FOR ENGINEERS AND ENGINEERING MANAGERS — WORLDWIDE

MAY 15, 1986

ELECTRONIC DESIGN

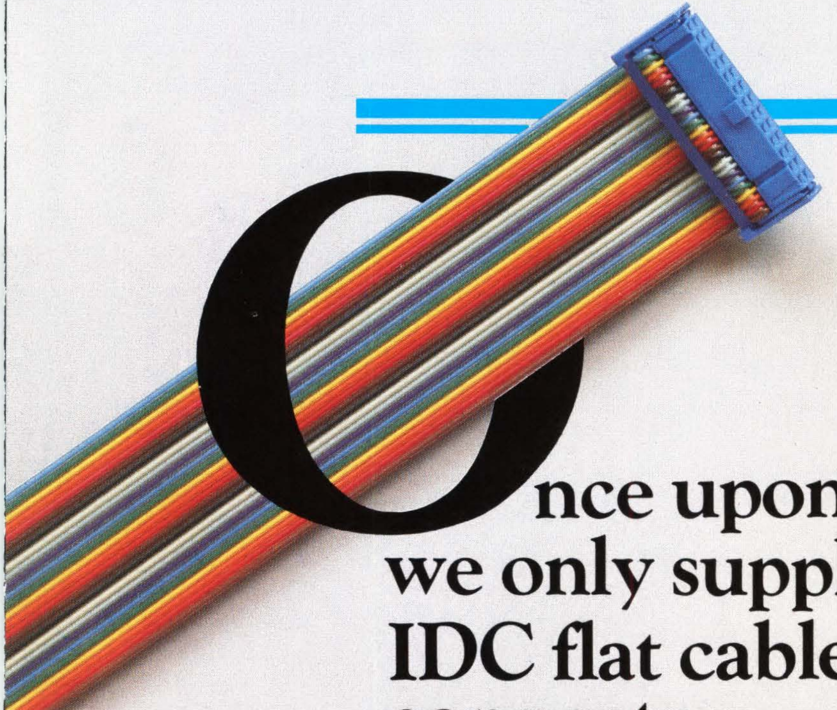
A HAYDEN PUBLICATION

Unix workstations: Heavy-duty processing on the desktop

GM's MAP moves ahead with push from new ICs

Instrument quartet upgrades tests for fiber optics

ECL BIT SLICES RUN FAST YET COOL



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For more information, call us at [619] 279-2200, or write Wavetek San Diego, Inc., 9045 Balboa Ave., P.O. Box 85265, San Diego, CA 92138. TWX 910-335-2007.

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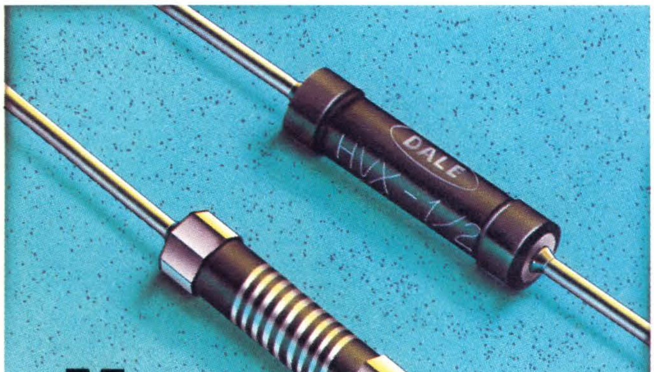
CIRCLE 2 FOR LITERATURE
CIRCLE 3 FOR DEMONSTRATION

Solutions



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For more details, call: **704-479-6451**

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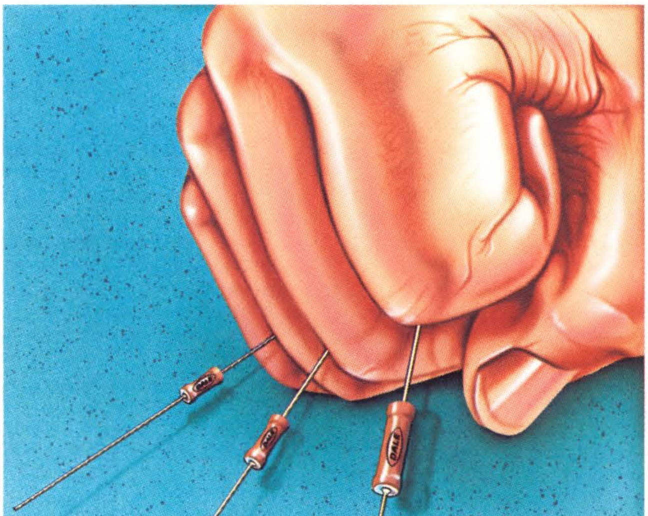

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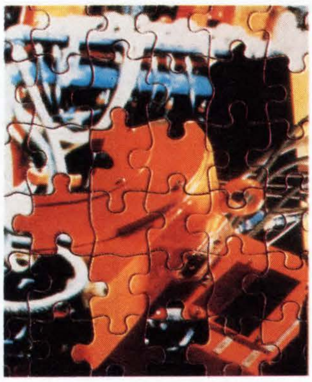
INSIDE LOOK

MAP: Big payoffs ahead



Unless you've been directly involved in designing programmable controllers or robotics systems or transducer interfaces, chances are that you've given little thought to industrial automation, outside of your own plant's efforts in that direction. The Manufacturing Automation Protocol, or MAP, will likely turn your thinking around. Why? First, the network protocol intends to forge a backbone of communication between the "islands of automation" in today's manufacturing facilities. More significant, MAP will open up the factory floor to a vast array of electronic gear, equipment that runs the gamut from communication and data collection to computer controls and even sensors.

In the past, industrial users rarely saw any gain in solving only isolated parts of the automation problem. MAP now addresses the problem as a whole. Just about every major industrial company in the world—General Motors, Renault, Eastman Kodak, IBM, Siemens, Dupont, you name it—is endorsing the effort and indeed throwing its full support behind it.

As end users, those companies are exerting tremendous pressure on suppliers to deliver MAP-compatible equipment and to reel out hardware and software to implement the plan. Customer pressure, especially from such corporate giants, makes a supplier sit up and take notice.

Some manufacturers have already gained a foothold in the MAP market. Fortunately, the field is so wide open and the scope of the MAP standards sufficiently broad that virtually all electronics companies can take part, not just a specialized few. Quite simply, the field is ready to explode.

No matter what your speciality is, you and your colleagues will no doubt have to come to terms with what MAP is all about. Our special report (p. 102) will give you a head start. It reports on the status of the standard, gives a wrap-up of today's relatively few hardware and software items, and addresses the testing matters that will ultimately ensure that one company's equipment or software works with another's.

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ELECTRONIC DESIGN

Departments

117 8-BIT-SLICE ECL CHIP SET

News

Newstrend

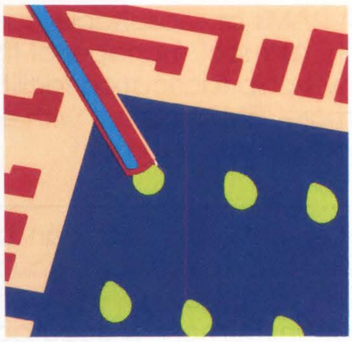
Industry Newsmakers

Electronic Design Reports

Design Entries

1986 winner, Jesse H. Neal
Editorial Achievement Award.
Best in-depth analysis article series:
1985 Technology Forecast

102 MAP PROGRESS



181 CONDUCTIVE EPOXIES

In The Next Issue

- Graphics coprocessor chip delivers variable-depth pixels to small systems
- ELECTRONIC DESIGN Report: Timing counts in testing high-speed VLSI ICs
- Product Report: Focus on ZIF and LIF connectors

Design Applications

Product Report

Cover photograph by Steve Eisenberg

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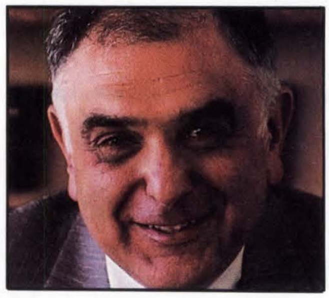
New Products

DON'T MISS THESE...

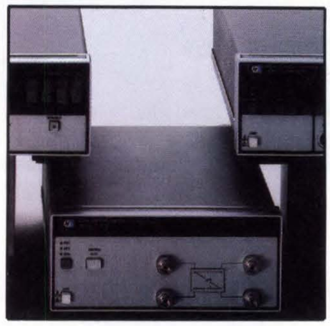
41 American manufacturers have conceded 1-Mbit dynamic RAMs to the Far East, right?

Wrong. IBM is making its own megabit RAMs at reasonable cost, says Paul Castrucci, manager of the company's chip fabrication facility. What's more, IBM is doing it with existing production equipment.



49 Fiber-optic systems can be tricky to test: When you're dealing with light, you have to worry about an instrument's accuracy and stability at high bandwidths.

The black magic disappears with four new instruments from Hewlett-Packard: an LED source, a power meter, an optical attenuator, and an optical switch.

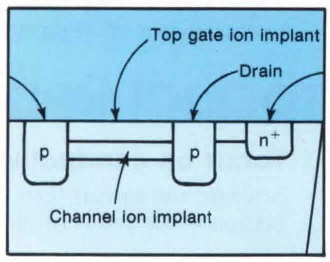


75 With lower-cost 32-bit microprocessors like the 68020 and 32032 now at hand, new workstations are coming within reach of most engineering labs.

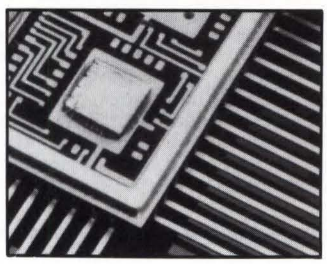
Add the Unix operating system and networking, and the machines become powerful interactive tools that rival minis and mainframes.

141 Trying to sense electrometer-level currents? A monolithic op amp that draws only 40 fA of bias current can help.

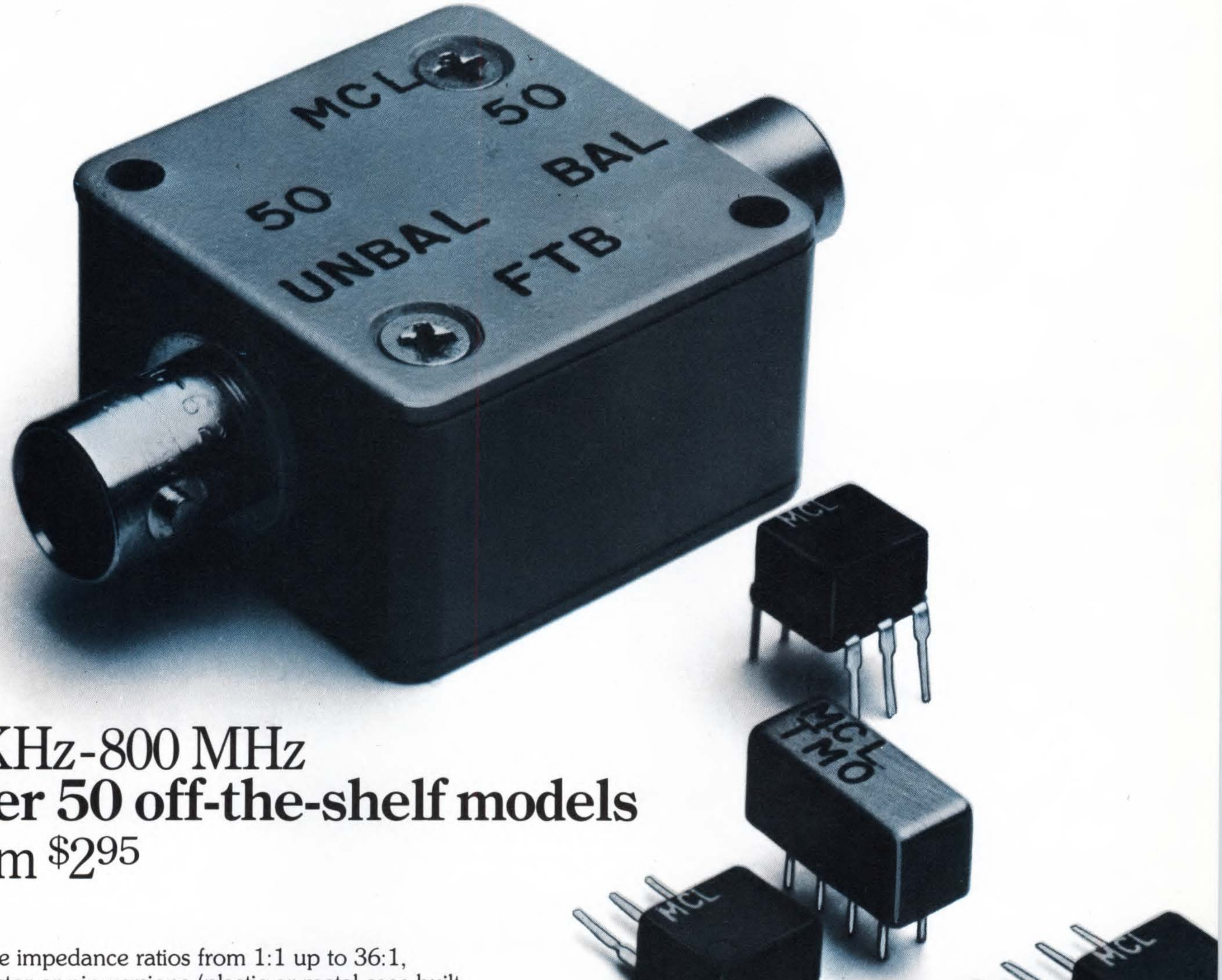
The chip can work as a transimpedance amplifier in a CAT scanner, or it can step into pH probes, photomultipliers, and precision integrators.



181 Surface mounting is shaping up as the most critical application for the new breed of conductive epoxies. With formulations that raise shear strength and reduce ionic contamination, the adhesives readily compete with both solder and polyimides.



