHz scope sells for $289

Priced at only $289, a 15-megahertz oscilloscope weighs 3 pounds and measures 2.7 inches high by 6.4 in. wide by 7.5 in. deep. Called the model MS-15 Miniscope, the instrument includes such features as internal and external triggering, automatic and line synchronization, and a horizontal input. It has 12 vertical gain settings, from 10 millivolts per division to 50 volts per division. The

horizontal time-base settings range from 100 nanoseconds per division to 500 milliseconds per division. The unit can be powered by batteries or the ac line.

Non-Linear Systems Inc., P. O. Box N, Del Mar, Calif. 92014. Phone (714) 755-1134 [355]

A digital F.R.A. with an exciting new feature.



Simplicity.

EMI has taken the complexity out of digital F.R.A. operation. In fact, our SM2001A is so simple that, in effect, all the operating instructions are on the front panel, reducing test time from minutes to seconds.

But don't think that simplicity means a sacrifice in performance. The SM2001A has complete harmonic analysis capability, so it's a frequency response analyzer in the fullest sense. Innovative digital techniques ensure high stability, resolution and accuracy. And a range of custom-built accessories provides unique flexibility.

Accessories include facilities for frequency extension, two-channel operation, plotter and computer interfaces. There are also modulator/demodulator and reference synchronizer units.

Frequency range is 0.00001 Hz to 999 Hz (up to 999 kHz with frequency extension).

The price is easy, too. The SM2001A costs far less than competitive equipment.

Contact EMI for complete information.

EMI Technology Inc., Instrumentation Division, 55 Kenosia Avenue, Danbury, CT 06810 (203) 744-3500, TWX: 710-456-3068

EMI

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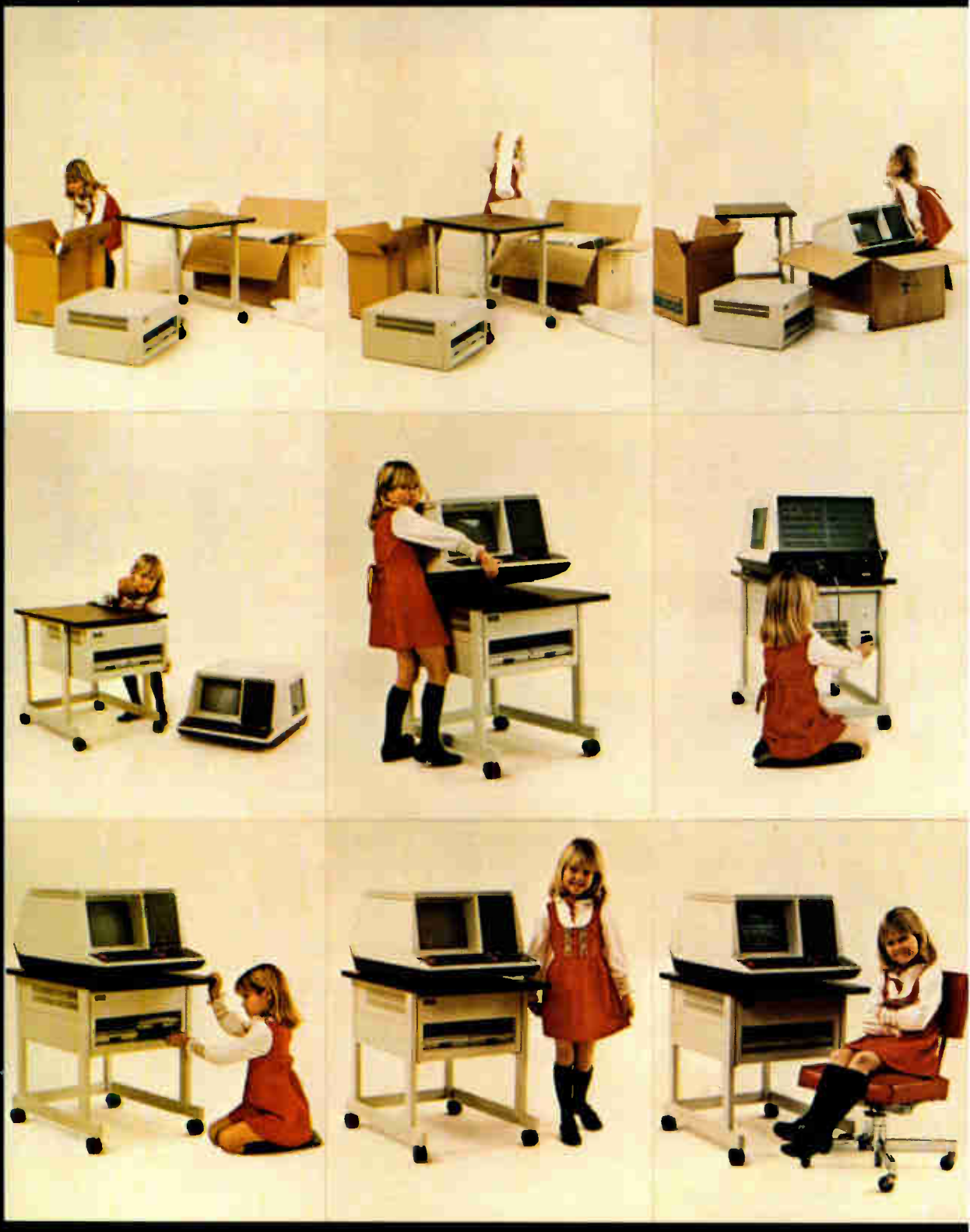

Digital introduces DECstation. A big computer system that's small enough for anyone.

Digital put an amazing LSI version of the PDP-8 inside a DECscope, added some ingenious interconnecting devices and created something new. The DECstation. A complete computer system big enough to do all kinds of work and small, simple and inexpensive enough to do it for almost anyone.

DECstation. A complete computer system in disguise. It looks like a terminal, but look again. The DECstation has a powerful general purpose computer, a video terminal, a dual diskette drive, and its own special operating system. What's more, you can hook up two different printers and a second dual diskette drive. Then put the whole thing in a mini-desk, and when you're done you'll have the smallest big computer you've ever seen.

The Video Data Processor. It's the big reason the DECstation's so small. The VT78 Video Data Processor is a computer wrapped in a terminal. Inside the familiar DECscope you'll find an LSI version of the PDP-8 with 16K words (32K characters) of MOS memory and built-in interfaces. Two serial asynchronous ports feature speeds from 50 baud to 19.2 kilobaud. A disk port interfaces with up to 4 diskette drives. A parallel I/O port for printers and custom interfacing provides data transfer rates up to 180 kilobits/sec. All standard.

You can go from carton to computer in less than an hour. If you can push a button, you can run a DECstation. Because one button is all it takes to start things up. The bootstrap and self-test routines are built in.

Put it together, plug it in, and immediately you can begin to run anything from the PDP-8 software library. Which means you start with one of the most comprehensive sets of software tools available in a small system. Including two proven operating systems: OS/78 for stand alone applications and RTS/8 for real-time. OS/78, an extension of OS/8, supports a number of languages, including FORTRAN IV and BASIC. So all you have to do is load the operating system and start programming your application.

Whatever that application, if you're looking for a sophisticated little system, at the right price, and a remarkable OEM tool, consider DECstation. $7995 each. $5436 OEM quantity 50.

For our free brochure, write Digital Equipment Corporation, Parker Street, Maynard, MA 01754. European headquarters: 81 route de l'Aire, 1211 Geneva 26. Tel: 42 79 50. In Canada: Digital Equipment of Canada, Ltd.

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Subassemblies

36 dc-to-dc converters bow

Single- and dual-output units keep high efficiency even when lightly loaded

A 36-model line of high-efficiency dc-to-dc converters is the first foray into the converter field for Computer Products Inc., a leading supplier of encapsulated switching power supplies. It sells the supplies under its own name and to 17 other companies for resale.

The new converters offer 65% efficiency at full rated load. But more importantly, the efficiency drops only slightly under light loading. The single-output models, for example, retain an efficiency of 60% when the loading drops to 20%, an important point, "because most dc-to-dc converters don't usually run at full rated load," points out project engineer Thomas Pantelakis. He says that "we go so far as to tell users in our data sheet what the efficiency compared to full load will be."

The PM900 series includes 5-watt and 6-W models, single- and dual-outputs, and dc input voltages of 5 volts and 12 v. The single-output models are offered with outputs of 5, 9, 12, and 15 v at currents from 400 milliamperes to 1 ampere. The dual-output versions put out either ±12 v or ±15 v at currents from ±190 mA to ±230 mA. Altogether, there are eight single-output converters in the line and four with dual outputs. But there are 36 distinct model numbers because each converter is offered in three popular pin configurations. The single-output models are priced at $67 in small quantities; the dual-output units sell for $79.

All models in the family have line regulation to within 0.02%. No-load to full-load regulation ranges from 0.02% to 0.04%, depending on the model. Other strong features of the PM900 series are low ripple and noise, radiation shielding on all six sides, and an absence of mechanical squeal. The latter is a problem in some converters when wires and cores begin to vibrate in the audio range during switching; the inverters in the PM900 series oscillate at ultrasonic frequencies, thus avoiding the problem.

Maximum peak-to-peak ripple is either 35 or 50 millivolts over a 20-megahertz bandwidth, depending upon model. Maximum noise, over the same bandwidth, is 1 mv for all models. The units offer output-current limiting and short-circuit protection for up to eight hours and are all housed in cases measuring 2 by 2 by 0.380 inches. Delivery is from stock, or consult the factory for large orders.

Computer Products Inc., 1400 N. W. 70th St., P. O. Box 23849, Fort Lauderdale, Fla. 33307. Phone (315) 974-5500 [381]

Analog-to-digital unit converts 14 bits in 12 μs

A modular analog-to-digital converter, the ADC1131, uses the successive-approximation technique to combine a resolution of 14 bits with a maximum conversion time of 12 microseconds. Four analog input ranges can be programmed by the user: 0 to 20 volts, 0 to 10 v, ±10 v, and ±5 v. Two versions of the converter are offered: the 1131J has a maximum differential linearity error of 1 least significant bit and a small-quantity price of $279; the 1131K reduces that error to ½ LSB, while raising the corresponding price to $369. Both units are guaranteed not to miss any codes over the temperature range from 0°C to 70°C, and both have a gain temperature coefficient of no more than 10 ppm/°C.

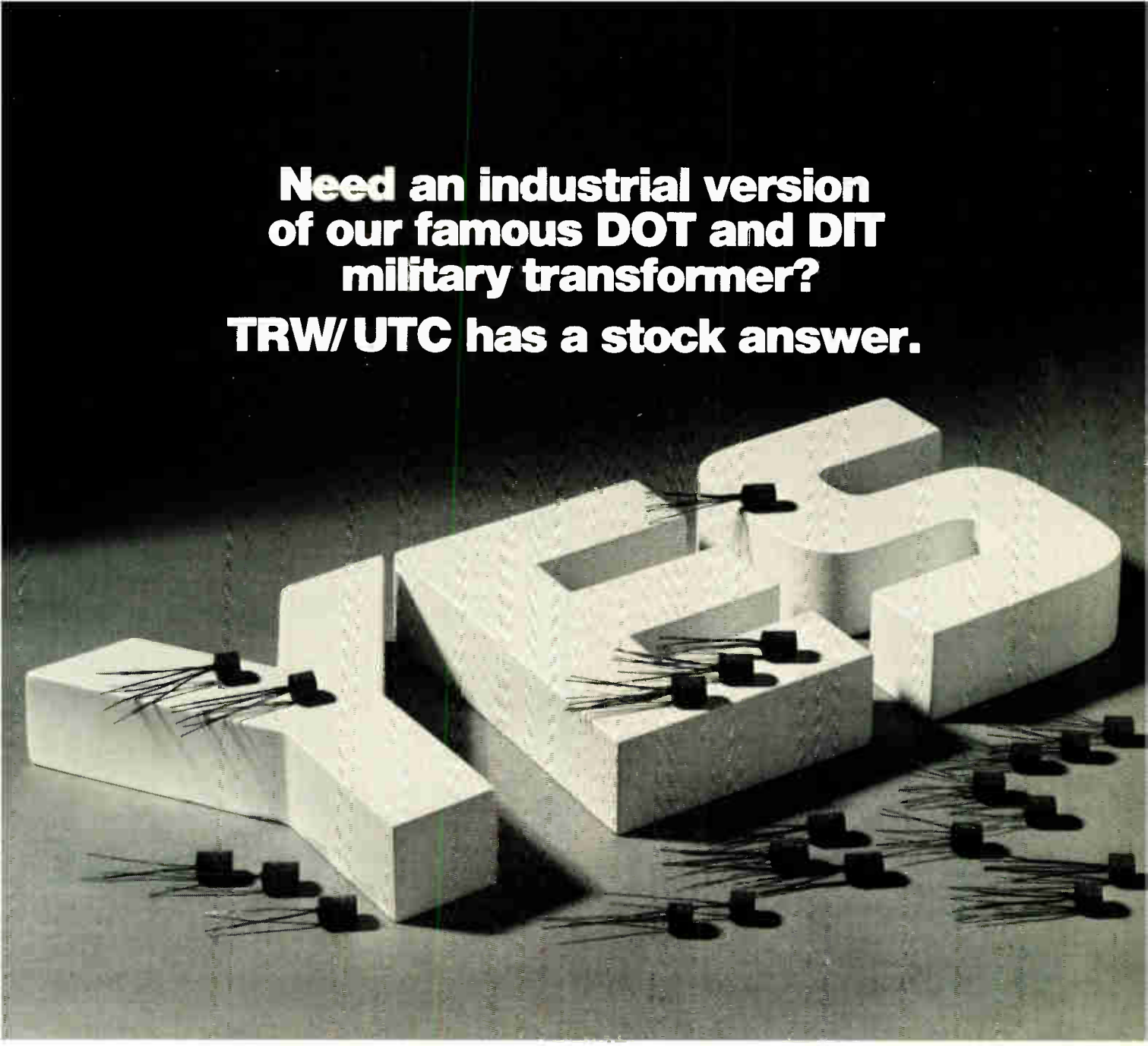
A companion converter, the ADC1130, is similar to the preceding units except that its maximum conversion time is 25 μs instead of 12 μs. Maximum differential linearity error for this unit is 1 LSB, and its small-quantity price is $239. The converters are all available from stock.

Analog Devices Inc., P. O. Box 280, Route 1 Industrial Park, Norwood, Mass. 02062. Phone (617) 329-4700 [385]

16-channel data-acquisition system resolves 12 bits

The ZMP 1000 is a self-contained 16-channel data-acquisition system with a resolution of 12 bits. The unit, which is furnished in an insulated steel case measuring 3.0 by 4.6 by 0.375 inches, is capable of multiplexing 16 channels of real-time

Need an industrial version of our famous DOT and DIT military transformer? TRW/UTC has a stock answer.



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The I-DOT family has a frequency response of ± 3 db, 300 hertz to 20K hertz. The I-DIT has a ± 3 db, 400 hertz to 100K hertz, and is available both with flexible leads and with uninsulated dumet wire leads for printed circuit board mounting.

Check your authorized TRW/UTC local distributor for immediate off-the-shelf delivery or contact TRW/UTC Transformers, an Operation of TRW Electronic Components, 150 Varick Street, New York, N.Y. 10013. Area code: 212-255-3500.

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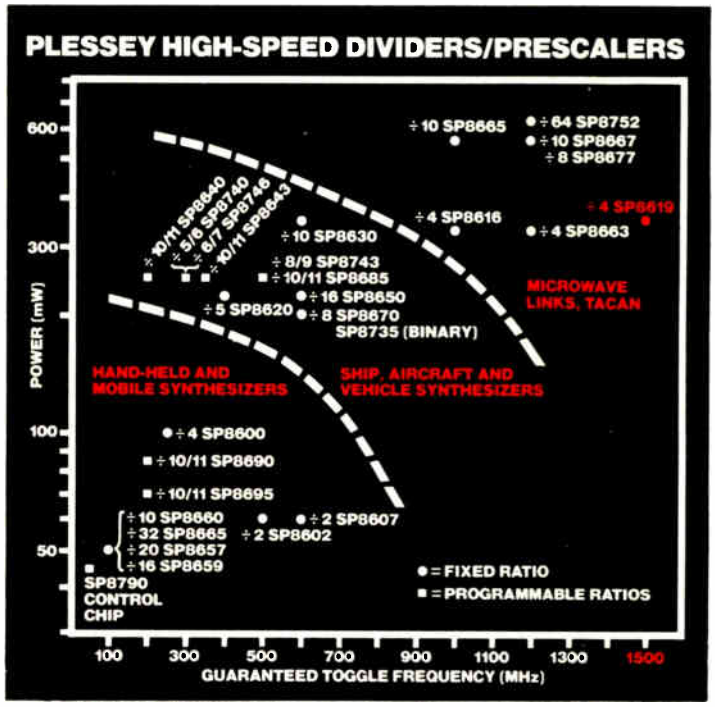

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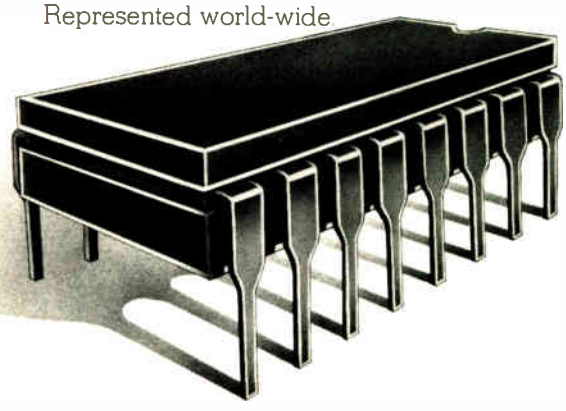


physical data from prime sensors. Monotonicity is guaranteed over the system's full operating temperature range of 0°C to 70°C.

With a maximum analog-to-digital conversion time of 12 microseconds, the ZMP 1000 is capable of throughput rates as high as 50,000 channels per second. Maximum differential linearity error is 1 least significant bit, and there are no missing codes. The unit's 16 channels are either single-ended or pseudo-differential; for true-differential operation, it provides only eight channels. Its price, in hundreds, is $300 each. Delivery is from stock to 30 days.

Zeltex Inc., 940 Detroit Ave., Concord, Calif. 94518. Phone (415) 686-6660 [384]

8-bit hybrid a-d converters have 2.5-μs conversion time

MN5140 series hybrid analog-to-digital converters are high-speed 8-bit units with a maximum conversion time of 2.5 microseconds. The devices operate from supplies of ±12 volts and +5 v. An otherwise-similar series, the MN5130, is for operation from ±15 v and +5 v. Both series have models for operation from 0°C to 70°C, from −55°C to 125°C, and over the latter range with processing to the military standard MIL-STD-883, Class B.

Both series are guaranteed to be linear within half a least significant bit over the full temperature range. And both are accurate to within 1 LSB at 25°C, with a maximum temperature-induced error of 2 LSB.

Housed in 18-pin hermetic dual in-line packages, the converters are laser-trimmed for adjustment-free operation. They typically dissipate 680 milliwatts. In small quantities, the commercial units sell for $59 each, and the military versions are priced at $118. Contact the company for pricing on the high-reliability devices.

Micro Networks Corp., 324 Clark St., Worcester, Mass. 01606. Phone (617) 852-5400 [386]

Programmable regulator is accurate to within 0.1%

Two precision programmable voltage regulators offer control of output voltages to within 0.1% without the use of any external components. Designated the model LH0075 positive regulator and the LH0076 negative regulator, the circuits use a constant-current source in combination with a string of laser-trimmed thin-film resistors to provide eight standard voltages: 3, 5, 6, 8, 9, 12, 15, and 18 volts dc. Other voltages up to 27 v can be obtained by adding one external programming resistor. Similarly, current limiting, between 0 and 200 milliamperes, can be achieved by adding two more external resistors. Both units are designed for easy current boosting.

The devices provide line regulation to within 0.008% per volt and load regulation to within 0.075%. Devices rated for operation over the commercial temperature range from −25°C to 85°C sell for $12.95 each in hundreds, while military-grade units (−55°C to 125°C) go for $18.75 each in the same quantity. Product availability is from stock to four weeks.

National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, Calif. 95051. Phone (408) 737-5000 [389]

Line of uninterruptible power supplies is expanded

Semiconductor Circuits Inc. has expanded its line of uninterruptible power supplies from 9 to 36 models. The expanded family now offers a choice of 12- or 24-volt back-up battery and two types of triple output: +5 v dc with either ±12 v or ±15 v. Various models offer bipolar outputs rated at ±100, ±200, or ±300 milliamperes and 5-v outputs capable of delivering 1, 2, or 3 amperes. A key feature of the designs is their reliability: mean times between failures are in excess of 50,000 hours at 25°C. Prices range from $155 to $225 for single units down to $148 to $205 each in quantities of 10 or more. Production quantities yield even larger savings. Deliveries are from stock to two weeks.

Semiconductor Circuits Inc., 306 River St., Haverhill, Mass. 01830. Phone (617) 373-9104 [387]

Modules reduce distortion errors in CRT displays

C104/C104B correction modules are solid-state function blocks designed to minimize geometric (pin-cushion) and focus distortion in flat-face cathode-ray tubes that use magnetic deflection. These units produce wideband corrected output functions for horizontal and vertical deflections plus dynamic focus.

Both modules feature a bandwidth of 10 megahertz, a slew rate of 400 volts per microsecond, a settling time (to within 0.1%) of 400 nanoseconds, and a typical uncertainty of 0.2% of full scale. The C104 is a voltage-output device, while the C104B has a current output. The output impedance of the C104 is 50 ohms. Pricing on the C104 is $395 each in quantities of one to nine pieces. For the C104B, the corresponding price is $275. Delivery time is four weeks.

Intronics Inc., 57 Chapel St., Newton, Mass. 02158. Phone (617) 332-7350 [388]

Industrial

Infrared detector cools itself

Thermoelectric cooling gives specific detectivity of 2.5 X 10^{11} cm-$Hz^{1/2}$/watt

Manufacturers of industrial smoke-detection, intrusion-alarm and optical gauging systems may want to take a good look at the new model TO-5-TE lead-sulfide infrared detectors being offered by Sanders Associates Inc., Nashua, N. H. The thermoelectrically cooled detectors, housed in hermetically sealed TO-5 cans, provide the high degree of sensitivity and long-term stability required for these and other applications, including moisture detectors and gas analyzers.