RF transformers



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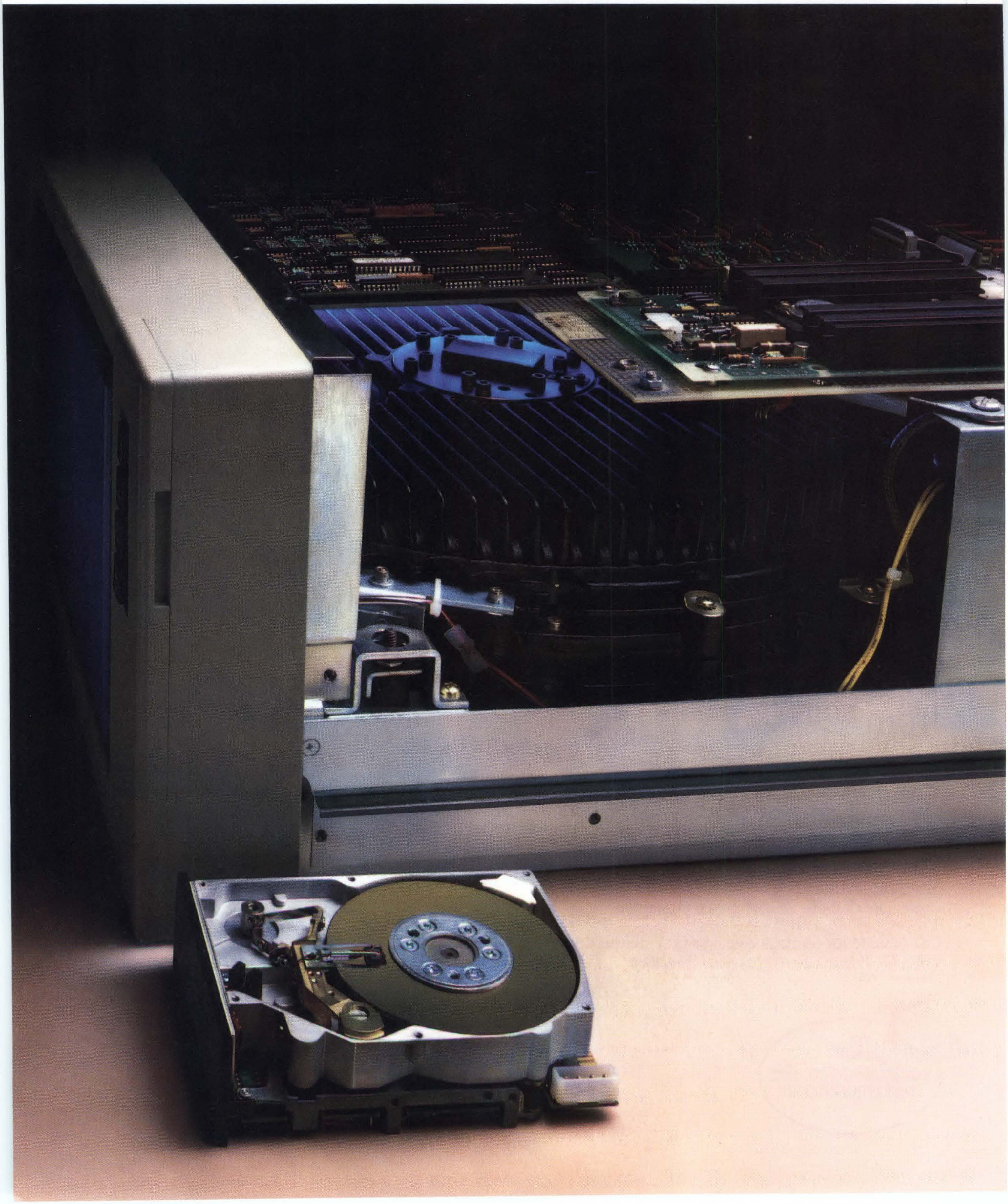


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ECL cell library runs on PC AT

The race to put an **ECL standard-cell library** on an IBM PC AT or look-alikes has been won by VTC Inc. (Bloomington, Minn.). The company's ECL bipolar library joins the myriad of CMOS libraries running on personal computers. Significantly, the library's process technology promises fully loaded gate delays of less than 400 ps, two to five times shorter than the best that CMOS can offer. The library contains cells ranging from simple gates to complex functions, such as a 4-bit-slice 2901 arithmetic element. Support software includes design rule checking to analyze captured schematics for fan-in or fan-out violations and I/O errors. To use the library, the host PC AT must also run CAE software from Computervision Corp. (Bedford, Mass.) and must be equipped with a plug-in graphics board and a grid-based mouse.

CAE tools and cells paired for ASIC uses

The cell library of **Harris Corp.'s Semiconductor Sector** (Melbourne, Fla.) has been paired with the CAD software from **SDA Systems Inc.** (Santa Clara, Calif.) to give application-specific IC designers **an end-to-end solution for standard-cell design.** Once limited to in-house designs, the primitives and macrofunctions—such as ROM, RAM, data-communication circuits—will be available to outsiders starting in the third quarter. They can thus be used with SDA's schematic capture, simulation, and placement and routing tools. Furthermore, the cell library and tools are machine-independent, since the software is written for the Unix operating system. With Harris' undisclosed minority financial interest in SDA, the company is extending its commitment to the ASIC business and to CAD tools.

Vector system achieves 18 MIPS for only $100,000

Mixing **scalar and vector processing** tasks, a computer costing under $100,000—a fraction of the price of other minisupercomputers—is making its debut this week at the Computer Graphics '86 exposition in Anaheim, Calif. The "personal supercomputer," or psc, from **Culler Scientific Systems Corp.** (Santa Barbara, Calif.) processes up to 18 MIPS or 4 MFLOPS for such computationally intensive CAD/CAE jobs as Spice simulation, autorouting, and three-dimensional solids modeling. Built around custom gate arrays, it fits under a desk and serves up to five engineers. Within three years, company officials say, performance could increase fourfold while the price could drop 50%.

Louder, clearer voices coming by speakerphone

A bipolar process raises voice quality of the next-generation **speaker-phone IC** from **Motorola Inc.'s Analog Integrated Circuits Division** (Phoenix). The chip's improved voice detection stems from four-point sensing through two on-board transmitter-receiver comparators; present devices have one comparator. The ratio of receiver-to-transmitter gain increased to 52 dB from 42 dB, yielding louder voice levels and reducing acoustic feedback oscillation. The chip is expected later this year.

Monolithic GaAs amplifier runs at 6 to 18 GHz

Though monolithic Gallium arsenide microwave amplifiers have performed before in the laboratory, commercial devices are just now arriving. Samples of a **one-chip GaAs amplifier** with a frequency band of 6 to 18 GHz will be available next month from **Harris Microwave Semiconductor Inc.** (Milpitas, Calif.). The chip gives a minimum small-signal gain of 5 dB with a positive 1-dB gain slope over the frequency range. Harris solves topology problems encountered during routing of the signal and power lines by etching via holes completely through the substrate, easing connection from the chip's surface to the ground plane on the back of the chip.

Logic analyzer sets its sights at 32-bit μPs

Packing a grand total of 115 channels and 400-MHz timing, the PM3570 **logic analyzer** stands ready to address the testing challenges posed by 32-bit microprocessors. Developed by **Philips Test and Measuring Instruments Inc.** (Mahwah, N.J.), the analyzer is clearly meant to compete with units from Hewlett-Packard and Tektronix. In fact, it is one of a number of products that Philips is now aggressively aiming at the U.S. test and measurement market. The modular unit can handle as many as 83 state-analysis and 32 transitional-timing channels, as well as software performance analysis. In the basic arrangement, the 32 timing channels operate at 100 MHz. Alternatively, the analyzer can be switched to 16 timing channels at 200 MHz or 8 channels at 400 MHz.

10-bit CMOS DAC steps in with military

After six years of "lobbying" military officials, **Analog Devices Inc.** (Norwood, Mass.) recently obtained Joint Army-Navy (JAN) qualification for a **10-bit CMOS digital-to-analog converter** chip made in its Irish factory. The approval from the Defense Electronics Supply Center, the first such for an Analog Devices part, makes the company the sole source for JAN versions of the d-a converter. The consent opens the door to MIL-STD-38510 qualification for the company's CMOS multipliers and switches as well.

Stretched mask illuminates CRT

Holding a **shadow mask under tension** is the trick that **Zenith Electronics Corp.** (Glenview, Ill.) is counting on to brighten color CRT images. The flat-tension-mask display, based on a 14-in. tube, boosts brightness by 80% and contrast by 70% compared with existing models. It does so by stretching the shadow mask in the frame around the CRT. Dome discoloration caused by electron-gun heat puzzled CRT designers for years, but Japanese display designers recently began offering more expensive prestressing processes to preserve mask integrity (ELECTRONIC DESIGN, Jan. 23, p. 137). When packaged with the new glare-free face and with dot pitches as small as 0.21 mm, the 14-in. tube, scheduled to be shipped next year, will boast the same resolution and appearance in a bright room that a 19-in. display sports in a dark room.

The analyzer that's right at home with components also does well on the circuit.

The HP 4194A Analyzer is the intelligent answer for impedance as well as transmission measurements. With powerful analysis capabilities built right in, and a color CRT for brilliant graphic display of results, it's the perfect tool for boosting engineering and test productivity.

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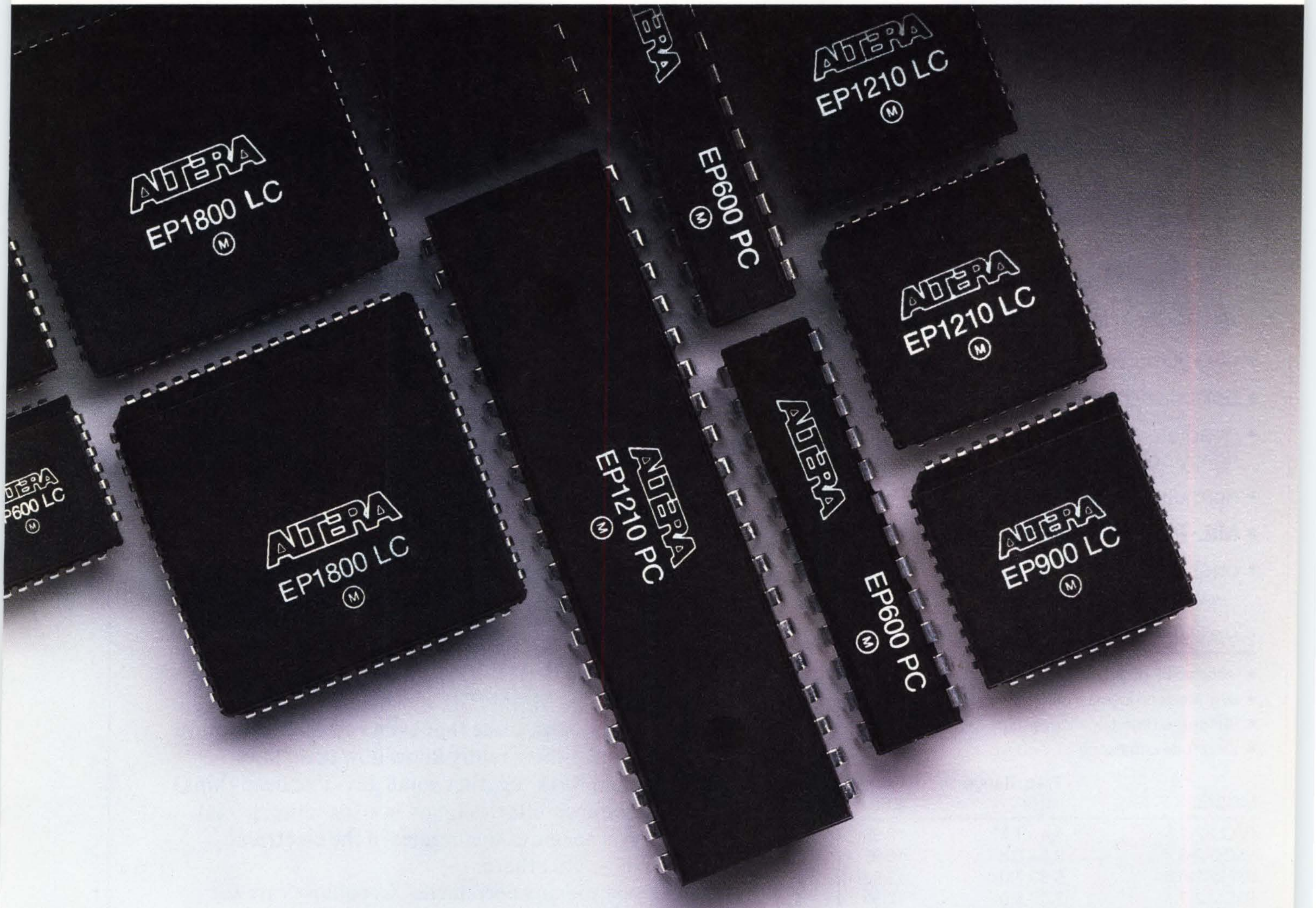
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EDITORIAL

Ohm meets Murphy

Ohm: Murphy, how did you do your law?

Murphy: It just hit me one day. I know that's what Newton said when he did his law of gravity, but it's the truth.

Ohm: I know what you mean. Apple schmapple. Newton was a bum lawmaker. Look what Einstein did to him. There was a lawmaker. Photons, waves—the whole bit.

Murphy: I've heard that Kirchhoff was overrated, too.

Ohm: Kirchhoff? Not bad in thermo and optics, but definitely overrated in electricity. Current law? Any dummy could figure out that what goes in has to come out. But you know who never got the credit he deserved? Thévenin. Nice French fellow. But he was always looking at circuits. Sat there and stared all day. Then he started talking about "looking into" circuits and "looking back into the output"—weird stuff like that. Everybody thought he had gotten too close to the Van de Graaff. But wait, you still haven't told me about your law.

Murphy: Oh, yes. One day, I'm sitting in the office. Nothing's going right. Suddenly it hit me: IF ANYTHING CAN GO WRONG, IT MIGHT.

Ohm: "Might?" "Might?" It's "will" isn't it?

Murphy: You know, I like that even better. Much more definite. You old-timers really know how to do laws. Maybe we could work together some day. I've been thinking of doing some corollaries to my law for some specialized fields. You're one of the biggies in the electrical game. We could start there.

Ohm: I never did any corollaries. Corollaries are for guys who didn't do their laws right the first time.

Murphy: Your law works even when my law is in effect?

Ohm: Would it be a law if it didn't? But it does depend on who's trying to use it. An engineer who's been around knows to look for your type of action—pain-in-the-rear things like capacitor leakage current, electrostatic charge damage, ground loops, solder bridges, and crosstalk. At least he should. I'll stick with my own law.

Murphy: Where can I get in touch with Kirchhoff?

Stephen E. Scrupski

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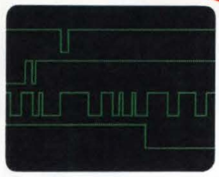
Analyzer  -channel in one package.