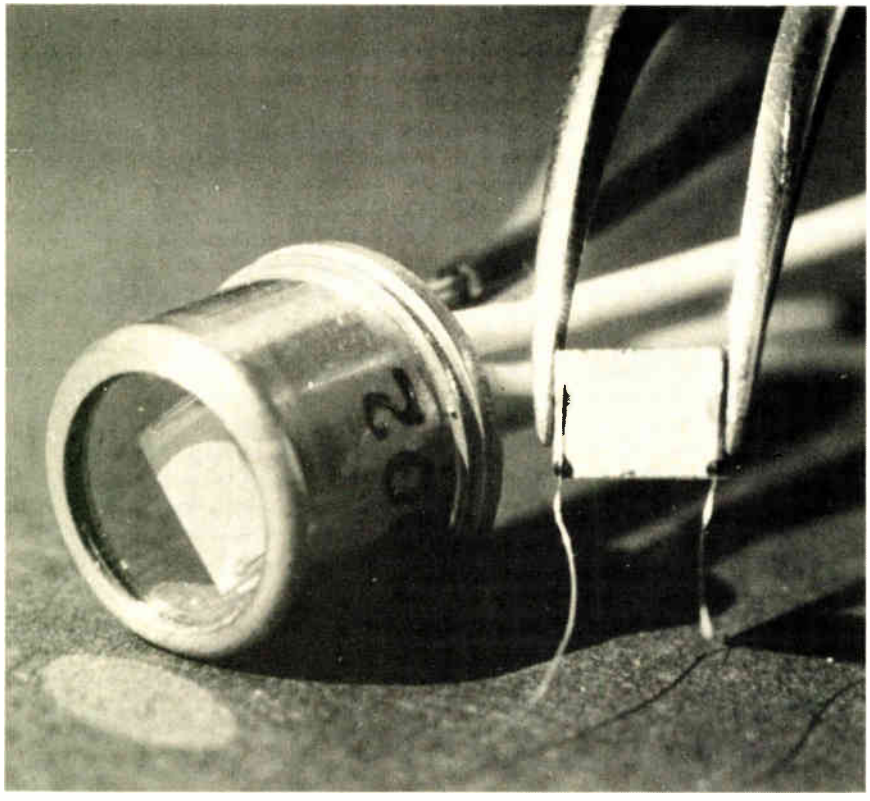
That is the opinion of Paul Murphy, manager of the detector group in Sanders' Defensive Systems division. He says that lead sulfide operates in the near infrared, with a spectral response from the visible out to about 3.5 micrometers. With their built-in thermoelectric cooling, these detectors operate at 2.3 micrometers—near the peak of the band where a variety of illuminators, including tungsten lamps, are readily available.

The two principal specifications for the detectors are responsivity and specific detectivity. The responsivity of the TO-5-TE is 10^6 volts per watt. The specific detectivity, D*, which is a figure of merit related to the device's signal-to-noise ratio, ranges from 2.5 to 5.0 × 10^{11} cm-$Hz^{1/2}$/watt at a chopping frequency of 400 Hz and at the detector's peak wavelength. That figure for D*, Murphy says, is better than those of the few other detector materials, such as indium arsenide, that operate in the 2- to 3-micrometer region.

It is the thermoelectric cooling to approximately −20°C that provides the good detectivity. Murphy says it is done by using a heat-transfer bismuth-telluride material below the detector to draw heat down through the pedestal to the flange of the TO-5 package for dissipation. The cooling function requires from 1 to 2 watts of power.

The detector elements, in a lens-capped package, are available in three standard sizes: 1-by-1, 2-by-2 and 3-by-3 millimeters. The single quantity price of the largest unit is $200, or $100 in quantities of 250. Delivery time is two to three weeks.

Sanders Associates Inc., 95 Canal St., Nashua, N. H. 03060. Phone the marketing manager for detector products at (603) 885-3010 [371]



Linear-motion pots have 60- and 100-mm strokes

A series of industrial linear-motion slide potentiometers with long-life conductive-plastic elements is offered with 60-millimeter and 100-mm stroke lengths and resistances of 1,000, 5,000, and 10,000 ohms ±20%. The MM-4 and MM-6 series devices are linear to within 1%. With their minimum life of 250,000 cycles, they are expected to be used in lighting controls, analog set-point controllers, speed controls, and so on. The shorter units sell for $10 each in hundreds, and the longer ones go for $12 apiece in the same quantity.

Waters Manufacturing Inc., Longfellow Center, Wayland, Mass. 01778. Phone (617) 358-2777 [374]

Microprocessor-based system provides tight positioning

A microprocessor-based digital servo-control system is available for use in applications requiring a faster and more accurate response than stepper motors provide. The model DS 2200 is programmable for position, velocity, and acceleration. In addition to running a complete program, the system can perform critical in-progress functions without reprogramming. Easily reprogrammed, it has applications wherever acceleration and velocity must be controlled so as not to excite the mechanical

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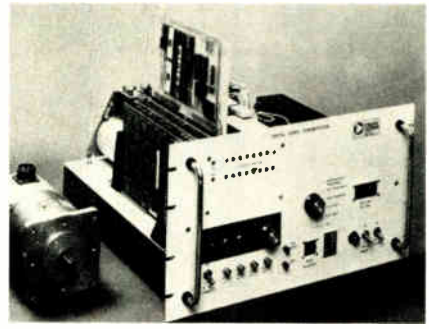


resonances of the system that is being regulated.

The unit takes in data as parallel 8-bit bytes. Position data is given as three bytes, while velocity and acceleration each require one byte. Data output is a serial pulse train with a maximum frequency of 10 kilohertz. Positioning accuracy is to within 1 bit.

Torque Systems Inc., P. O. Box 588, Waltham, Mass. 02154. Phone (617) 891-0230 [373]

Shaft encoder withstands heavy mechanical loading

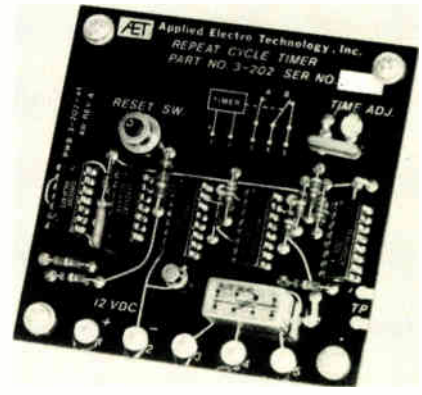
Designed for physically demanding applications, the model 70B shaft-angle encoder employs an internal flexible shaft coupling to protect its delicate encoder elements from heavy axial and radial shaft loading. The unit, which provides a fixed number of pulses for every shaft rotation, is available with a variety of options: bidirectional output, reference pulse, dual-channel output, and others. Output voltage is either 5 or 12 volts at a current rating of 20 millliamperes.

Measuring 3 by 3 by 6 inches, the 70B meets NEMA 12 (dust-tight), NEMA 4 (water-tight), and NEMA 3 (weatherproof) requirements. It sells for $180 and has a delivery time of two weeks.

Kessler-Ellis Products Co., Atlantic Highlands, N. J. 07716. Phone (201) 291-0500 [375]

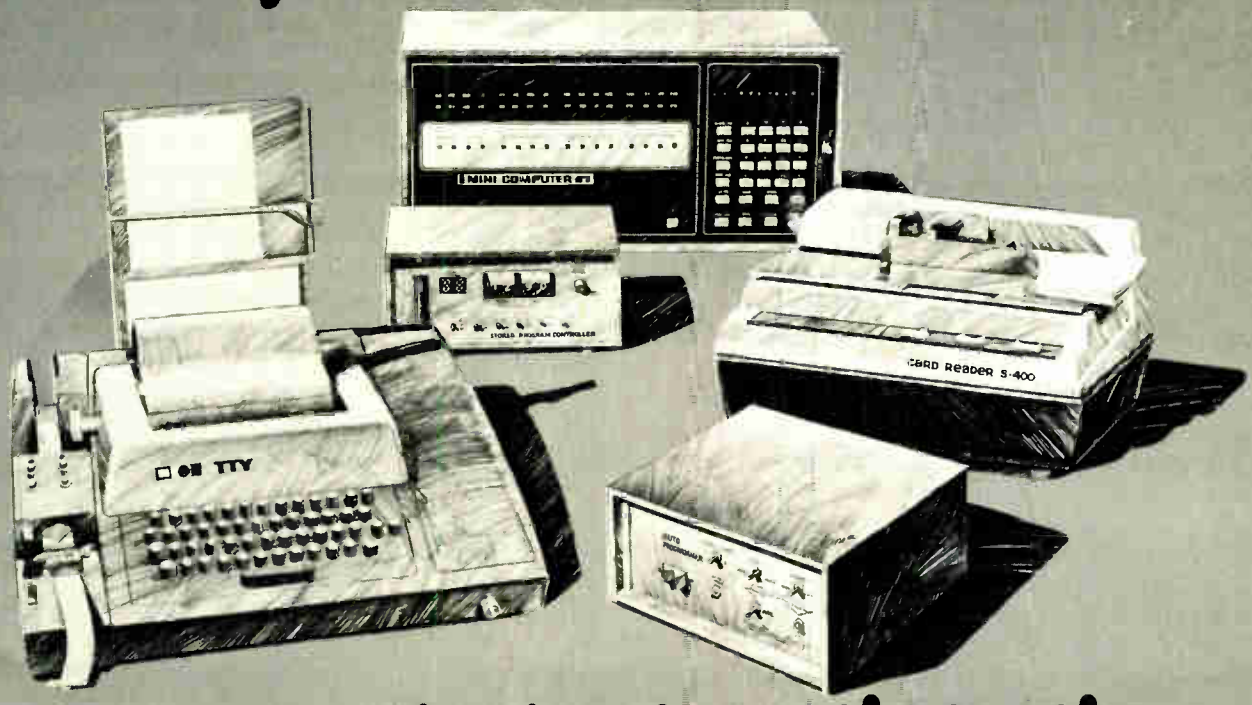
Timer board provides high accuracy for long periods

A repeat cycle timer for applications requiring the accurate, continuous repeating of long cycle times is available as a conformal-coated circuit board. The model 3-202 uses a crystal-controlled oscillator to provide cycle times that are accurate to within 0.005% for periods from a few hours to several months. Its output is a form C (single-pole double-throw) relay that can handle 2 amperes at 28 volts dc. The relay switches periodically at a factory-set rate specified by the customer. A reset button is provided to ensure that the first cycle is as accurate as all that follow it.



Operating-temperature range for the 3-202 is −30°C to 65°C. The maximum temperature-induced error is 0.025%. In its standard configuration, the circuit requires an input supply voltage of 12 v dc ±15%. Priced at $82.97 for one to nine pieces, the timer has a delivery time

If you have one of these...