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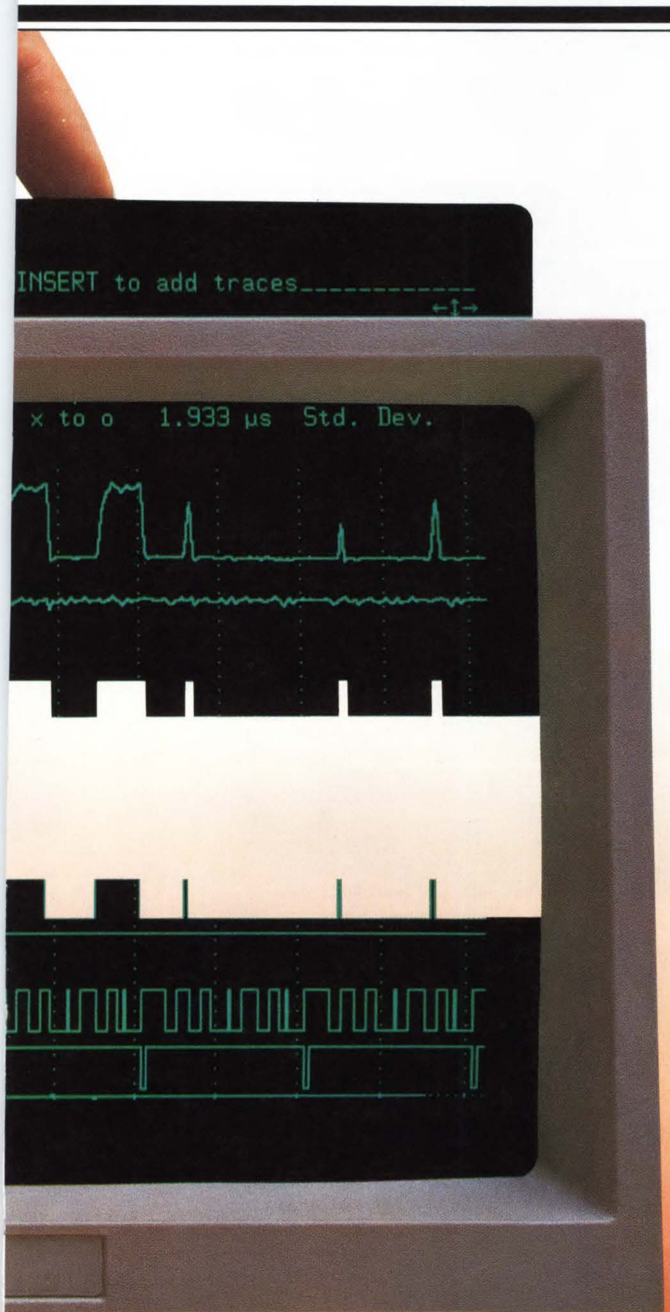

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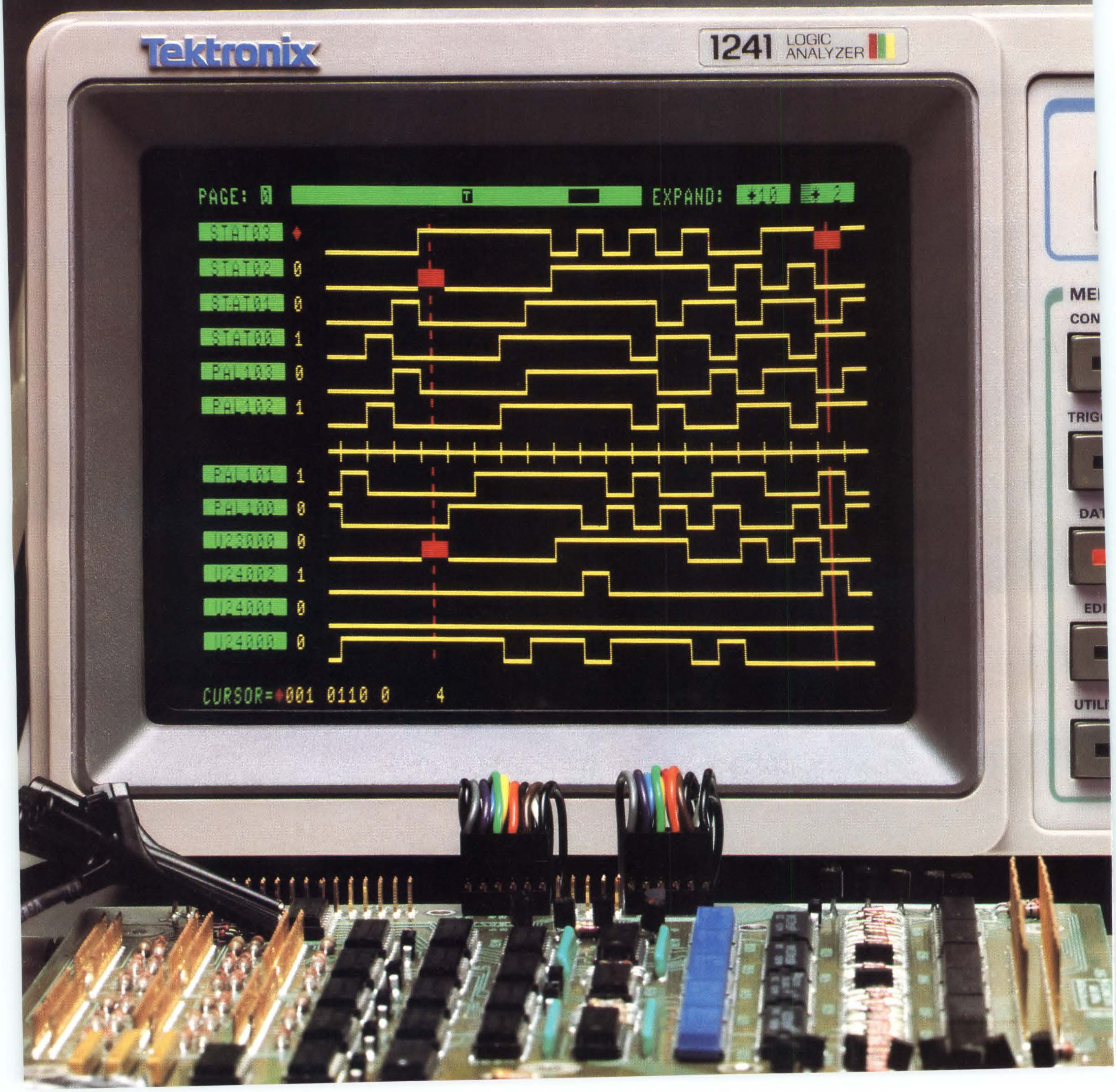
TEK'S NEW COLOR LOGIC ANALYZER: MORE ACCURACY FOR MORE PRODUCTIVITY.



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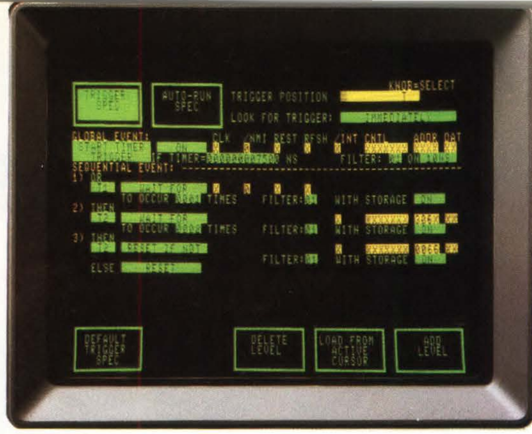
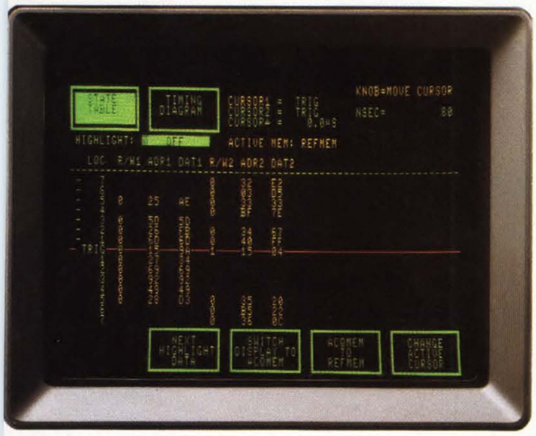


2 Like all members of the 1200 Series, the 1241 clearly



shows what your hardware and software are doing at the same time. For integrating partitioned designs, only the 1200 Series' Dual Timebase feature accurately depicts real-time interactions between independently-clocked modules. This lets you monitor relationships between two processors, or between hardware and software. Combine Dual Timebase with performance analysis on the 1241 to analyze the entire system and software performance. Monitor, for example, the range of time spent by one processor waiting for a service request response from a second processor. The 1241's histogram display and 10ns resolution make these measurements clear and precise.

3 For both hardware and software analysis, Tek offers unsurpassed triggering. Software problems are pinpointed by 14 levels of conditional triggering combined with data and program flow qualification. Triggering on the timing characteristics, as well as the state of the hardware activity, is made possible by counters, timers, and duration filters.

4 Ease of use extends beyond the color screen. Four distinct levels of operation add features as your design challenges require. A unique touch-screen menu display lets you select over 50 high-level commands right off the screen. The big front panel knob provides flicker-free scrolling.

5 Modular, expandable and versatile, Tek's 1200 Series keeps costs low and compromises few. Support for all major microprocessors includes three types of disassembly. With 14 combinations of 9- or 18-channel acquisition cards, you configure the best data width (up to 72 channels), memory depth (up to 2K) and sample rate (up to 100 MHz). Add ROM packs for data analysis; RAM packs for storage; COMM packs for RS-232 and GPIB links to computers, plus printer interfacing; and master/slave capability

that links two systems via modem for teleservicing.

The 1241 is the newest reason why Tek is the logic analyzer leader. For more information or a demo, call 1-800-245-2036. In Oregon, call 231-1220. Or contact your local Tek Sales Engineer.

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The LSI cells were developed by WaferScale Integration Inc. (WSI) and will be alternate sourced by RCA. WSI will also offer RCA's CMOS standard cell library.

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8840A-09 TRMS AC option	$185	8842A-09 TRMS AC option	$250

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* Patent pending

Channelless gate arrays meet military specs

BY RAY WEISS

Boston—For designers of high-reliability digital systems, the search may be over for fast logic chips with 20,000 active gates yet needing only CMOS power levels. A channelless "sea of gates" approach in CMOS produces a chip with ECL speeds and reliability that meets military specifications. The device will make its debut at this week's Electro show by Hughes Aircraft Co.'s Semiconductor Division (Newport Beach, Calif.).

A standard-cell version, interchangeable with the gate arrays, is also available. Together they constitute a one-two approach to implementing application-specific ICs. A design can be developed using the channelless gate arrays for fast turnaround and a low-cost prototype. Later, when the chip is ready for long-term production, it can be automatically transferred to a standard-cell implementation in a more efficient size.

With 50% gate use, the 40,000 gates in the Hughes U-series of channelless arrays can lead to designs of up to 20,000 active gates (see the figure). To underscore the possibilities, the company points out that the U-series of channelless gate arrays has been in beta testing for almost nine months, the standard cells for six.

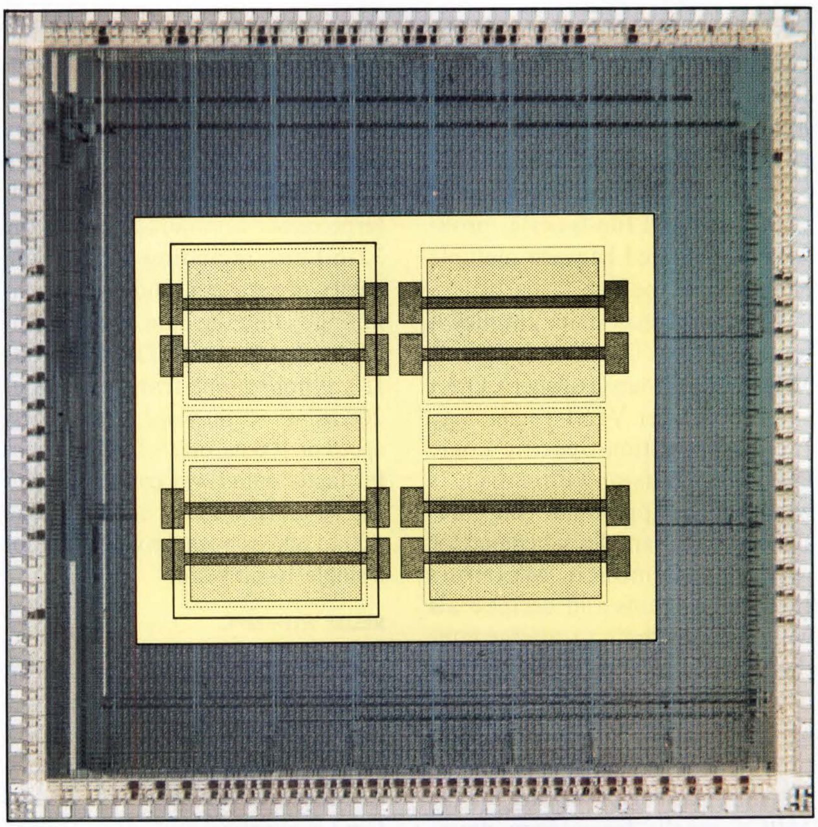
Typical of the tasks requiring the density and low power of the new parts, one undisclosed military contractor is building a full MIL-STD-1750A instruction set computer with five gate-array chips for an embedded airborne processor. The chips will deliver over 2 MIPS of computing power.

Logic developed with the U-series arrays approach ECL in speed with CMOS power dissipation: Two-input gates have average delays of 0.4 ns. Clock rates exceeding 125 MHz can be realized, while individual flip-flops can switch at 240-MHz rates. The blazing speed teams with modest power dissipation, averaging 8 μW/gate/MHz.

LOTS OF CHOICES

Unlike many products introduced by start-up companies, the U-series comes with a wide range of CAE interfaces, integrated peripherals, and packaging choices:

- With the results of the gate layout and routing, an innovative simulator resimulates the design in standard cells. Correct first silicon is much more likely when the effects of the actual layout line lengths and loadings are simulated.
- The design library supplies special gates with standard TTL and three-state outputs.
- Packaging options include leadless chip carriers, pin-grid arrays, and flat packs.
- A custom hybrid service from Hughes' Semiconductor Circuits Division (also in Newport Beach) offers a hierarchy of packages, including on-chip hybrid design,



The U-series CMOS arrays from Hughes Semiconductor contains the equivalent of up to 40,000 two-input gates on a chip. The evaluation device has 32,000 gates. The inset contains a typical eight-transistor cell.

daughterboards, and fully custom boards that meet military specifications.

The U-series is based on Hughes' HCMOS-II, a double-layer metal CMOS process. Its 2-μm geometry results in an effective channel length of 1.2 μm. The final metal layers have pitches of 7 and 9 μm.

In the device's channelless structure, fixed gate patterns are laid out in a manner similar to that used in standard-cell placement and routing. In fact, the only difference between the U-series channelless gate arrays and standard cells is that the gate-array cells are fixed—generated by a macro library and made up of a basic eight-transistor, two-gate cell.

Standard cells have the same functionality as the hardware macros but are tailored to meet layout considerations. While circuits based on the standard cells are smaller and more efficient, they require more time to design and lay out.

SOS VERSIONS, TOO

Designer options do not just stop with layout, though. Gate-array or standard-cell designs that must be radiation-hardened can be developed in the U-series and then transferred to more secure silicon-on-sapphire (SOS) processes. The support software can automatically generate the masks for SOS processing.

The design library consists of hardware macro sets for generating SSI and MSI logic blocks. Other macros tailor RAMs and ROMs. The software tool kit runs on popular workstations and under their operating systems, Hughes says.

An evaluation array with 32,000 gates is available, and it will show propagation delays, various fanouts, and interconnection wiring distances.□

Coprocessor IC spurs Multibus II applications

BY TERRY COSTLOW

Chicago–The semidormant Multibus II specification will soon begin chasing the VMEbus in earnest. Designers are counting on the long-awaited message-passing coprocessor (MPC) chip to relieve the connection and file-transfer problems encountered between multiple processors on the bus.

The coprocessor chip, unveiled a few weeks back by Intel Corp.'s Multibus II Group (Hillsboro, Ore.) and codeveloper VLSI Technology Inc.'s Application-Specific Logic Products Division (Phoenix), is whetting the appetite of board designers. With samples scheduled for release this month, Multibus II–based systems and peripherals will no doubt begin to emerge later this year, some representing entirely new systems but others dusted-off earlier projects. "We used the Multibus I protocols for the basics of our system, then began waiting for the MPC," recalls Jerry Horn, president of Rubicon Systems Inc. (Maitland, Fla.), a maker of cell controllers for factory automation. "We couldn't proceed until we knew how message passing would be handled."

Now Horn's company can move on. The coprocessor, a 149-pin CMOS chip, handles all facets of interprocessor communication for the 32-bit bus, including arbitration, parity generation, and error monitoring within the data packets generated by the chip. The Multibus II's synchronous transfer rate of 200 ns per 32-bit word, with a burst speed of 100 ns, offers large systems far faster data flows compared with the 16-bit Multibus I and its typical 500 to 600 ns asynchronous rate for a single 16-bit word.