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Applied Electro Technology Inc., 2220 S. Anne St., Santa Ana, Calif. 92704. Phone (714) 556-6570 [376]

Unit converts and displays synchro and resolver data

The SR300 shaft-angle encoder-indicator is a panel-mounting instrument that converts analog synchro or resolver data into a four-digit display and an equivalent binary-coded-decimal output. The unit may be specified to read directly in degrees of shaft rotation (0° to 359.90° or ±179.90°), or it can be scaled to read in any units that can be linearly related to a shaft angle. Configured like a digital panel meter, the SR300 measures 2.156 inches high by 4.5 in. wide by 7.5 in. deep. It is powered by the ac line and may be specified to accept 11.8-, 26-, or 90-volt synchro or resolver data at either 60 hertz or 400 Hz. In small quantities, the encoder-indicator sells for $585; a three-digit version is priced at $480. Delivery time is six weeks.
ILC Data Device Corp., Airport International Plaza, Bohemia, N. Y. 11716. Phone Don Lavaglio at (516) 567-5600 [377]

Line-voltage analyzer stores worst-case readings

A new type of integrating ac voltage-to-frequency converter, for which a patent is pending, permits high-speed ac measurements so that a compact instrument can monitor the line voltage as often as twice each cycle. Each measurement is compared with values stored in two memories—the highest and lowest readings obtained so far. A switch allows the user to read the present line voltage or to look at the two stored values. A second switch offers a choice of three time bases: one-half, one, or two cycles. The LVA-110 sells for $545.
Power-Science Inc., 8076 Engineer Road, San Diego, Calif. 92111. Phone (714) 292-4422 [378]

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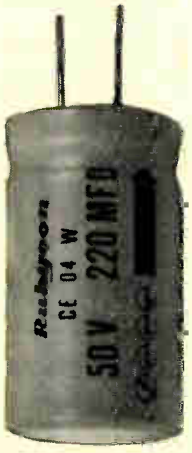

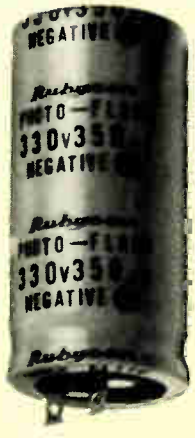

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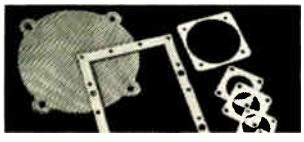

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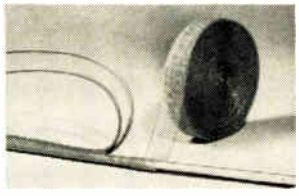

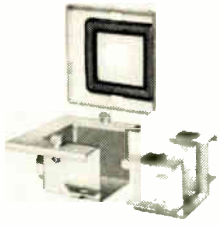


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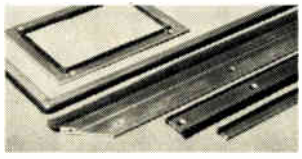
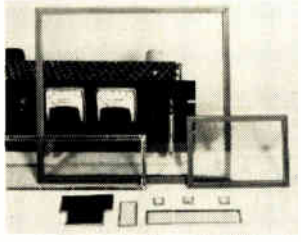
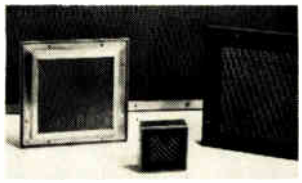
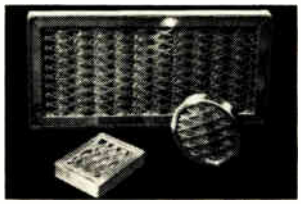
- Bulk Frame-Strip Gasketing
- Shielded Windows... ready to install...custom-fabricated
- Shielded Ventilating Panels
- Shielded Air Filters

CONDUCTIVE-ELASTOMER EMI/RFI XECON® GASKETS AND COMPOUNDS*

- Composite EMI/Pressure-Seal Gasketing...7 durometer ratings...sheets, strips, custom die-cut gaskets, molded gaskets
- Armored Xecon™ High-Tensile-Strength Gasketing
- Vulcanized Xecon™ Pressure-Seal Gaskets
- O-Ring Gaskets for Waveguides
- Standard Connector Gaskets
- Conductive Adhesive
- Conductive Compounds...for EMI/RFI shield coating, caulking, cementing

*Xecon gasketing compounds are homogenous conductive elastomers consisting of high-grade silicone in which are suspended microscopic silver-coated glass particles that provide the conductive path through the gasket.



METEX
Metex Corporation
970 New Durham Road, Edison, New Jersey 08817 • (201) 287-0800 • TWX 710-998-0578

CAL-METEX
Cal-Metex Corp. • A Unit of Metex Corporation
20437 South Western Avenue, Torrance, California 90501 • (213) 320-8910

Components

New process hikes cell capacity

Plate improvements allow 5% to 35% capacity increase in rechargeable batteries

In the battery business, the name of the game is increase energy capacity without increasing size. General Electric Co. has done just that with a line of high-capacity, rechargeable nickel-cadmium cells in the following standard ANSI sizes: ½AA, AA, ½subC, A_F, subC, ½D, and D. Typical of the performance of the new line is that of the D cell: at a C rate of discharge it has an energy capacity of 4 ampere-hours, compared with 3.5 A-h for a standard nickel-cadmium D cell.

A major innovation in plate technology, allowing better use of the active material, gives the cells their high capacity, according to GE engineers. The process combines a non-screen stipple substrate with a patented plaque material that has a high energy density. In addition, an advanced winding technique allows more plate to be wound.

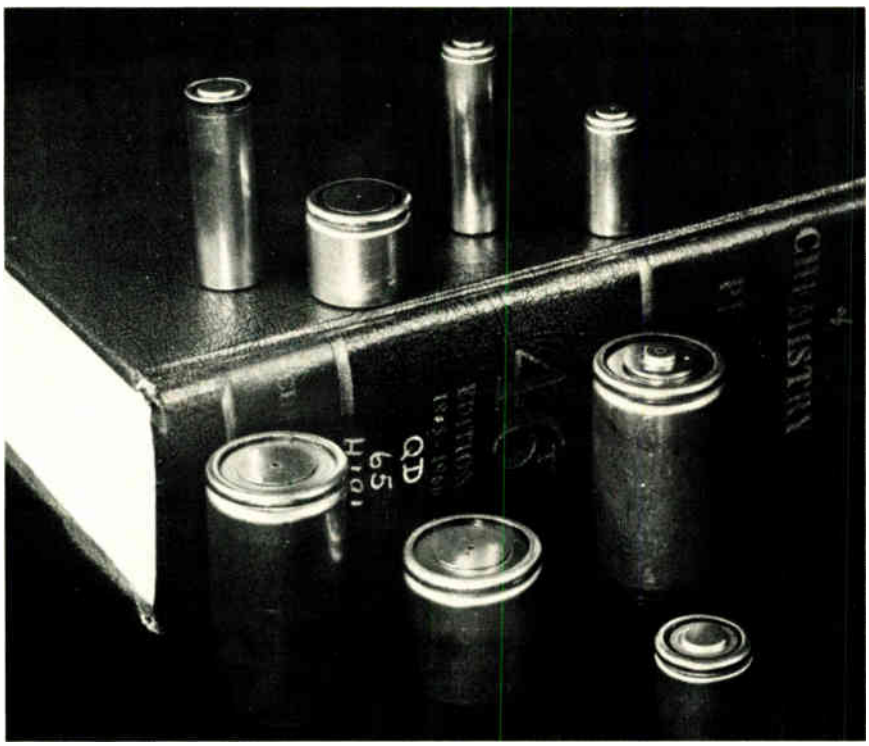
Aside from capacity, the new batteries are essentially identical to standard units, except for a slightly higher internal impedance. They are equipped with four-piece resealable safety vents, can be operated in any position, and can be stored for extended periods. Cells can be charged up to 1,000 times and can sustain continuous overcharging for long periods with no damage.

The high-capacity batteries are expected to find application in such diverse areas as radio transceivers, portable instruments, power tools, and calculators.

General Electric Co., Battery Department, P. O. Box 992, Gainsville, Fla. 32602. Phone (904) 462-4742 [341]

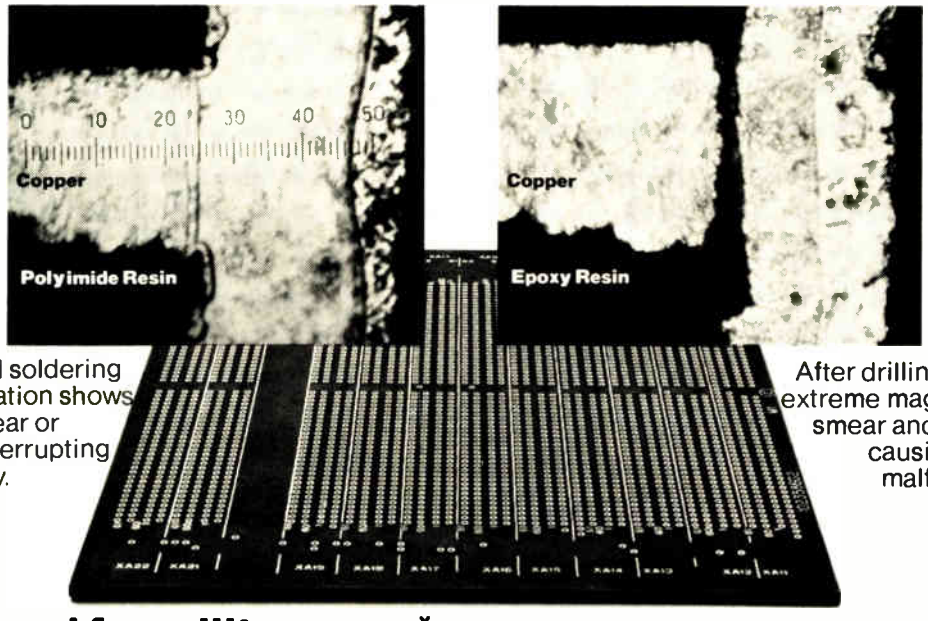
Self-regulating transformers are stable to within 1%

At least 50% smaller than equivalently rated ferroresonant regulators, a line of miniature regulating transformers provides output regulation



POLYIMIDE VS. EPOXY

Kerimid®601 | **Epoxy**



After drilling and soldering extreme magnification shows no resin smear or delamination interrupting circuitry.

After drilling and soldering extreme magnification shows smear and delamination causing circuit malfunction.

Now approved for military use.*

Kerimid 601 can significantly improve production yields by dramatically reducing smear and delamination. Which, when you consider the defective rate of epoxy boards, more than pays for the higher cost of Kerimid 601. Not to mention the gain it offers to your reputation for reliability in meeting promised delivery dates and in ultimate in-use functioning. In fact, one customer of ours hasn't rejected one circuit board due to smear or delamination in three years.

Kerimid 601 makes all this possible because it brings to circuit packaging the twin advantages of high heat resistance (4-500°F) and epoxy processability (355°F/200Psi). Additionally, void-free laminates offer improved characteristics over epoxies in z-dimensional stability and moisture resistance.

We think the combination of production and performance advantages offered by Kerimid 601 makes it well worth your investigation.

For more information, direct inquiries to: Rhodia Inc. Specialty Plastics Department, P.O. Box 125, Monmouth Junction, New Jersey 08852 (201) 846-7700.
Rhone-Poulenc, 22 Av. Montaigne, Paris-8e, France 256-4000.

KERIMID® 601

Rhodia
A SUBSIDIARY OF RHÔNE-POULENC

* MIL P-13949/10 Amendment 2; MIL P-55617 revision B; MIL G-55636 revision B.

to within 1%. The Mini-Reg devices are offered for use at 60 hertz and 400 Hz, for 115- and 230-volt ac lines. The regulators are relatively insensitive to frequency shifts and are unaffected by rectified loads. A MIL-T-27 version in a hermetic can measuring 2.375 by 2.75 by 3.875 inches weighs less than 2 pounds and is operable from −55°C to 125°C. It provides a regulated output of 115 v ac at 60 Hz from a line varying between 105 and 125 v ac. Power rating is 250 watts. This unit sells for $39 in lots of 500 pieces.