RELIEF WITH MPC

One such system, in development at military contractor Planning Research Corp. (Omaha, Neb.), will contain 21 single-board computers, 43 Mbytes of main memory, and 12 Gbytes of optical and magnetic disk storage. The 35-MIPS system, which will translate the many communication protocols used by the military, will lean heavily on Multibus II's message-handling capabilities, which are well suited to multiprocessor applications.

"To do that much processing in one system, you need a good mechanism for moving data. We would not try to build a system like this without the message-passing coprocessor," rhapsodizes Steve Sidner, project manager at Planning Research. "In the same amount of board space some systems use for 16-bit interfaces, the chip packs 32 bits, plus all memory-handling and message-passing circuitry."

LIMITED OPTIONS BEFORE

Until the announcement of the coprocessor, design options were limited. "There have been three alternatives for Multibus II board developers," explains Bill Moren, marketing engineer at Ciprico Inc. (Plymouth, Minn.), which makes disk-drive controllers. "One was to wait for Intel's silicon, the second was to take on the monumental task of developing your own silicon or a discrete alternative, and the third was to build a docket board using Intel specifications."

Ciprico chose the latter route for a caching disk controller that it will introduce at the National Computer

Conference next month. The controller contains the 3-by-6-in. docket board and sustains a message transfer rate of 3 Mbytes/s, with short bursts of slightly over 4 Mbytes/s.

However, using the docket board to pass messages only serves to get the controller out quickly, since the board has limited capabilities. "It's a compromise, but using the docket board gets the controller out quickly until the chip is here," sums up Moren.

When the MPC eventually replaces the docket board, the controller's sustained transfer rate will double to 6 Mbytes/s, and its burst rate will leap to 10 Mbytes/s. The coprocessor will also wring out higher throughput, since it can handle 32-bit transfers, the docket board only 16 bits.

The delay in developing the chip has given the VMEbus a head start in 32-bit implementations, but the contest now has the earmarks of the race between the tortoise and the hare. Even in Europe, where the VMEbus is heavily favored, Multibus II has fans. One U.S. marketing director for a peripherals company carried mostly VME material to Europe for a recent meeting with customers, only to send an urgent request to headquarters for a hefty supply of Multibus II data sheets.

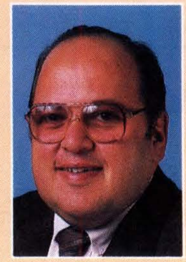
Typifying the enthusiasm overseas is Bull Systems (Les Claye, France). It plans to use the Multibus II architecture for 68010- and 68020-based workstation engines. Like its U.S. counterparts, however, its plans have awaited the MPC chip.

NOT A PANACEA

The coprocessor might seem to be a panacea, but at least one designer who is sold on Multibus II found the chip to lack an important feature—direct memory access. Preferring not to be quoted by name, the designer, manager of a high-performance graphics project, notes that the chip could not support the shared-memory concept used in his

INDUSTRY WATCH

Falling MOSFET prices could shake up new system designs



A dollar gap has existed for years between power MOS and tried-and-true bipolar transistors, but the situation is changing as prices of MOSFETs tumble. The trend is clear. MOSFETs with ratings of 50 V and 12 A, housed in plastic packages, cost the same as bipolar parts—60¢ each.

What's more, higher-power MOSFETs, with ratings of 60 V and 27 A, have slid more than 50% over the past year, from $10 to $3.50 in quantities of 1000. A bipolar device with similar specifications has remained relatively stable at about $1.50.

Even MOSFETs of 500 V and above, which are still much costlier than their bipolar counterparts, are beginning to feel the pressure. A popular 500-V MOS device now goes for nearly $15 in 1000-piece orders; a year ago it cost about $40. On the other hand, bipolar units with equivalent performance have remained relatively constant at about $4.35.

One reason for the narrowing price gap is increasing competition: About a dozen vendors are jockeying for market share. Technology advances also are driving down prices. Just as digital IC makers pack an ever-growing number of bits on a memory chip, power MOS designers are boosting the cell density per square inch of silicon and thus the device's current rating. A race is now under way to increase cell density even further.

Earlier this year, Siliconix announced MOSFETs that squeeze in a record-breaking 1.6 million cells/in.^{2}, a twofold improvement over previous parts (ELECTRONIC DESIGN, Jan. 9, p. 44). More recently, RCA's Solid State Division has begun offering samples of a 50-V MOSFET with 2 million cells/in.^{2}. At less than 3¢ an ampere, a 50-V device rated at 12 A would sell for 36¢.

Designers of power supplies are taking advantage of the price changes, particularly for devices of 200 V and below. Consider what's happening at power-supply maker Stevens-Arnold, a division of Computer Products (Boston). Art Parker, director of engineering, recently told me, "The initial objective for using MOSFETs was to increase frequency and decrease the physical size. However, there was always a cost penalty. But I've seen the price of some MOSFETs fall by a factor of three over the last few years." In addition, with the cost penalty diminishing, Parker believes that most designers will switch over to MOSFETs.

Martin Gold

Martin Gold

system. This particular graphics product relies on large memory transfers, which an off-chip DMA controller, Intel's suggested design, would have to assume if the MPC were used.

If enough manufacturers demand DMA power, help may be in store. NCR Corp.'s Engineering and Manufacturing Division (West Columbia, S.C.) is now testing a prototype two-chip set that mimics the functions of the MPC and also tackles DMA communication and both sequential memory and input/output transfers.

The chip set, dubbed Dame for data-address management element, consists of two 84-pin CMOS ICs, each handling 16 data bits at once. The chip set handles all functions during long data transfers, freeing the host for other tasks. Designed at NCR's microelectronics facility in Fort Collins, Colo., the ICs are now slated for internal use, with external sale tentative.□

Cell development system leans on Lisp base

BY MARTIN GOLD

Rochester, N.Y.—Artificial intelligence deserves much of the credit for a library development system that compiles cells and generates complete circuit layouts in eight hours. The Score system, which Gould AMI Semiconductors Inc. (Santa Clara, Calif.) plans to demonstrate at the Custom IC Conference here this week, uses MIT's Lisp-based Design Procedure Language to create cells with unique characteristics for application-specific ICs.

Gould's program, which runs on a workstation from Symbolics Inc. (Concord, Mass.), adopts Lisp's ability to mimic a human being's reasoning of spatial relationships and adds cell information to the DPL to produce space-efficient layouts. Moreover, Score eliminates the need for designers to deal with several different languages throughout the IC design process, since they can use the same English-like commands to define relationships during the entire cycle. For example, points on the boundary of a cell are accessed by name—such as "top of the cell"—rather than by calculating coordinates. The system saves more than a week of development time.

Already incorporated into the Gould library are 22 cell compilers representing a wide variety of primitives—gates, flip-flops, I/O pads, counters, and multiplexers. Megacells such as ROMs, RAMs, and PLAs will soon be added to the library, and the company plans eventually to include analog cells for analog-to-digital and digital-to-analog converters and for references.

Score does not prestore cell simulation models or mask layouts, as most development systems do. Instead, it accepts a customer's specifications—cell function and process along with physical and electrical considerations like height, loading, and propagation delays—to drive the cell compilation procedures.

A built-in algorithm automatically analyzes the speed and load parameters, calculates the required transistor sizes, and determines the proper gate arrangement. The algorithm then takes the gate information and combines it with the prescribed cell height to generate a finished layout and simulation model.

BENT GATES

Cell heights can vary between transistor rows, reducing silicon requirements. Score surveys the cell types in the net list and adjusts overall cell heights according to the overall distribution pattern, rather than basing cell heights on the least or most complex unit. The system then bends or splits the cell transistor's gates automatically to smooth the cell row and minimize chip size.

The cell and gate layout can be changed in minutes simply by rerunning the appropriate compiler program, primarily because the simulation models and mask layouts are not prestored in a database library. Instead, the specifications for cell construction are provided as inputs. Thanks to the AI-based software, the cell compiler needs only the inputs to generate the cells. Furthermore, the system works independently of the semiconductor process, so that designers can specify geometries of 3 μm down to 1 μm or less.

When constructing a new cell, the compiler produces geometrical mask data, a simulation model, a net list for verification, and placement and routing information, including pinouts and cell dimensions. From that data, it performs other operations automatically, such as design rule checking and resimulation.

FAST DOCUMENTATION

Score also produces data sheets immediately after cell generation, so that users no longer have to wait weeks for the design engineer to create and edit the documentation.

AMI will use Score internally, offering customers the option of building entirely new cells independently of any particular library. "Score enables us to break the barrier between standard cell and custom development," states an AMI official.□

Newsfront section continues on p. 30

Academic dream machine arrives on scene

BY RAY WEISS

Westlake Village, Calif.—The face of academic computing is about to change. Ten years ago a desktop computer with 1 Mbyte of memory, a display with 1 million pixels, processing speed of 1 MIPS, and a maximum $5000 price tag existed only in theory. Now the fabled "three-M" workstation has arrived, but the initial entry is a dark horse in a field that includes Apple, Hewlett-Packard, IBM, and Next. Definicon Systems Inc. will be first to deliver the machine proposed in 1977 by the Inter-University Consortium for Educational Computing.

Definicon stepped ahead of its larger competitors by taking a less complex, piecemeal approach. Instead of building a new workstation from the ground up, the company developed two low-cost boards to fit the slots of an IBM PC or compatible computer. One card contains a 68020-based coprocessor; the other is an advanced graphics expansion adapter. With 1 to 4 Mbytes of dynamic RAM having 120-ns access time, the processor card delivers performance of 2 to 4 MIPS.

The graphics processor can be programmed for resolution of 320 by 200 pixels to a full 1200 by 960 pixels in color. Besides hitting the 1 million pixel mark, Definicon's system offers up to 64 colors, depending on resolution.

The graphics adapter exploits a new generation of CRTs that synchronize different video signal rates. Thus, the system can support the low-level IBM color graphics adapter (320 by 200 pixels) or the deluxe version with 1280 by 980 pixels. Because high-resolution color monitors are available for $595, the workstation price is less than $5000.

Definicon's boards are just the opening round of a large-scale battle. Though other vendors have declared themselves in the competition and some workstations already meet or exceed "three-M" performance, none is less than $5000.

MORE TO COME

Apple Computer Inc. (Cupertino, Calif.) declared its intention in January to deliver such a machine. Ironically, another contender, Next Inc. (Palo Alto, Calif.) is the new company of Apple founder Steven Jobs. Digital Equipment, IBM, and Sun are also busy with such projects.

In case the competition gets tough, Definicon has built in some flexibility—the boards contain space for additional memory and other features. The current boards can be upgraded to 8 Mbytes with standard cards or using halfboards to 12 Mbytes of RAM with full floating-point processing and virtual memory.

As for universities, they are raising their sights as hardware prices drop and processing power climbs. Now they seek 2 to 4 Mbytes of memory and performance of at least 2 MIPS. Indeed, academic goals may exceed the size of the pocketbook: A requirement for hard-disk storage makes it difficult for vendors to meet a $5000 price.

At Carnegie-Mellon University (Pittsburgh), researchers are considering how to apply such workstation power (see "Introducing Andrew," below). In addition, IBM is contributing over $37 million toward developing a sophisticated network made up of high-performance workstations.□

Newsfront section continues on p. 32

Introducing Andrew

Pittsburgh—The optimal academic workstation takes a step closer to reality with the completion this year of Andrew, a workstation software project named for Andrew Carnegie and Andrew Mellon. The Carnegie-Mellon package will encompass a network and a windowing system running under the Unix operating system. Accommodating over 10,000 nodes, the software allows files to be shared and remotely executed across the network.

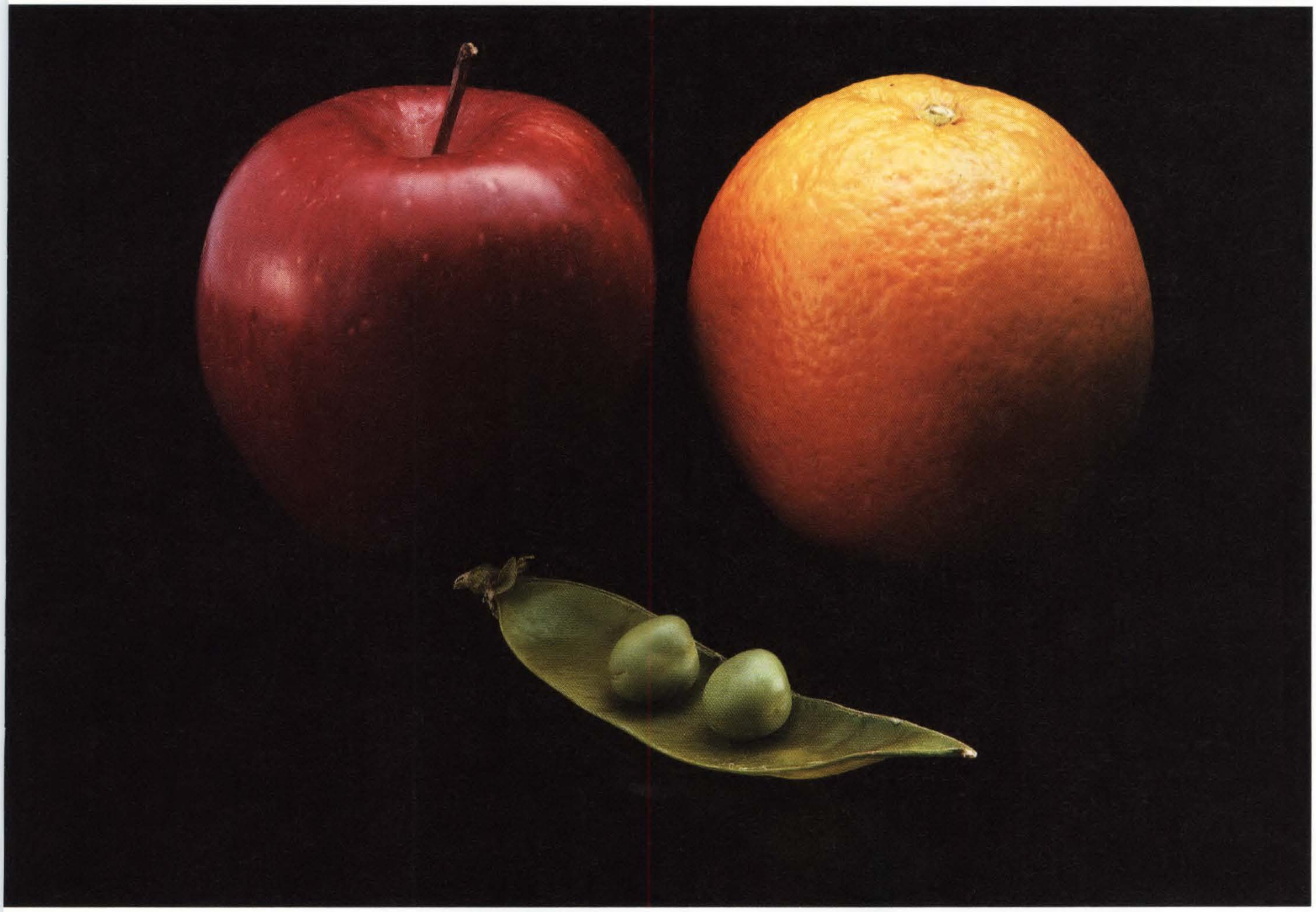
With Andrew, a user can access files at any node and even "borrow" excess computing power from other processor nodes on the network. In the network, a node doubles as a stand-alone workstation and as a file server supplying transparent file access to users.