Power-Controls Division, KEM Co., 142 Peconic Ave., Medford, N. Y. 11763. Phone Howard Kanner at (516) 654-2084 [343]

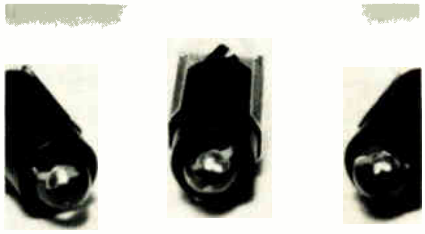
10-position code switch needs only 0.18 square inch of front-panel area

Pico series 10-position subminiature code switches occupy less than 0.018 square inch of panel space per decade and incorporate a bidirectional push-button mechanism to provide ascending and descending numerical functions. The switches are available with four-line binary-coded decimal or complementary-BCD output codes. The Pico-131-AK, a typical BCD unit, sells for $4.25 each in hundreds.

Alco Electronic Products Inc., 1551 Osgood St., North Andover, Mass. 01845. Phone Tom Clark at (617) 685-4371 [344]

Light-emitting-diode lamp replaces incandescent bulbs in push-button telephones

Designed to replace the miniature incandescent bulbs used in illuminated telephone push-buttons, the 5SBS lamp is a light-emitting diode mounted in a short #5 base. The lamp is available in three colors—red, amber, and green. At a forward current of 20 milliamperes, the LEDs have typical outputs of 50 millicande-



Circle 173 on reader service card →

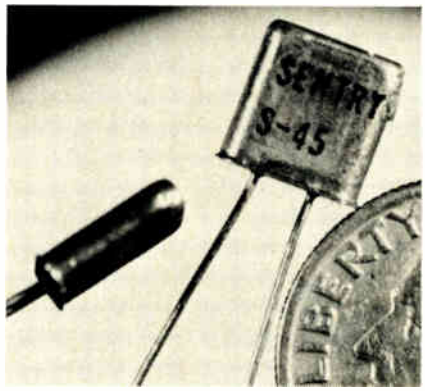
New products

las (red), 35 mcd (amber), and 24 mcd (green). The lamps are available with built-in resistors for operation with voltages ranging from 5 to 48 v dc. For ac operation, rectifiers can also be built in. In large quantities, the 5SBS sells for as little as 80 cents each.

Data Display Products, 303 N. Oak St., Inglewood, Calif. 90301. Phone (213) 677-6166 [345]

Quartz crystal occupies only 0.0077 cubic inch

Claimed to be the world's smallest quartz crystal, the S-45 measures a mere 0.078 by 0.275 by 0.285 inch. Gold-plated and mounted in a hermetic metal holder, it meets the requirements of MIL-C-3098. Intended for use in hand-held pagers,

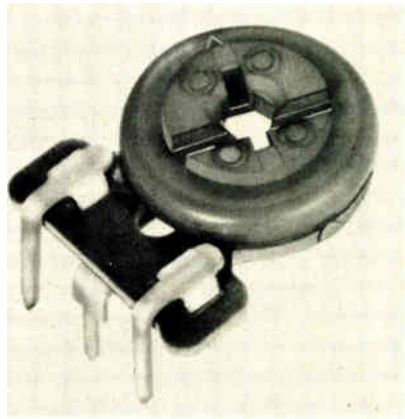


miniature citizens' band transceivers, and similar compact communications gear, the crystal is available in fundamental frequencies from 6 to 25 megahertz and in overtone frequencies from 18 to 125 MHz.

Sentry Manufacturing Co., Crystal Park, Chickasha, Okla. 73018. Phone (405) 224-6780 [346]

Carbon-composition trimmer saves both space and money

Series 278 carbon-composition trimming potentiometers are intended for commercial applications requiring a small, inexpensive device. The miniature 17/32-inch-diameter adjustment knob takes up little space and allows vertical and horizontal-mounting configurations. Resistances from 100 ohms to 5 megohms

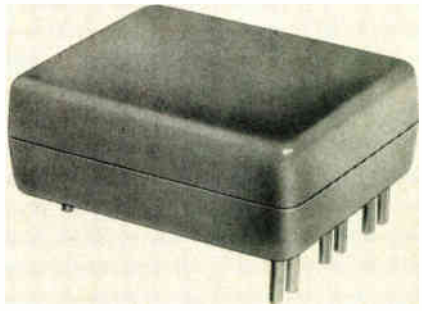


are offered with a standard tolerance of ±30%. Power rating is 0.25 watt at 55°C derated to no load at 100°C. In production quantities, the pot sells for less than 12 cents apiece.

CTS of Elkhart Division, 1142 W. Beardsley Ave., Elkhart, Ind. 46514. Phone Ray McCuddy at (219) 295-3575 [347]

Low-profile relay stands 0.415 inch above pc board

Designed for applications in which height is a problem, the model 240 miniature low-profile relay is a dc device with an installed height of only 0.415 inch. Available in both single-pole double-throw and double-pole double-throw versions, the unit can be driven from transistor-transistor-logic circuits with a driver buffer. Sensitive and standard coils are available, as are coil voltages from 5 to 24 v dc. Typical operate



VACTEC Photodetectors

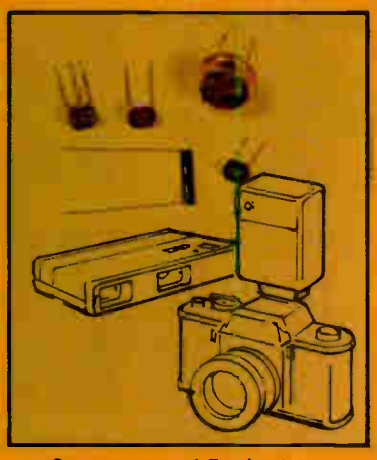
The Industry's Broadest Line Provides More Semiconductor Detectors for More Design Applications

Vactec serves manufacturers of a wide range of modern electronic products. Pictured are a few examples. All these devices are both made and sold by Vactec, including complete lines of LDR's (photoconductive cells, CdS and CdSe); silicon solar cells, as well as silicon high speed and blue enhanced cells; NPN phototransistors and darlingtons; opto-couplers (LED/LDR, lamp/LDR and neon/LDR); selenium photovoltaic cells; silicon photodiodes, blue enhanced and PIN; and custom C-MOS and bi-polar IC's. Write for technical bulletins on the types that suit your requirements. Or send your application, and Vactec will recommend the right cell for the job.

Vactec, Inc.
2423 Northline Industrial Blvd.
Maryland Heights, Mo. 63043
(314) 872-8300

Electronic Organs

LED or lamp/LDR Vactrols for audio, and CdS cells for swell pedal controls.



Cameras and Projectors

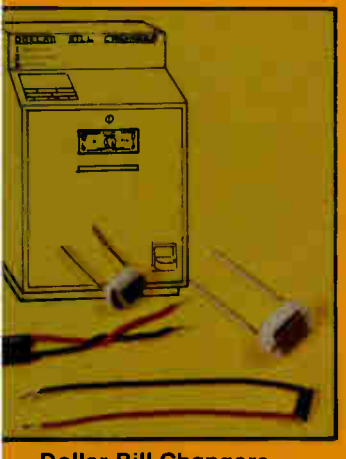
CdS or blue enhanced silicon photodiodes for automatic shutter timing, aperture servo systems for automatic projector focus and slave flash controls.

Triac Motor Controls

A special Vactrol gates a triac for forward and reverse motor operation as in hospital beds.

LED Watches

Photoconductive or phototransistor chip controls LED brightness.



Dollar Bill Changers

Silicon photovoltaic cells analyze optical characteristics.

Machine Tool Controls

High-speed photovoltaic cells or transistor arrays help computer control repetitive operations, non-contact sensing, and counting and weighing.

Telephone Equipment

Neon/LDR Vactrols sense ringing. Direct a-c coupling, slow LDR response isolates electronics from noise.

Scientific Instruments

Blue enhanced silicon or selenium photovoltaic cells detect solutions densitometrically for precise blood chemistry and other analyses.

Circle 175 on reader service card

time of the 240 is 3 milliseconds.
Deltrol Controls/Division of Deltrol Corp., 2745 S. 19th St., Milwaukee, Wis. 53215. Phone (414) 671-6800 [348]

Compact solid-state relays are rated up to 40 amperes

Although they occupy less than a third of a cubic inch, solid-state relays in the J-TAB series have current ratings from 5 to 40 amperes and voltage ratings up to 280 volts ac. More importantly, they have 1-millisecond peak-surge ratings that are 25 times the steady-state-current limit. This allows them to handle applications with high turn-on current transients. Electromechanical relays in similar applications would need very high current ratings to avoid contact welding.

The optically coupled J-TAB devices require a control current of approximately 15 milliamperes at 5, 12, or 120 volts. They have an isolation-voltage rating of 2,500 v ac and a maximum leakage rating of 1 mA. Pricing for 120-v models, in thousand-piece lots, ranges from $3.75 each for the 5-A JTA-1205 to $12 each for the 40-A JTA-1240. Delivery time is from six to eight weeks.
Theta-J Relays Inc., 1 DeAngelo Drive, Bedford, Mass. 01730 [349]

Thick-film resistor networks have protective molded coat

A line of thick-film resistor networks intended mainly for use in pull-up and pull-down applications is protected by a tough, uniform molded coating. Available in 6-, 8-, and 10-pin single in-line packages, the networks are available for immediate shipment in 49 standard values from 33 ohms to 1 megohm. The standard circuit consists of five, seven, or nine resistors with one common pin and no isolation. A typical price is 29¢ each for the six-pin, 100-ohm circuit in thousands.
Dale Electronics Inc., Box 74, Norfolk, Neb. 68701 [350]

"Get yer connectors here!"

When it comes to connectors, there are vendors — and there are interconnection specialists. There's quite a difference. When your interconnection problem can't be solved by off-the-shelf (or off-the-cart) equipment, that's when you need us. Our speciality is solving interconnection problems. That means, for starters, designing a system to fit your unique requirements. Then tooling up, manufacturing, and assembling the system at our completely-equipped plant. And finishing up with on-time delivery, installation, and service.

We've been solving interconnection problems for many "blue chip" companies for 20 years. So your problem won't throw us. And with our high standards of quality, we won't throw you for a loop, either. Don't settle for just any off-the-street solution. See the interconnection specialists.

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☐ Fabri-Pak™ backpanel systems ☐ Molded connectors ☐ Plate connectors
☐ Flat cable connector systems ☐ Commercial ☐ Telephone connectors
☐ Military ☐ Send literature ☐ Have salesman call

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NATIONAL CONNECTOR DIVISION
9210 Science Ctr. Drive • Minneapolis, MN 55428
(612) 533-3533

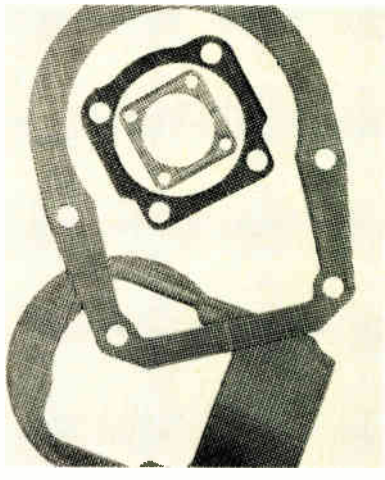
Circle 204 Fabri Pak TM backpanel systems
Circle 205 Flat cable connector systems
Circle 206 Molded connectors
Circle 207 Plate connectors
Circle 208 Telephone connectors

New products/materials

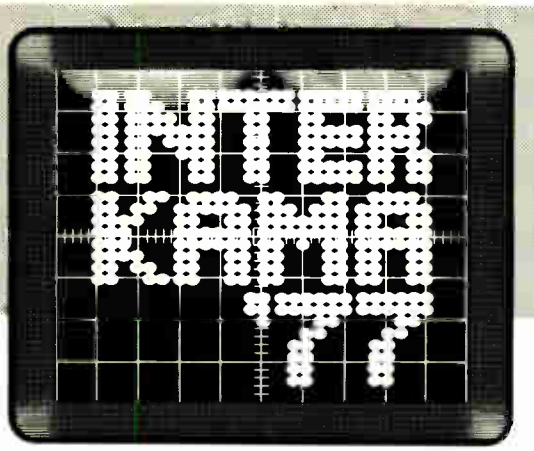
An opaque epoxy especially developed for coating light-sensitive components can be applied directly to integrated-circuit chips. Called Epo-Tek H62, the material is a thermally conductive, electrically insulating formulation. It adheres well to metallic, glass, ceramic, and semiconductor surfaces. The one-component thixotropic paste requires no refrigeration in shipping or storage and has a room-temperature shelf life of up to six months. Curing requires 30 minutes at 150°C or 60 minutes at 120°C, resulting in a volume resistivity of 10^{14} ohm-centimeters and a lap shear strength of 1,000 pounds per square inch. The operating-temperature range extends from −67°C to 330°C. Trial evaluation kits are available at a price of $15 for 3 ounces. Deliveries are from stock.