Furthermore, Andrew's hardware independence is of interest beyond the ivy walls of academia. At Carnegie-Mellon, over 500 nodes are running with the software linking a mix of IBM RTs, Sun workstations, and Digital Equipment MicroVAX IIs.

Moreover, Andrew will have competition in the race to design the ultimate workstation software. Project Athena at the Massachusetts Institute of Technology, for example, includes X-windows, a windowing package for Digital Equipment's new high-performance graphics workstation, the VAXstation II/GPX.

—Ray Weiss

So, Is There a Real ASIC Second Source Setup in the Picture?



(Hint: Raytheon's RL7000 and LSI Logic's LL7000 are like . . .)

There's been a lot of wishful thinking about an active, genuine, semi-custom logic array second source. For very good reasons, but without a very good solution. Now, the right people, technology, and systems have been brought together. Raytheon and LSI Logic. It's happening.

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Access to the right technology

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Extra input JFET sharpens video buffer's fidelity

BY CURTIS PANASUK

Sunnyvale, Calif.—For want of an accurate video buffer, you could lose a million-dollar tester.

Suppose you are using a video buffer to provide a final boost of current for your tester's output waveforms. Suddenly, you discover that a perfect square wave is getting 10 mV of its negative extension shaved off. You figure something is wrong with the tester's generic LH0033 video buffer, but what?

Bob Underwood knows. Underwood designed the first LH0033 when he was at National Semiconductor. Now at Maxim Integrated Products Inc., he recently dealt with the incorrect waveform by installing an extra JFET and battery equivalent in the input stage of Maxim's buffer. He then rechristened the buffer the Max460.

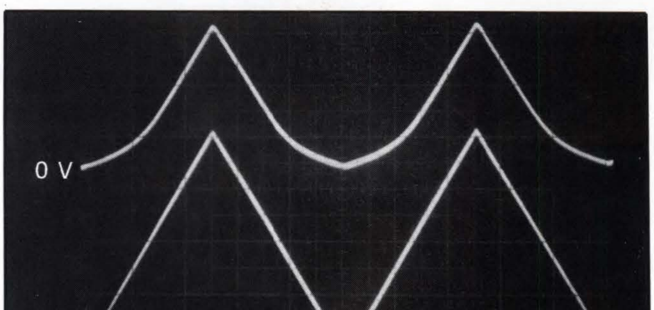
Underwood warns others to check their tester's buffer. "It is a matter of caveat emptor," he declares. "Any video buffer may exhibit the same distortion."

One characteristic of the LH0033 video buffer is its ability to boost 100-MHz waveforms to output drive levels of 100 mA. But another trait knocks the waveform's shape out of kilter: As the input voltage swings from a high value downward, the tiny amount of current that trickles out of every video buffer's input rapidly increases (Fig. 1).

STOPPING THE LEAKS

Known as input bias current, the leak increases by an order of magnitude for each 5-V decrease in input voltage. This effect is caused by avalanche current produced as the gate-to-drain current becomes more reverse-biased.

By the time the input voltage slides into the negative range, the input bias current has built up to 10 nA, distorting the waveform even



1. The trace at the top shows the distortion from a standard LH0033 video buffer and the corrected trace below. As the input voltage swings negative, a rush of input bias current transforms a triangle wave into a humpback wave. The voltage graticules are in 5-V increments, while the timing is in 200-ns segments. Therefore, from the 10-V peak, the unprotected current only drops to −15 V instead of to −10 V.

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COMPONENT NEWS

Vol. 3

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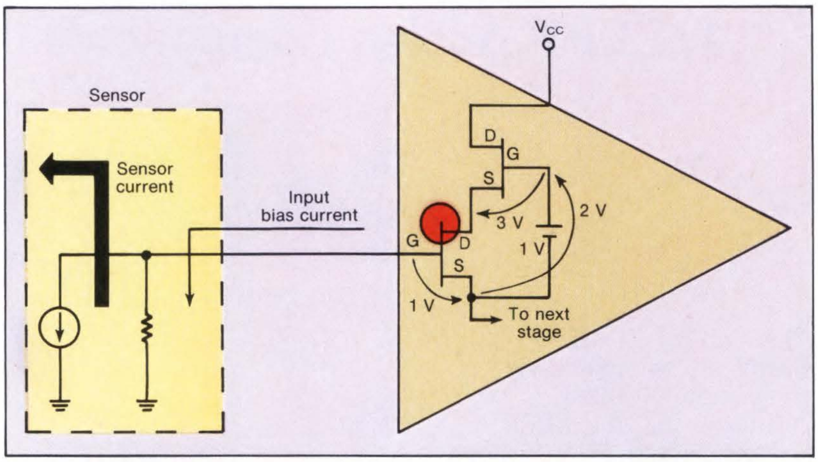
CIRCLE 23

before it reaches the next buffer stage. Naturally, at that point the input voltage significantly bucks the sensor current in the resistor, thus lowering the sensor voltage.

In a few cases, the sensor resistor is small and the voltage drop is not great enough to interfere with the signal. However, since the majority of sensors and signals that feed buffers come from high-impedance sources, the leak of the input bias current becomes significant. In addition to distortion, the current can drive many types of sensors haywire.

Underwood says his solution was simple, since the Maxim LH0033 substrate has room for the extra JFET and battery source (Fig. 2). Together, they deliver a constant 3-V difference between the gate and drain regardless of input voltage. This fixed gate-to-drain voltage of 3 V ensures that no avalanche breakdown will occur at any input voltage.

The Max460 comes with a price tag of $19.80 in quantities of 100, about $3 more than Maxim's version of the standard part, because of the extra components. □



2. The MAX460 packs an extra JFET and "battery," which ensure that the voltage from gate to drain (trace the red arrow) remains at a constant 3 V regardless of the input voltage level. Thus input bias current stays low for all input voltage values and the input voltage remains unaffected.

Standard tools launch Ada's civilian career

BY MAX SCHINDLER

Fort Lauderdale, Fla.—With about 30 validated compilers available, Ada—the Department of Defense's programming language of choice—has been flashing the "ready when you are" signal for several years. Yet, there have been few takers outside of the aerospace industry, because most potential users have been waiting for more efficient and affordable tools to appear.

Their wait is over.

Gould Inc.'s Computer Systems Division now offers Common Apse Interface Set (CAIS) to link commercial tools to Apse—the Ada programming support environment. The package contains the essential utilities for running Ada code, including a compiler, linker, debugger, and command line interpreter.

Although CAIS was written for

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NEWSFRONT

Gould's 32-bit superminicomputer running under UTX/32—a variant of the Unix 4.2 operating system—source code is available, for $500, to simplify adaptation to other machines.

CAIS furnishes the interface between the Apse kernel, which surrounds the hardware, and machine-independent development tools. Without the CAIS layer, development tools would have to be adapted for each machine, much as Fortran tools must be.

CAIS, which represents nearly 10 man-years of effort, is the first such interface for Ada that abides by the hardware-independence requirement laid down by the DOD's Ada Joint Program Office. Naturally, Gould hopes its self-funded effort will prove popular or even become a de facto standard.

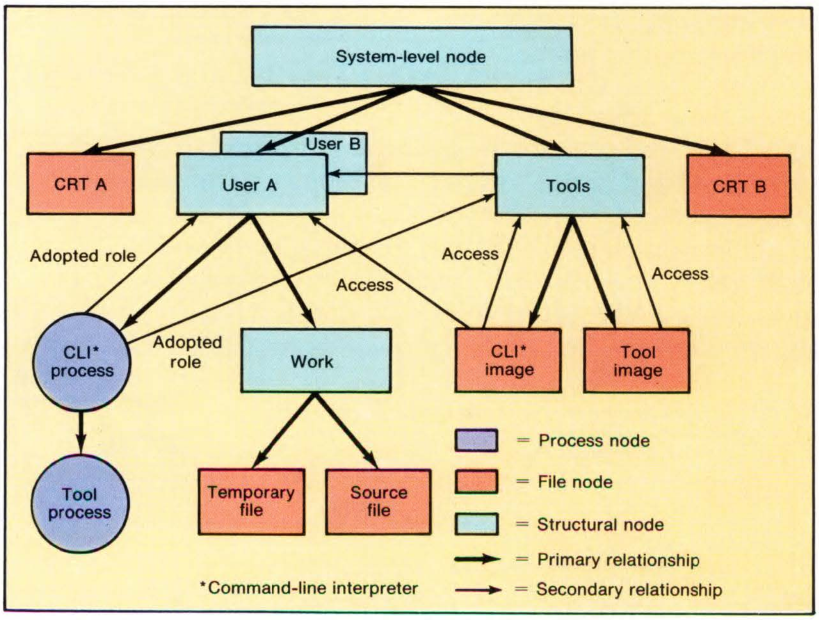
CAIS was more than just a programming effort. Rather, it is primarily an operational philosophy that took 50,000 lines of mostly Ada code (nearly 1.5 Mbyte) to implement in order to manage the often bulky Ada programs.

Because of the megabyte-and-up size of Ada programs typical for aerospace applications, precise and complete definitions of access relationships must be included in any tool kit. The philosophy behind CAIS begins with the program's files and modules, both called CAIS nodes. Attributes such as status, parameters, and access rights for each node are included in the program. Together, they determine what kind of interactions are permissible (see the figure).

Two types of relationships are defined in CAIS. Primary relationships essentially defined a hierarchy such as the typical parent-child arrangement. Secondary relationships may operate in the opposite direction or indicate external connections.

Some relationships—especially primary ones—are implicit in the environment, but most must be explicitly predetermined by the user. For example, preparing a specific configuration with two users and two output devices (see the figure) may take 10 minutes, but such is the price of file security.

In addition, once established, the definitions need not be repeated. Selecting primary and secondary links also presets default conditions. □



A simple configuration of nodes with two potential users illustrates the difference between primary and secondary relationships.

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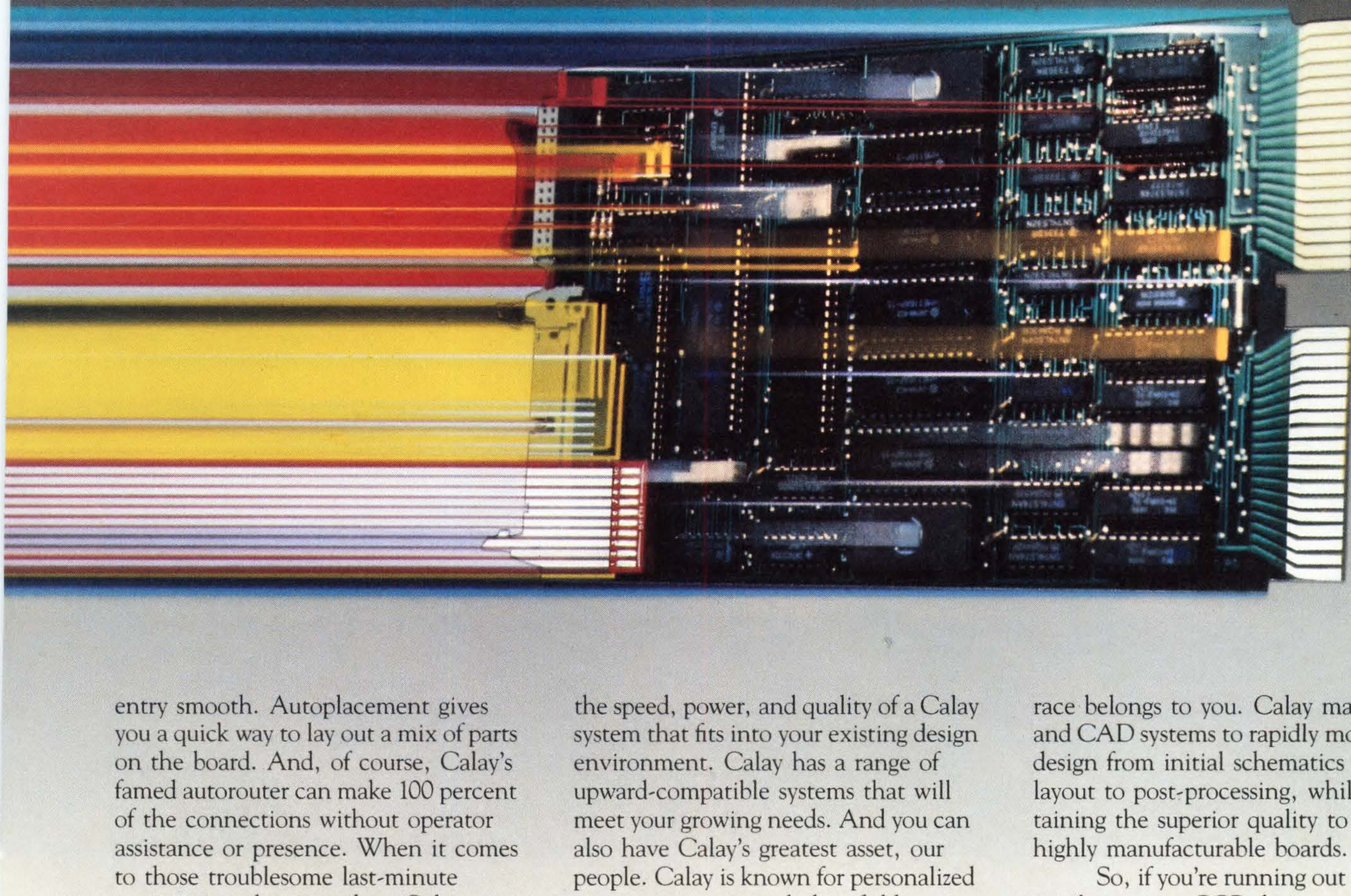

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CIRCLE 27

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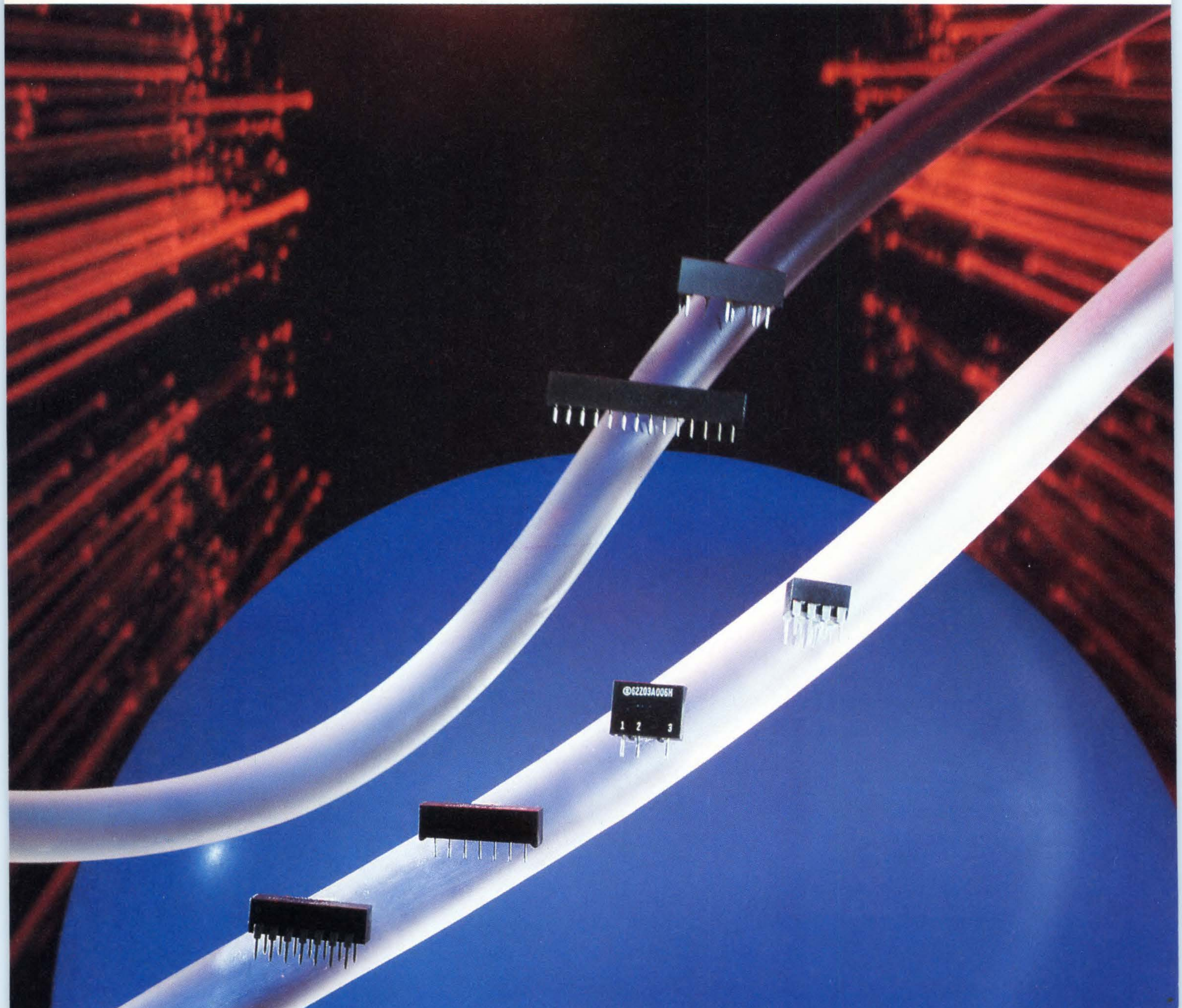

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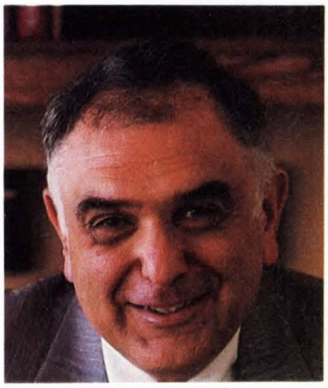
VIEWPOINT

EXCLUSIVE INTERVIEW

U.S. can compete in 1-Mbit DRAM arena



Paul P. Castrucci

Paul Castrucci is manager of IBM Corp.'s chip fabrication site in Essex Junction, Vt., where MOS memories and logic are produced. Employed at IBM for 30 years, Castrucci has held management positions in the company's component and system products divisions. He was named to his curent job in September 1984, and he has a bachelor's degree in physics from Union College in Schenectady, N.Y.

Cost-competitive 1-Mbit dynamic RAMs can definitely be manufactured in the U.S., contends IBM's Paul Castrucci. While most U.S. producers of memory circuits have abandoned the next generation of dynamic RAMs to Far East vendors, IBM is producing megabit memories in volume. Initially, the company is using them as the main memory in its top-of-the-line 3090 mainframe computers.

To produce megabit chips without delay, in high volume, and at reasonable cost, the company relies on existing fabrication equipment. IBM also calls on processing and design techniques—for example, redundancy—developed for its 288-kbit RAMs.

Stretching the lifetime of the fabrication line is critical to controlling costs. "The equipment for producing semiconductors today is perishable," he notes. "It may only be good for three to four years."

To turn out MOS devices with geometries of under 2 μm, IBM modified its Perkin-Elmer full-field projection aligners rather than using new step-on-wafer systems adopted by other companies. Engineers from the two companies tinkered with the projection unit to handle the 1- and 1.5-μm geometries in the megabit RAMs. The new devices are metal-gate NMOS.

IBM will switch technology strategies for the next generation of memory chips, though. "We are now developing new technologies in parallel," Castrucci says. "We will have to switch to silicon-gate processing—now running on the same fab line as metal-gate—to push geometries down to 0.7 μm."

Redundancy, he adds, is the key to reducing the impact of defects, especially in the early phases of the chip's life cycle. The IBM megabit chip, configured as 256k by 4 bits, has four extra word lines. Redundancy maintains high yields, because "defect control when building a perfect megabit chip is very difficult," he acknowledges. Smaller geometries exacerbate the difficulty: "A defect that did not hurt at 1.5-μm becomes a killer at 1 μm."

Indeed, the defect problem is so severe that several flawed megabit chips are used on some of the 3090's memory boards. The number of chips is doubled to 32 to fill a board with 2 Mbytes of memory. "The use of redundancy and partially good chips is very important in the front end of a program," Castrucci explains, "to increase the volume of devices we produce and especially to meet the schedule for the systems that incorporate these circuits."

While IBM continues to practice cost-saving tactics, he points out, U.S. dynamic RAM vendors choose to forsake the business. The withdrawal worries him. "The technology that drives this industry is pushed by dynamic RAMs," he laments. "I don't believe that a semiconductor producer can get ahead without dynamic RAMs."□

Martin Gold

EXCLUSIVE INTERVIEW

Digital scope interfaces can boost user productivity

Thomas E. Vos

Tom Vos has worked 20 years for Hewlett-Packard Co., the last three as general manager of the instruments division in Colorado Springs, Colo. He has also held a variety of engineering and marketing positions in the company's San Diego division. He holds a BSEE from California Polytechnic State University, San Luis Obispo.

Anytime you want to start a heated debate among electronics engineers, just broach the subject of human interfaces for digital oscilloscopes. Normally calm EEs offer impassioned, but differing opinions about whether digital scopes should have an analog feel, emphasize knobs over pushbuttons, or operate like logic analyzers. Tom Vos wants to tone down the rhetoric and focus on what he says is the real issue—productivity.

"As engineers, we need to take this debate to a much higher level," Vos urges. "The issues really boil down to whether you have random or sequential access to a scope's feature set and how that affects measurement productivity."

Vos explains that traditional analog scopes, with their multitude of knobs, offer random access to their features. Each control gives the user instant access to, say, triggering or time-base functions. The actual measurement process, though, is sequential.

"To measure rise time, for example, you begin by setting up the triggering," explains Vos. "Then the amplitude and time base are adjusted for an on-screen trace. Finally, the trace is aligned with the graticule markings to measure the waveform parameters."

With digital scopes, however, the user typically accesses the various features through a series of nested menus. This arrangement means that users go through a sequential process to access many scope functions. At first glance one would think the sequence wastes time, especially experienced users.

Vos is quick to point out, however, that many of these functions automatically measure waveform parameters. "All a user has to do is select 'rise time' and the digital scope gives him the answer," he notes. "So if you're interested in obtaining a measurement result, the bottom line is that digital scopes increase your productivity. The whole controversy of analog vs digital control recedes into the background."

Vos concedes that for certain types of troubleshooting, such as pinpointing circuit malfunctions, a mix of analog and digital controls is probably the best alternative because of the high degree of interaction necessary between the user and the scope. In those cases, he cautions, scope designers should avoid confusing the user. "For instance, to change the high-frequency reject on a trigger, do you send the user to an analog knob or to a softkey?" he asks.

In fact, Vos says some digital scopes today have worsened the interface problem by offering too many knobs coupled with a poor choice of analog and digital control functions. "Clearly, digital scope interfaces are improving, but I don't think we're all the way there yet," he emphasizes. "I think it's safe to say, though, that future digital scopes will give engineers a few knobs to turn."□

Bob Milne

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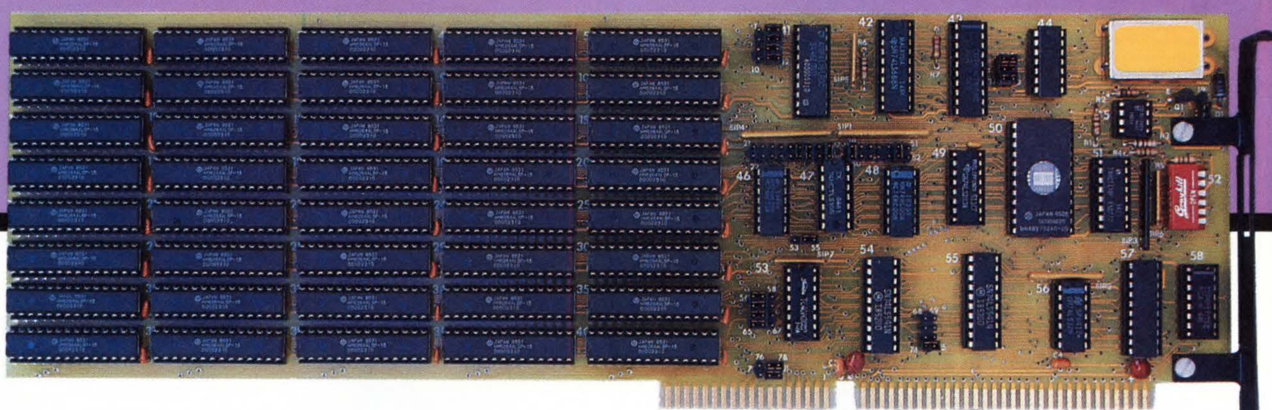

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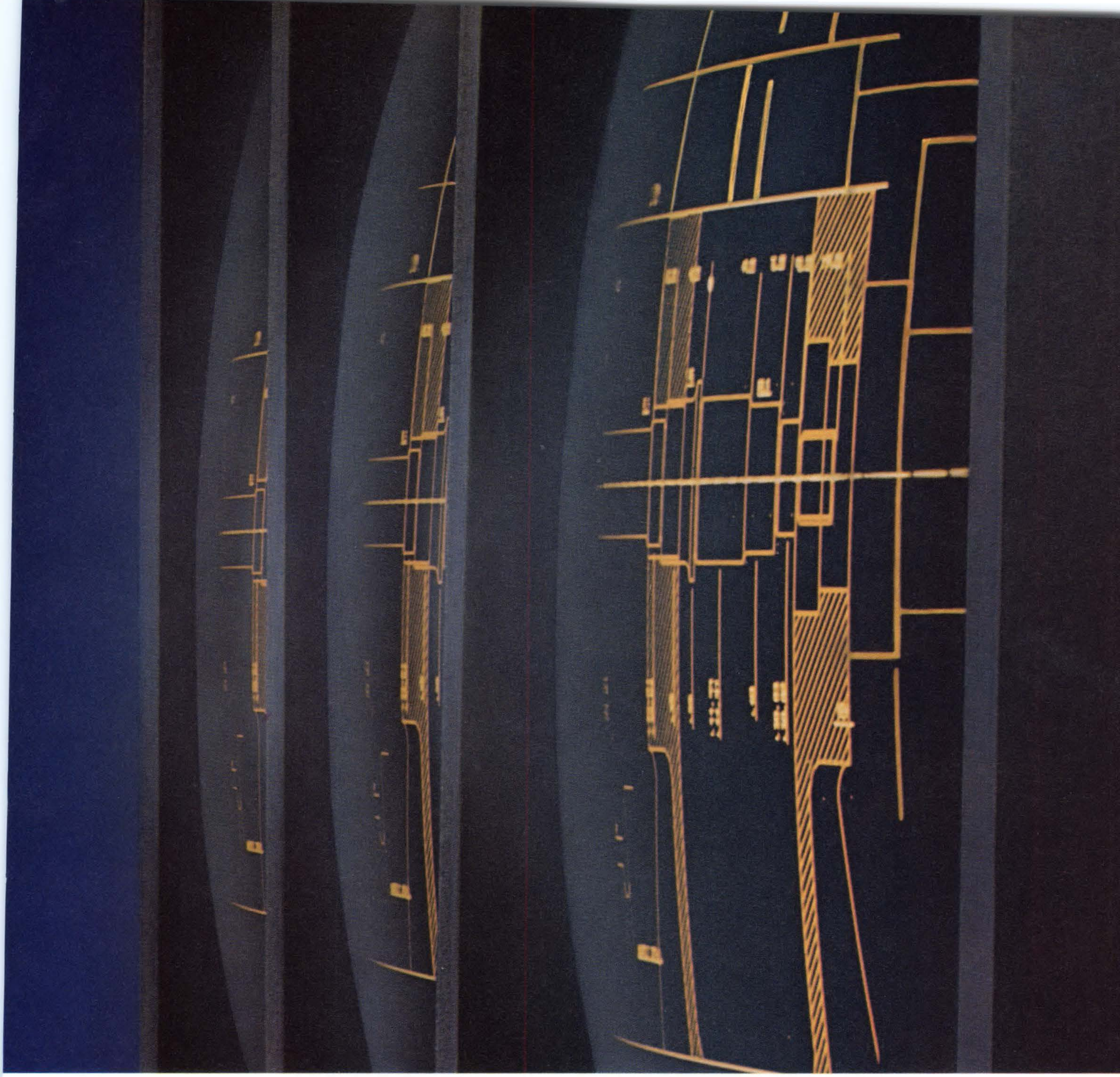