Marketing Department, Epoxy Technology Inc., 65 Grove St., Watertown, Mass. 02172 [476]

Rf-gasketing material Alu-Flex is a rubber-impregnated aluminum-wire cloth that can be used for pressure-sealing gases and liquids and for providing low-resistance connections between metal surfaces, as well as for shielding against radio-frequency interference. The material is available in two formulations: Alu-Flex HT, for high-temperature use, and



Alu-Flex Standard. The HT formulation is impregnated with silicone rubber for operation from −65°F to 500°F. The standard material, which



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Note the date: October 5 and 6, 1977, with repeat discourses on October 10 and 11, 1977.

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1) Measuring technique and pattern recognition in production engineering
Measuring and testing in production engineering, non-destructive test methods, image evaluation, pattern recognition of situation and state, recognition of conspicuity, plausibility checks "intelligent" television sensors.

2) Automation of measuring and checking systems
Microprocessors as component parts of measuring systems, spatially distributed measuring networks, automatic signal analysis for the determination and prediction of magnitudes which cannot be measured directly and for early warning fo faults or hazardous system states.

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Experience gained with model making, estimation of parameters and states and the use optimum adaptive multi-control systems in complex processes.

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The place of the human being in automated systems, integration of various tasks in a control desk (e.g. process control and arrangement of process supervision), rationalization and planning the manufacture of control rooms, Input/Output screen terminals. Actual examples.

5) Spatially distributed process computer systems
Microprocessors as integrated components of control and regulating systems, their effect on the construction of process computer systems and their programming procedures, new possibilities and limits, data transfer via busbar systems including optic conductors.

6) Reliability and safety (appliances)
Methods for the improvement of reliability, definition and assessment of safety, proper functioning of appliances and programs for safety devices, fault recognition facility, self-monitoring, cost of reliability.

7) Reliability and safety (systems)
Methods for the improvement of reliability, definition and assessment of safety, proper functioning of appliances and programs for safety devices, fault recognition facility, self-monitoring, cost of reliability.

8) Computer-aided design and application programming of regulating, controlling and monitoring systems
Automation concepts, design of processes and equipment suitable for automation, new programming procedures (software production) in as much as they have a substantial effect on application programming.

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Name and initials _____

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New products/materials

is impregnated with neoprene, has a range of −20°F to 220°F. Both types are available in two thicknesses—16 mils and 20 mils—as custom-cut parts or as sheets up to 8 inches wide.

The Auburn Manufacturing Co., 306 Stack St., Middletown, Conn. 06457 [477]

An air-firable thick-film system of materials is intended for the fabrication of planar dc gas-discharge displays. The system includes Nicyl 9530 nickel-electrode composition, silver conductor 7713 for glass-seal feedthroughs, crossover dielectric 9740, and contrasting dielectric 9741. All compositions are designed for compatibility with soda-lime glass substrates. The materials can all be fired in air, in conventional belt furnaces, at 570°C to 600°C.

E. I. du Pont de Nemours & Co., Wilmington, Del. 19898. Phone (800) 441-9475, Ext. 7665 [478]

Low-K dielectric pastes for screen-printing thick-film crossovers or multilayer circuits can be refired many times without softening. In fired films 1.4 to 1.7 mils thick, the materials have a dielectric constant of less than 10, a breakdown voltage in excess of 550 volts, and an insulation resistance of more than 10^{10} ohms. To accommodate processing other materials on the substrate, the pastes are offered with three firing-temperature ranges: 750 to 810°C (Iso-Ohm 1003), 800° to 890°C (1005), and 880° to 1,000°C (1007).

Thick Film Systems Inc., 324 Palm Ave., Santa Barbara, Calif. 93101 [479]

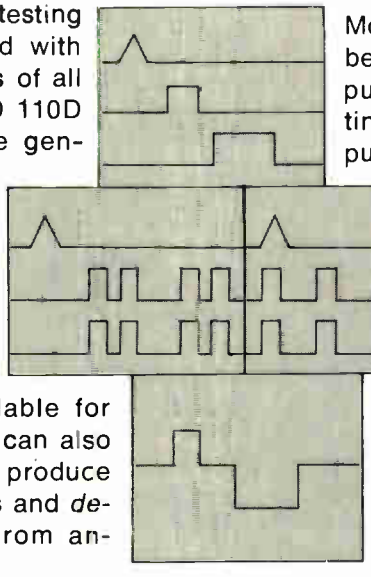
A punchable epoxy-glass laminate for making two-sided printed-circuit boards with plated-through holes is intended to replace the more expensive composite laminates commonly used for such applications. Called GEM, the material is now in pilot production. When it goes into full production later this year, the company estimates that it will sell for $1.60 per square foot in the 59-mil gage with 1-ounce copper foil bonded to both sides.

New England Laminates Co., Elm Street, Walden, N. Y. 12586. [480]

S-D's new dual channel ±18v pulse generator

THE LOGICAL CHOICE

Attention all of you working with 2 and 4-phase logic systems, bipolar logic, radar testing and simulation, and with complex waveforms of all types: the new S-D 110D dual-channel pulse generator is for you.



In one compact instrument, Model 110D contains *two* complete pulse generators with all pulse parameters separately controllable for each channel. You can also *mix* the channels to produce complex waveforms and *delay* one channel from another.

That's why you can produce a true 2-phase system (4-phase with two slaved 110D's) as well as double and triple pulse pairs and controllable pulse trains for data simulation. For sheer variety of pulses, nothing today touches Model 110D.

Model 110D is the latest member of a growing family of S-D pulse generators whose distinguished ancestors — Datapulse Models 110B, 110A, and 110—set the industry standards in their time.

Key 110D data: Amplitude, ±18v into 50 ohms • DC offset to ±18v • rise/fall time variable from 5 ns to 500 millisec • repetition rate 50 MHz • Price $2,250 (U.S. only). Get the facts on the first modern-day 2-channel pulser.

Contact Scientific Devices or Systron-Donner at 10 Systron Drive, Concord, California 94518, Phone (415) 676-5000.

SYSTRON DONNER

New literature

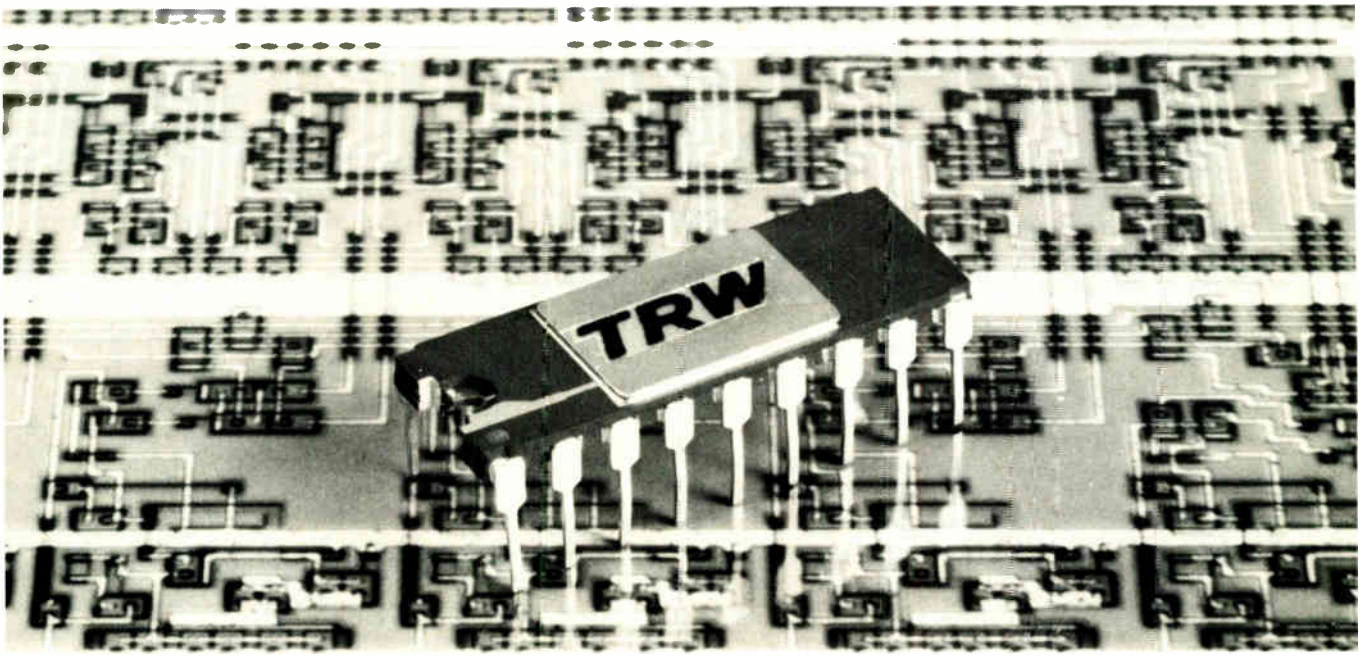
Semiconductor measurement technology. A technique for using a commercial C-meter with a bias-isolation unit (BIU) for capacitance measurements at bias-voltage magnitudes up to 10 kilovolts without damage to the measuring equipment is described in a newly released report. Basic principles of operation and details of the electrical design of a BIU are also discussed. Copies can be obtained at $1.45 each using order number C13.10:400-34. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

Pressure regulator purging. A question often asked by semiconductor manufacturers is, "How can I be sure my regulator is adequately purged?" A 4-page brochure answers this and related questions by outlining in simplified step-by-step form the procedures required for adequate purging with either a cross-purge or tee-purge assembly. With a cross-purge assembly, one can save time and expense while minimizing the hazards involved in purging a highly toxic or flammable gas. Matheson, 1275 Valley Brook Ave., P.O. Box E, Lyndhurst, N.J. 07071. For a copy of the brochure, circle reader service number 422.

Instrument/computer interfacing. A new 12-page brochure is available that offers an easy-to-read explanation of instrument/computer interfacing and the development and use of the Hewlett-Packard interface bus (IEEE Standard 488). Up to 15 different devices can be quickly linked on each bus, providing the user with a previously unavailable system versatility. A bibliography of pertinent literature is included. Inquiries Manager, Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, Calif. 94304. [423]

Wires. A comprehensive technical booklet is now available containing information on magnet wire, resistance wire, and other major alloys. It covers a wide range of magnet wire film insulations, bare and insulated dimensional data, and the physical

8-Bit high-speed monolithic A/D



Priced under $100

TDC-1002J	**1000 ns**	**$75 in 100's**
TDC-1001J	**400 ns**	**$175 in 100's**

Two performance ranges—400 and 1000 ns conversion times: two price ranges for a wide variety of high-speed A/D applications.