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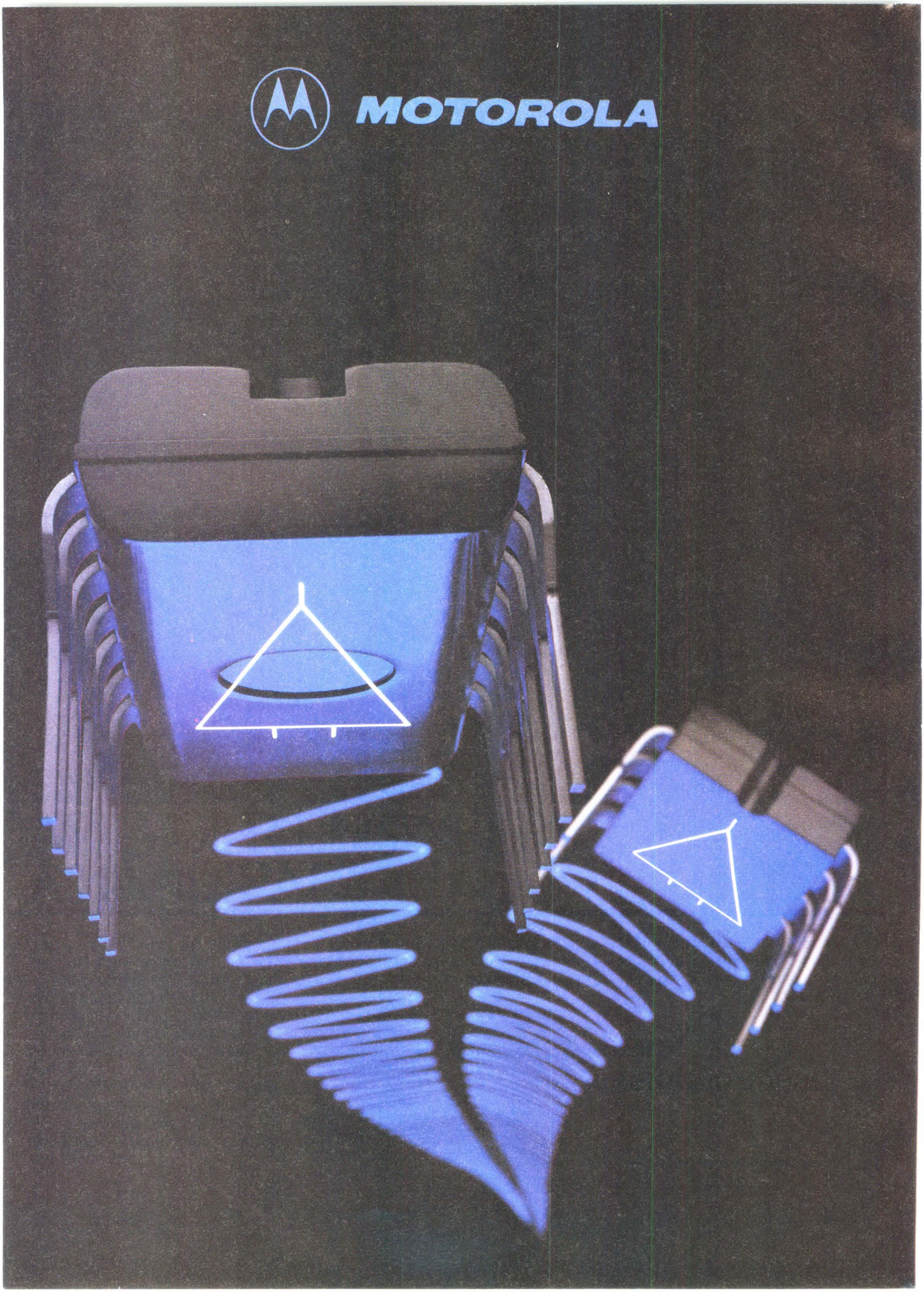
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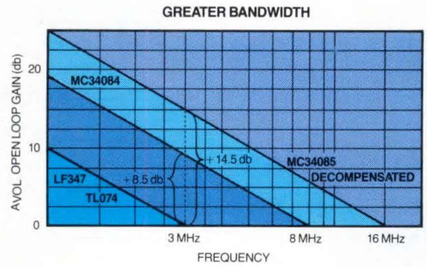

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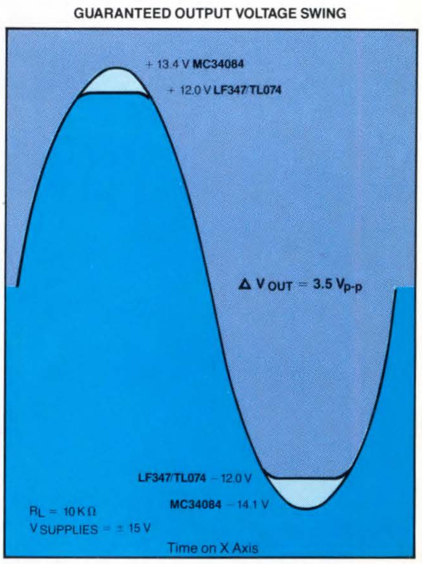

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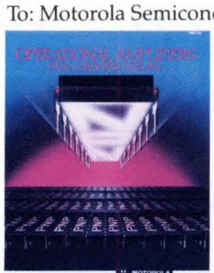

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DDC NEWS

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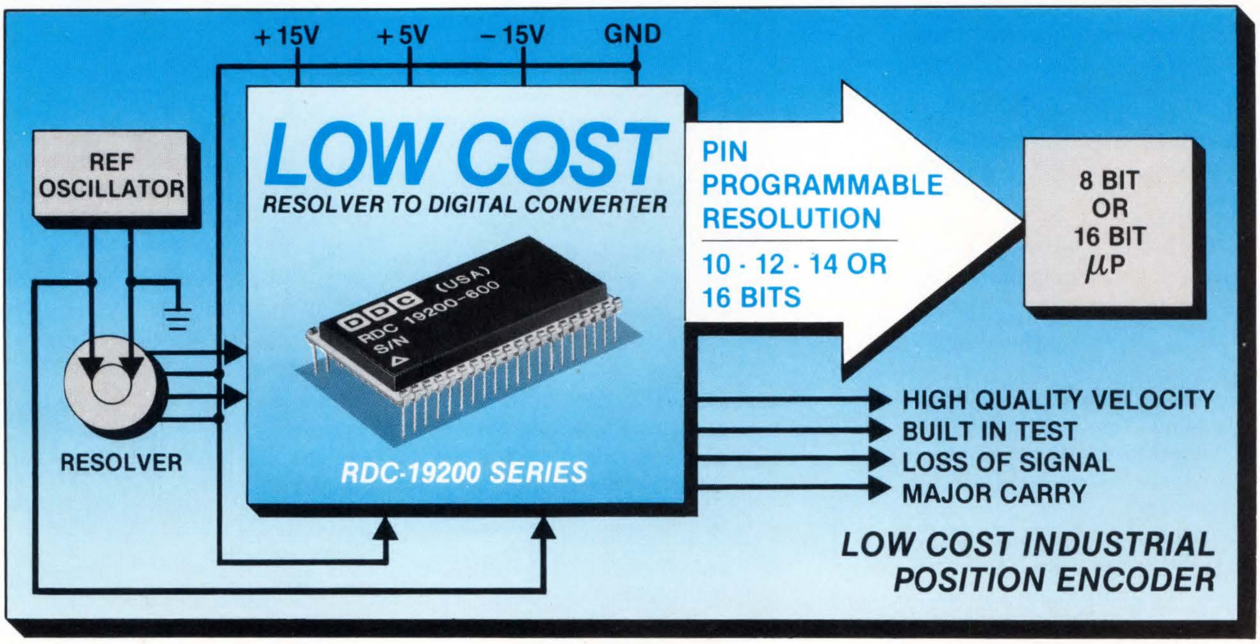

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A high quality velocity output (VEL) is also provided by the RDC-19200. VEL is a ground based voltage of 0 to ±10VDC at the maximum tracking rate of each resolution. VEL is positive for an increasing angle. Should an application require less than ±10VDC at the highest tracking rate, VEL can be scaled down with an external resistor.

The RDC-19200 incorporates a custom LSI chip in its circuitry, characteristic of DDC's well known Monobrids®. This results in fewer parts, thereby increasing reliability. Power consumption is just 450mW.

All RDC-19200 converters offer Built-In-Test (BIT), Loss of Signal (LOS) outputs and a choice of either 11.8V or 2.0V input. The internal servo loop is a type II design which exhibits no lag up to the specified tracking rate.

The converters are packaged in a compact 40 pin TDIP measuring 1.1" x 2.0" x 0.23" and weigh 0.5 oz. Two operating temperature ranges are available: 0°C to +70°C and −30°C to +150°C.

The RDC-19200 converters coupled with brushless resolvers, result in high reliability while lowering costs. Use of the VEL output, eliminating the tachometer, results in near term cost reduction. Because the converter/resolver combination is inherently rugged and reliable, long term repair and maintenance costs are minimized.

The RDC-19200 Series are designed for modern high performance commercial and industrial control systems. Some typical applications are CNC machine tooling, motor control, antenna positioning, robot axis and process control. Contact the DDC office nearest you to learn how the RDC-19200 can improve your designs and lower your costs. □

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ELECTRONIC DESIGN EXCLUSIVE

Test instruments tackle fiber optics

Offering full HP-IB programmability, four fiber-optic test instruments emphasize accurate and stable measurements.

BOB MILNE

Engineering is as much a science of repeatable measurements as it is of innovative design. Paraphrasing Lord Kelvin, unless you can measure something, you really know nothing about it. Nowhere is that more relevant than in systems that are pushing the limits of today's technology—fiber optics, for example.

Fiber-optic communication systems are shifting from short-wavelength operation, at about 850 nm, to longer wavelengths of 1300 to 1550 nm. That change, coupled with the growing use of single-mode rather than multimode fibers, calls for reliable instrumentation equipment that can handle the broad bandwidths and deliver the high stability required for single-mode operations.

The payoff of reliable measurements can be big, not only for individual manufacturers but for the industry as a whole. Testifying on the proposed budget for the National Bureau of Standards' fiscal year 1987, John W. Lyons, director of the NBS engineering laboratory, told the House Subcommittee on Science, Research, and Technology that better measurement technology will play an important role in the ability of the U.S. fiber-optic industry to compete with countries such as Japan.

Against this backdrop, four instruments from Hewlett-Packard—all targeting 1300- and 1500-nm applications—make a timely entrance. The HP 8154B 1300-nm LED source, the HP 8152A optical average power meter, the HP 8158B optical attenuator, and the HP 8159A optical switch all can be programmed over the company's HP-IB bus (Fig. 1).

Stressing accuracy and stability, the instruments offer a one-year calibration cycle. Moreover, their accuracy specifications can be traced to the NBS and to West Germany's Physikalisch-Technische Bundesanstalt (PTB) national standards laboratory.

Leading off the group is the high-performance 1300-nm LED source, which blends both short- and long-term stability. Consider the short term: Within a 1-hour time frame and an environmental temperature change of ±2°C, the unit's output power varies less than 0.02 dB (and that includes the effects of the output optical connector).

Now for the long term. Over one year and an operating temperature range of 0° to 55°C, the instrument exhibits a stability of better than 0.3 dB. That predictable performance translates into shorter measurement time and fewer pieces of test equipment, since power levels need not be monitored constantly.

MEASURING POWER

Whereas many power meters are optimized for a particular wavelength, the HP 8152A optical average power meter accepts plug-in optical heads that feature individual calibration factors as a function of wavelength. A high-performance lens assembly transforms the input light into a parallel beam with a constant 3-mm spot. The germa-

1. Four fiber-optic test instruments from Hewlett-Packard combine stability and accuracy with full HP-IB programmability. In the top row are an optical attenuator (left) and an optical average power meter. At the bottom are the LED source (left) and the optical switch.

nium p-i-n diode detector in the head is thermoelectrically cooled to −15°C to achieve a noise floor well under −70 dBm.

Fitted with the HP 81521B optical head, for example, the meter attains a relative accuracy of ±0.15 dB over +3 to −50 dBm. What's more, it reaches that performance over 1000 to 1600 nm and 0° to 40°C. If the ambient temperature is held to 25°C ±2°, as it would be in a typical lab, the relative accuracy improves to ±0.05 dB.

Before shipment, all optical heads are individually calibrated over the full wavelength range, and the sensitivity factors are individually stored. A user simply enters the wavelength of interest, and the unit automatically takes into account the corresponding correction value.

The meter is sufficiently accurate to serve as a secondary standard in a metrology laboratory or as a reference unit for power measurements. At 1300 nm, the absolute calibration accuracy is better than 5%, traceable to the PTB laboratory.

The power meter seems to be tailor-made for evaluating wavelength-division multiplexers. Given its two optical inputs, it can measure two independent power levels simultaneously—at the same or different wavelengths. The $4^1/_2$-digit display is backed up by status and error indicators, along with an analog meter that determines optical coupling efficiency and helps select the best measurement range.

Setup is a snap. A microprocessor-driven menu uses only the minimum number of accessible measurement functions needed to properly control the instrument. To further simplify operation, pressing the AUTO key selects the measurement range with the best signal-to-noise ratio for a particular power level. When the optical signal falls below 10% or when it exceeds 90% of full scale, the next proper range is selected automatically.

Optical power measurements can be displayed in linear notation (picowatts to milliwatts) or in logarithmic notation (dBm). Moreover, the output power may be shown as decibels relative to a user-set reference.

Each time the meter is turned on or after it receives an appropriate HP-IB command, it tests itself for possible hardware failures. If it detects one, it displays a self-diagnostic code that pinpoints the origin of the problem. The same hardware diagnostic information can also be passed over the HP-IB.

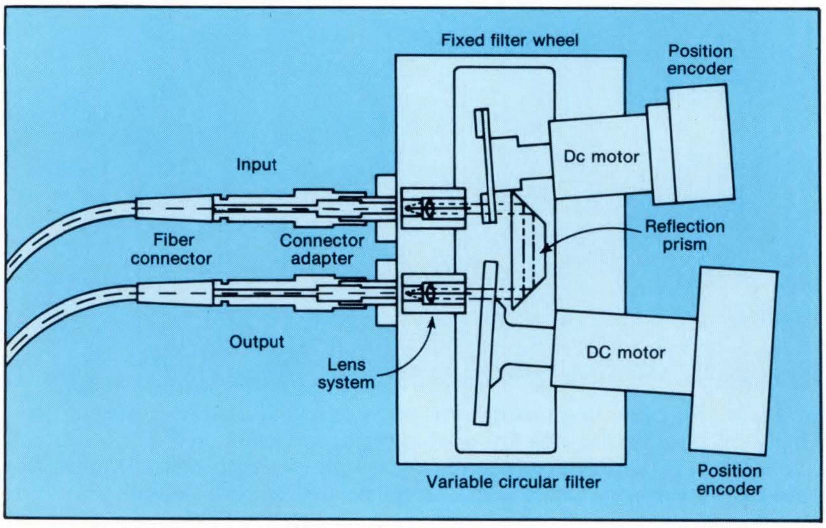
OPTICAL ATTENUATOR

Using an advanced optical system that incorporates no fibers, the HP 8158B attenuator works with any fiber core. It is calibrated at both 1300 nm and 1550 nm before shipment, proving suitable for both single-mode and multimode fibers.

Attenuation can be set over 0 to 60 dB with a resolution of 0.1 dB and a repeatability of 0.04 dB. Accuracy of that sort allows a user to program the unit directly for any required attenuation without resorting to a power meter to monitor the actual value. This eliminates error-prone manual reconnections.

To attenuate signals between the unit's two optical ports, a high-precision optical system collimates the light of the input fiber to an expanded parallel beam and refocuses it onto the output fiber (Fig. 2). A reflection prism, a five-step fixed filter, and a continuously variable circular filter all lie between the two lens systems. The five fixed filters supply attenuation in 10-dB steps over 1200 to 1650 nm. Augmenting them is a continuously variable circular filter with 0.01-dB resolution; it adjusts attenuation between the 10-dB steps.

The filters are coated with a metallic material, the optical density of which is independent of wavelength. To prevent interference modulation and minimize insertion loss, all optical surfaces are coated with multilayer, broadband reflection coatings. Moreover, the filters' angle to the optical axis prevents back-re-



2. The HP 8158B optical attenuator uses no fiber-optic cables in its light path. Instead, it employs fixed and variable filters containing neutral-density metallic-coated optics.

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Fiber-optic test instruments

flection into the fibers.

Two digitally controlled motors and an optical encoder keep both filters aligned to the optical path. Realignment typically takes less than 50 ms. With fiber optics, any misalignment between two fibers increases the coupling loss of the attenuator. To counter that, the fiber ends must be exactly positioned in three planes. Therefore, the attenuator's connector adapters are precisely adjusted at the focal point of the lens system with better than 0.2-μm repeatability.

To maintain the precision over the attenuator's operating life, each connector adapter uses a hard-metal bushing and a Diamond hard-metal connector, the HMS-10. The combination typically keeps insertion loss, including both connectors, to 3 dB for single-mode operation and to 1 dB for multimode.