Linearity is ± 1/2 of LSB. Nine clock periods per conversion. All output bits are ready one clock period after the status signal indicates "ready to convert." There are no missing codes — ever!

TDC-1001J and TDC-1002J are supplied in an 18-pin ceramic DIP package designed to operate at a commercial temperature range of 0° to 70° C.

For more information and complete specifications, call (213) 535-1831, or use this coupon.

TRW LSI Products
E2/9085 • One Space Park
Redondo Beach, CA 90278

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***TRW* LSI PRODUCTS**

...from a company called TRW

New literature

and electrical properties of most of the major resistance and heating-element alloys. Magnet Wire Supply Co., 20731 Marilla St., Chatsworth, Calif. 91311. [424]

Fiberglass laminates. A variety of ready-to-use shapes of glass-epoxy insulation components available from open-stock tooling including bobbins, coil-form tubing, header plates and potting forms and structurals is described and pictured in a catalog. Insulators can be individually tooled and quoted to customers' drawings. Stevens Tubing Corp., 128 North Park St., East Orange, N.J. 07019. [425]

Solid-state relays. Information to aid prospective users in selecting the proper solid-state relay for their individual needs is available in a 20-page catalog. Charts and graphs

provide complete specifications and design data of ac- and dc-controlled, triac and SCR solid-state relays.

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SPECIFICATIONS FOR MAX-100

Frequency Characteristics Range: 20 Hz to 100 MHz (guaranteed): 110 MHz typical. Gatetime: 1 sec. providing 1 Hz resolution throughout freq. range. Accuracy: ± 1 count + Time Base error.

Input Characteristics Impedance: 1 MΩ shunted by 56 pf. Connector: phone jack. Coupling: AC Sine Wave Sensitivity: 30 mVRMS; 10 Hz-50 MHz; 100 mVRMS, 50 MHz to 80 MHz; 300 mVRMS, 80 MHz and above. Maximum Input: 200 V Peak, 20 MHz-500Hz; 100 V Peak, 500 Hz-1 KHz, 75 V Peak, 1 KHz-10 MHz; 50 V Peak, 10 MHz and above.

Internal Time Base Characteristics Frequency: 3.579545 MHz crystal oscillator. Setability: ± 3 ppm @ 25°C. Trimmer Adjustment: ± 4 ppm. Temperature Stability: Better than 0.2 ppm/°C, 0 to 50° C. Maximum Aging Rate: 10 ppm/year.

Display Characteristics Display: Eight .6" high LED digits, with anti-glare window. Lead-zero blanking: decimal point automatically appears between sixth and seventh digit when input frequency exceeds 1 MHz. Overflow: When input signal exceeds 99,999,999 Hz, the most significant (left hand) digit flashes, allowing user to read in excess of 100 MHz. Display update: Fixed 1/6-second plus 1 second gate time. Low Battery Indicator: When batteries or power supply falls below 6.6 VDC, all eight display digits flash at a one-Hz/second rate. During battery operation, flashing display extends operating time of unit.

GENERAL Power Requirements: 6 AA Alkaline or NiCad batteries (internal battery compartment); External: 110-220/AC Battery Eliminator charger; Automobile cigarette lighter adapter for both charging and operating: 7.2 to 10 VDC external power supply; Battery Life: Alkaline, 3 hrs., cont. use; 8 hrs. intermittent use. NiCad, 3 hrs., cont. use, 6 hrs. intermittent use. Battery Charging: 12-14 hours required for full charge. Size (HWD): 1.75" × 5.63" × 7.75" (4.45 × 14.30 × 19.69 cm). Weight: Less than 1.5 lb. (0.68 kg) with batteries. Accessories Included: 100-IPC clip-lead input cable; detailed applications/instruction manual.

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Magnecraft Electric Co., 5575 North Lynch Ave., Chicago, Ill. 60630. [426]

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Load cells. Catalog 351 provides formulas and coefficients that will allow the user to determine the maximum allowable load limits for installation, information that is vital for the proper selection of a load cell. A selector chart is also included. Lebow Associates, 1728 Maplelawn Rd., Troy, Mich. 48084. [429]

Cermet trimming potentiometers. A 56-page booklet is a compendium of information on cermet trimming potentiometers. Nine key advantages of using cermet trimmer technology are discussed and compared with those of metal-film, carbon, and wirewound technologies. Beckman Instruments Inc., Technical Information Section, Helipot Division, 2500 Harbor Blvd., P.O. Box 3100, Fullerton, Calif. 92634. [430]

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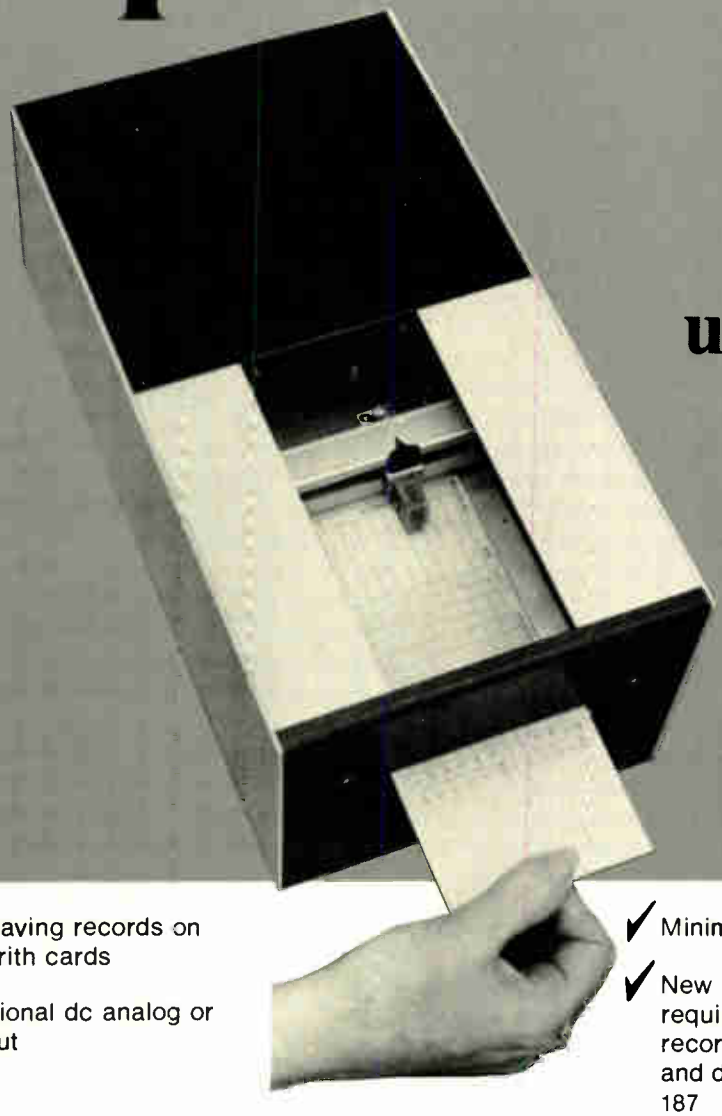

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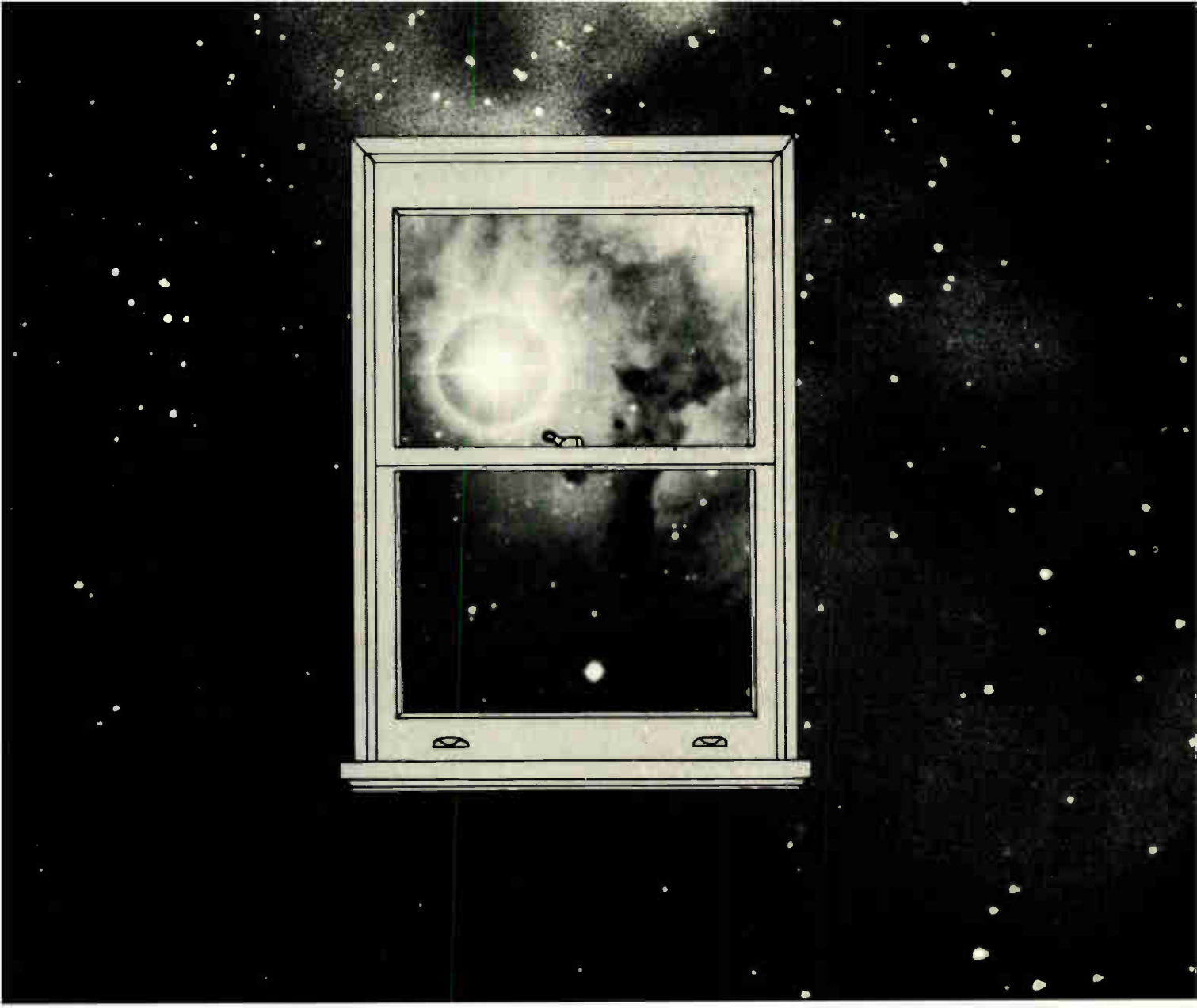

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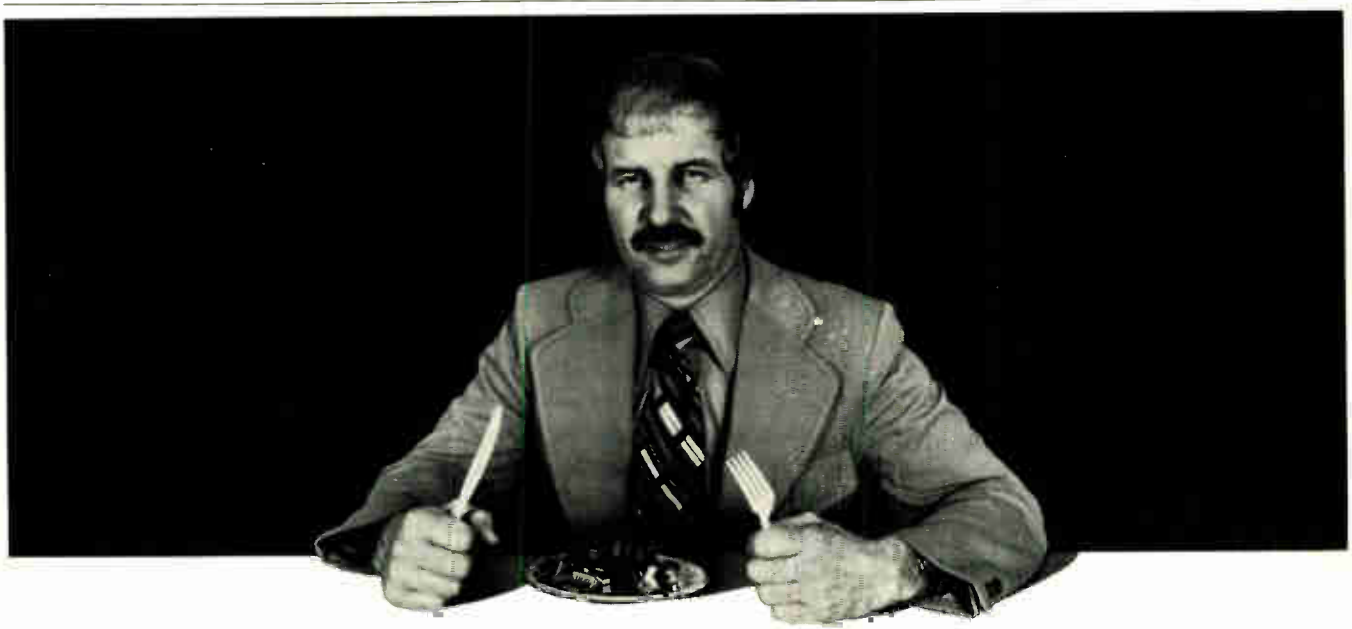

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Maybe TOKO Converters will convert you!?

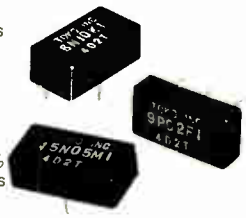
We think so. Otherwise we would not have bought space in this publication.
Below are some of the specifications of the new TOKO DC-DC converter Modules,
F • M • K Series and E (floating type) Series. For complete details,
please circle on the reader service card.

FMK-Series

● **1-Channel PLUS Output** Input, Vin: +5V±10%
Output, Vout: +6V±4% to +24V±4% for different types
Current, Io: 7-13mA to 100-167mA, depending on type
Conversion Efficiency: 65-75%

● **1-Channel MINUS Output** Input: +5V±10%
Output, Vout: −5V±4% to −20V±4% for different types
Current, Io: 7-13mA to 100-200mA depending on type
Conversion Efficiency: 55-75%

● **2-Channel PLUS MINUS Output** Input, Vin: +5V±10%
Output, Vout: ±6V±5% to ±20V±5% for different types
Current, Io: ±3-25mA to ±12-84mA depending on type
Conversion Efficiency: 55-70%



E-Series (Floating Output)
Input, Vin: 5V±10%; 12V±20%; 24V±20%
Output, Vout: 5V±6%, 12V±5%, 24V±5%,
±12V±6% and 15V±6%
Current, Io: 150-300mA, 25-125mA,
15-60mA, ±12 ±63mA and
±10 to ±50mA
Rated Output, Po: 1.5W
Conversion Efficiency: 60-65%
Regulation:
VS Input Current, ±1.0 to ±1.5%
VS Output Current, ±4.0 to ±8.0%

TOKO is known worldwide for precision electronic parts, highest quality and dependable performance.
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and ten factories in Brazil, Korea, Taiwan, Hong Kong, Singapore, Malaysia and Malta.

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● WIRE MEMORY SYSTEM ● MICRO COMPUTERS
TOKOM-80 ● IC MEMORY ● SEMICONDUCTORS
● PULSE TRANSFORMERS ● DELAY LINES
● DC-DC AC-DC CONVERTER MODULES

Circle 195 on reader service card

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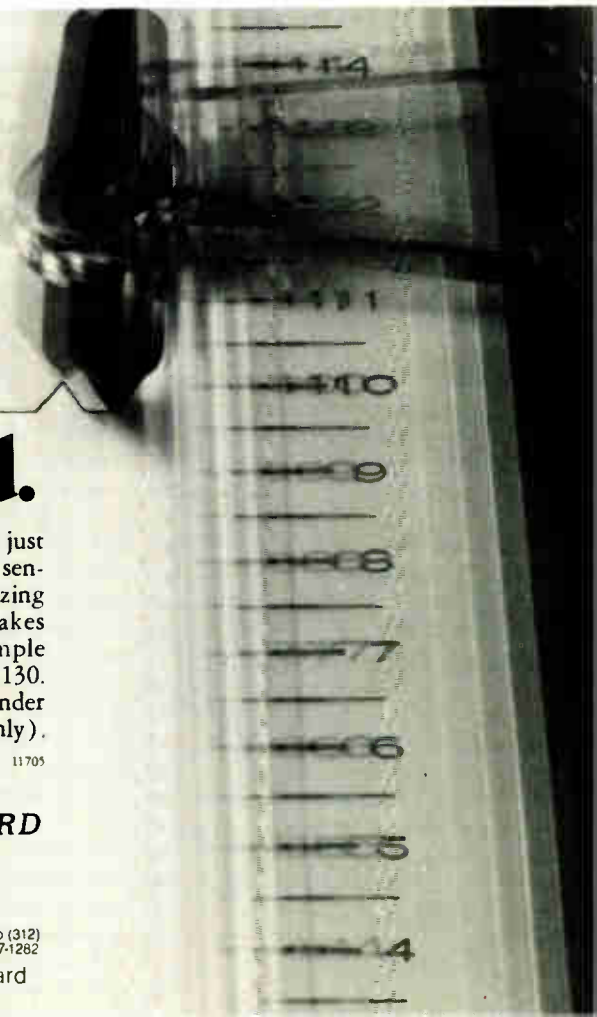

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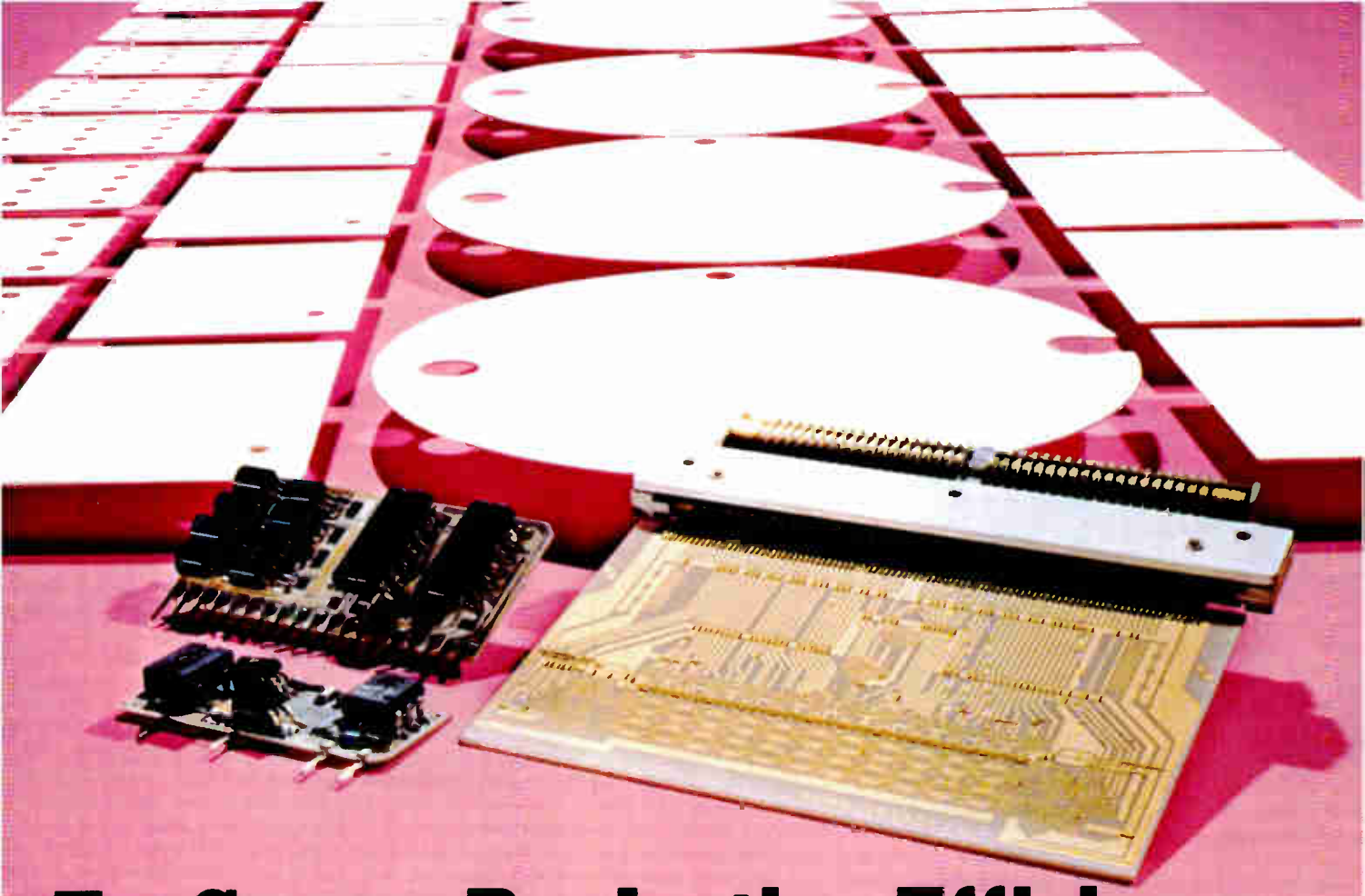

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Circle Number 901 on Reader Service Card

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WIREWOUND

Style	Characteristics	Qualified Terminals	Description
MIL-R-27208			
RT10	C2	L,P	1" long
RT12	C2	L,P,Y	1¼" long
RT22	C2	L,P,W,X	½" square
RT24	C2	L,P,W,X	⅜" square
RT26	C2	W,X	¼" square
MIL-R-39015			
RTR12	D	L,P,Y	1¼" long
RTR22	D	L,P,W,X	½" square
RTR24	D	P,W,X	⅜" square

CERMET

Style	Characteristics	Qualified Terminals	Description
MIL-R-22097			
RJ12	C,F	L,P,Y	1¼" long
RJ22	C,F	L,P,W,X	½" square
RJ24	C,F	L,P,W,X	⅜" square
RJ26	C,F	P,W,X	¼" square
RJ50	C,F	P	⅛" round
MIL-R-39035			
RJR12	C,F	L,Y	1¼" long
RJR24	C,F	P,W,X	⅜" square
RJR26	F	P,W,X	¼" square
RJR28	C,F	P	½" long
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