Containing 50/125-μm graded-index fibers, the HP 8159A optical switch features a repeatable insertion loss of better than 0.2 dB. It accommodates all common wavelengths between 820 and 1300 nm. Moreover, its two inputs, A_{in} and B_{in}, and two outputs, A_{out} and B_{out}, can be combined under program control in the following three configurations: A_{in} to A_{out}, B_{in} to B_{out}, or A_{in} to B_{out}.

Furthermore, because the switch can be used to eliminate manual reconnection of a device under test to a reference power meter, it can automate production-test measurements. Switching at 20 Hz, it helps shorten measurement times—an important consideration in any testing situation manual or automatic. Moreover, because crosstalk between the two channels is more than 50 dB down, interference between channels does not influence the test results.□

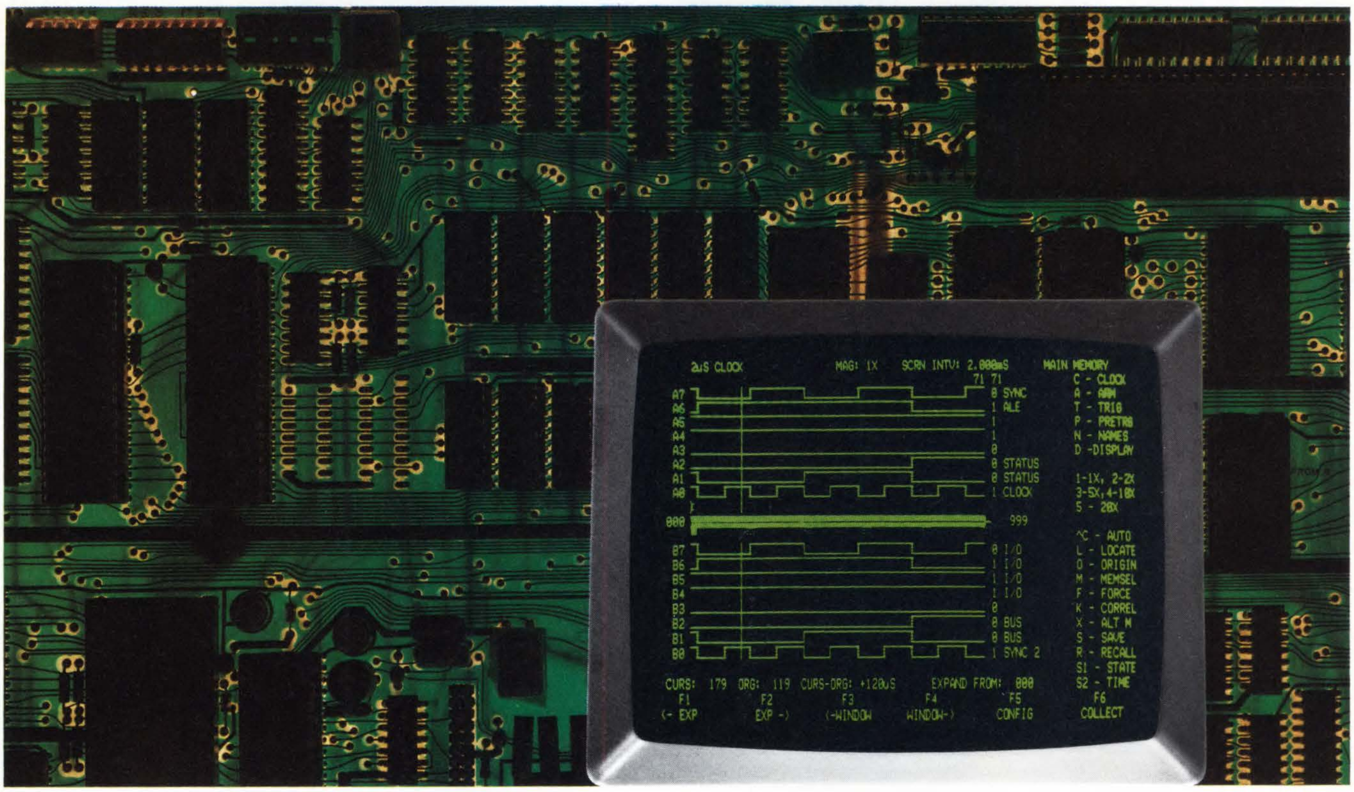
Price and availability

The HP 8154 LED source is priced at $4900 and the HP 8158B optical attenuator at $6100. Prices for the HP 8152A optical average power meter and the HP 81521B optical head are $2900 and $1750, respectively. The HP 8159A optical switch goes for $4300. Delivery is within six to eight weeks.

Hewlett-Packard Co., 1820 Embarcadero Rd., Palo Alto, CA. CIRCLE 512

CIRCLE 98

THE TOTAL LOGIC ANALYSIS SYSTEM



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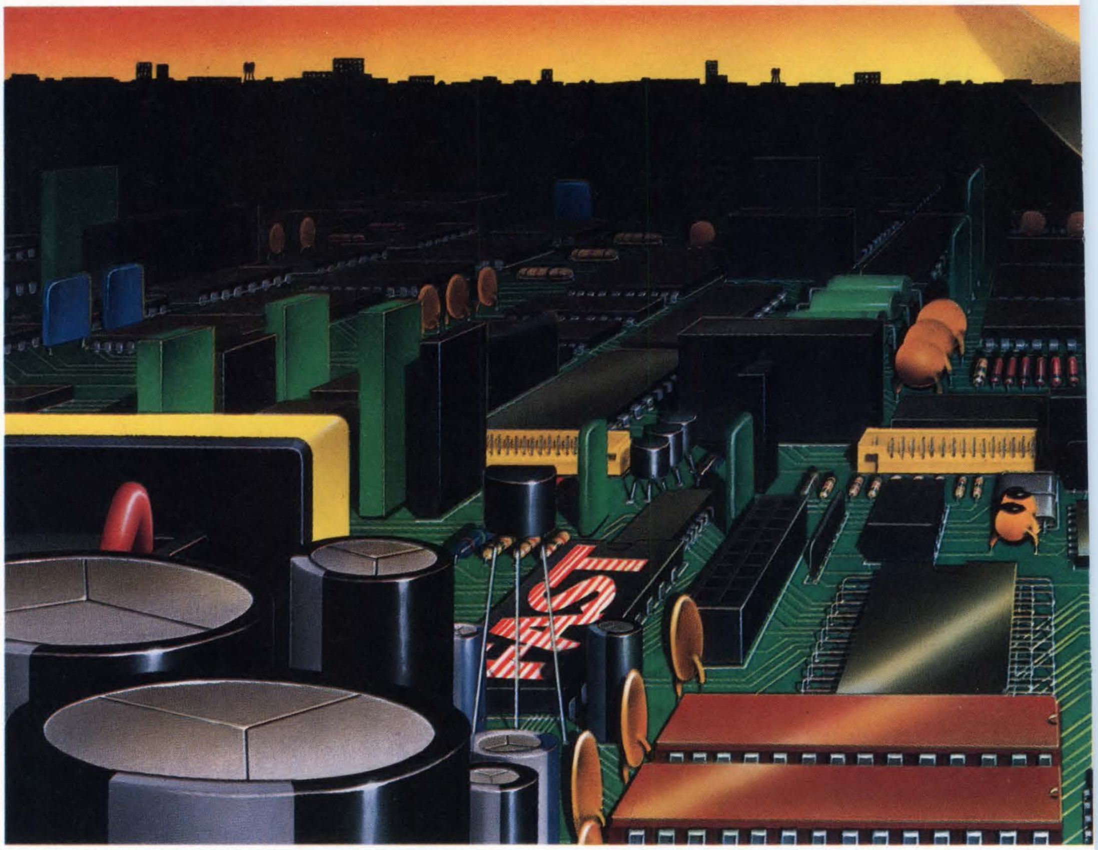

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CIRCLE 36

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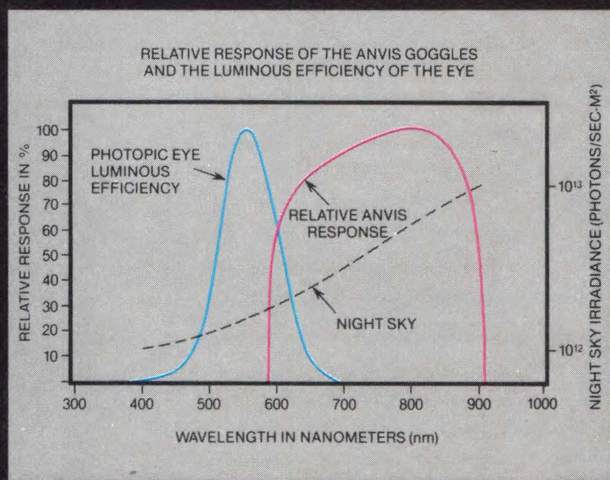

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CIRCLE 37

ELECTRONIC DESIGN EXCLUSIVE

Image IC detects edges in real time

The first single-chip edge detector races through 225 million operations/s to replace boards and systolic arrays in image analysis.

BY MITCH BEEDIE

Before any image-processing system, including the human eye, can enhance or indeed make sense of what it sees, it must detect the image's edges and determine their orientation. Plessey's CMOS edge detector chip, the PDSP16401, does those fundamental jobs and also delivers a 13-bit word that gives a measure of how sharp the edges are. The IC handles images at input data rates of 15 MHz and makes its mark as the first single-chip edge detector to process broadcast-quality images in real time.

Working with three simultaneous streams of 10-bit pixels, the chip churns through a massive 450 Mbits/s and 225 million operations a second. That sort of performance traditionally belonged to boards packed with expensive ECL and TTL components or to large systolic array processors needing complex software. As part of its great attraction, Plessey's IC does all processing exclusively in hardware, so it needs no software.

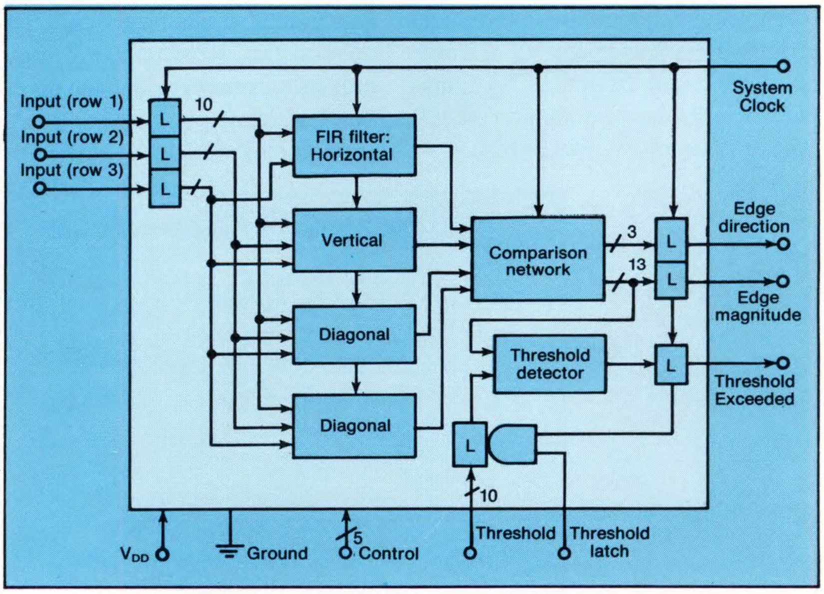
PIXEL PUZZLE

When the edge detector IC examines a pixel, it also takes in the eight surrounding pixels, for a square block containing nine pixels. It compares the block against four convolution masks, looking for the sharpest edge in the horizontal, vertical, and two diagonal directions.

Since a light-to-dark transition has the opposite sign of a dark-to-light one, the four masks can detect an edge in any one of eight orientations. The directions—defined as the vector normal to the edge, heading from dark to light—are indicated by a 3-bit output, coded from north (000) counterclockwise to northeast (111).

The brightness of each pixel is represented by a 10-bit value. Each mask assigns a weight factor to individual pixels and multiplies the 10-bit value of each pixel by the factor. Weighting helps accentuate changes in brightness in the corresponding direction (see the table, p. 58).

The horizontal edge mask, for example, multiplies the pixel values in the bottom row by -1, in the middle row by 0, and in the top row by $+1$. It then algebraically adds the nine numbers together. Thus, if there is no change in brightness across the nine-pixel block, the negative factors counterbalance the positive numbers, making the sum zero. If brightness changes significantly across the block, the brighter pixels will outweigh the dimmer, and the sum will be a larger number, either positive or negative. Identical operations, using a different weighting scheme, are simultaneously conducted on the same nine pixels for



The edge-detector chip uses four finite impulse response filters that act as convolution masks to accentuate any edges in the image being scanned. The comparison network selects the sharpest edge and indicates its direction and degree of sharpness.

Single-chip edge detector

the other three directions.

The resulting four sums, one for each direction, are compared in pairs—horizontal vs vertical and diagonal vs diagonal. Run in parallel, the comparisons take only 50 ns. The largest sum indicates the presence and direction of the edge. In this way the IC convolves incoming pixels (literally, rolls them together) into one value, which represents the central pixel in the incoming block.

The convolution masks are implemented by four finite-impulse-response (FIR) filters (see the figure), the outputs of which give the degree of correlation between the image and that mask. The arrangement effectively forms four high-pass filters that pick out the high-frequency changes caused by edges in one of four directions.

The sharpest possible edge causes the masks to produce a signal that is at most four times the maximum 10-bit input signal, adding 2 bits to the length of the 10-bit word. Two's complement arithmetic in the filter contributes another sign bit, and one more bit comes from the 1.5 scaling factor in the horizontal and vertical masks. The total is now 14 bits.

The outputs from the filters are compared, sorted, then retranslated into unipolar arithmetic to form a 13-bit word. That output, representing the sharpness of the edge, finds a variety of uses, including following brightness trends in the image. It can be truncated, for example, to 8 bits to match the word length of the subsequent image enhancement circuit.

A WEIGHTING GAME

The circuit's simple weighting coefficients allow the filters to use only shift, invert, and delay elements for multiplication and addition. For instance, the input for row 2 need not be connected to the horizontal FIR filter, since the row coefficients for that filter all are zero. Multipliers, which consume chip area and are inherently slow, are not needed.

In addition, the filters are set up in a pipelined fashion that saves gates over a full carry-look-ahead circuit. The pipeline results in a total latency of 20 cycles for the chip. The normal line stores of an image-processing system afford the necessary line delays.

A 512-by-512-pixel image requires 2.5 million multiplication operations and 2 million additions for one frame—all done within the 20-ms video frame. The pace corresponds to the real-time rate of 225 million operations/s.

ON THE THRESHOLD

A threshold detector produces an output when the 10 MSBs of the edge magnitude output exceed a 10-bit external threshold level. With the variable threshold, the image recognition and enhancement circuits following the edge detector work at much lower data rates than they would with high-speed video images. Therefore they can be controlled by standard microprocessors like the 68000.

The chip is designed with Plessey's Megacell system and represents the first Megacell-based device available outside the company in production quantities. Put into silicon at the company's Caswell Research Laboratories, it accepts a 5-V supply, dissipates less than 1 W at the full 15-MHz clock frequency, and works between 0° and 70°C.□

Pixel weighting factors

Orientation	Mask	Scaling factor
Horizontal	1 1 1 0 0 0 −1 −1 −1	×1.5
Vertical	−1 0 1 −1 0 1 −1 0 1	×1.5
Diagonal (bottom left to top right)	2 1 0 1 0 −1 0 −1 −2	×1
Diagonal (top left to bottom right)	0 −1 −2 1 0 −1 2 1 2	×1

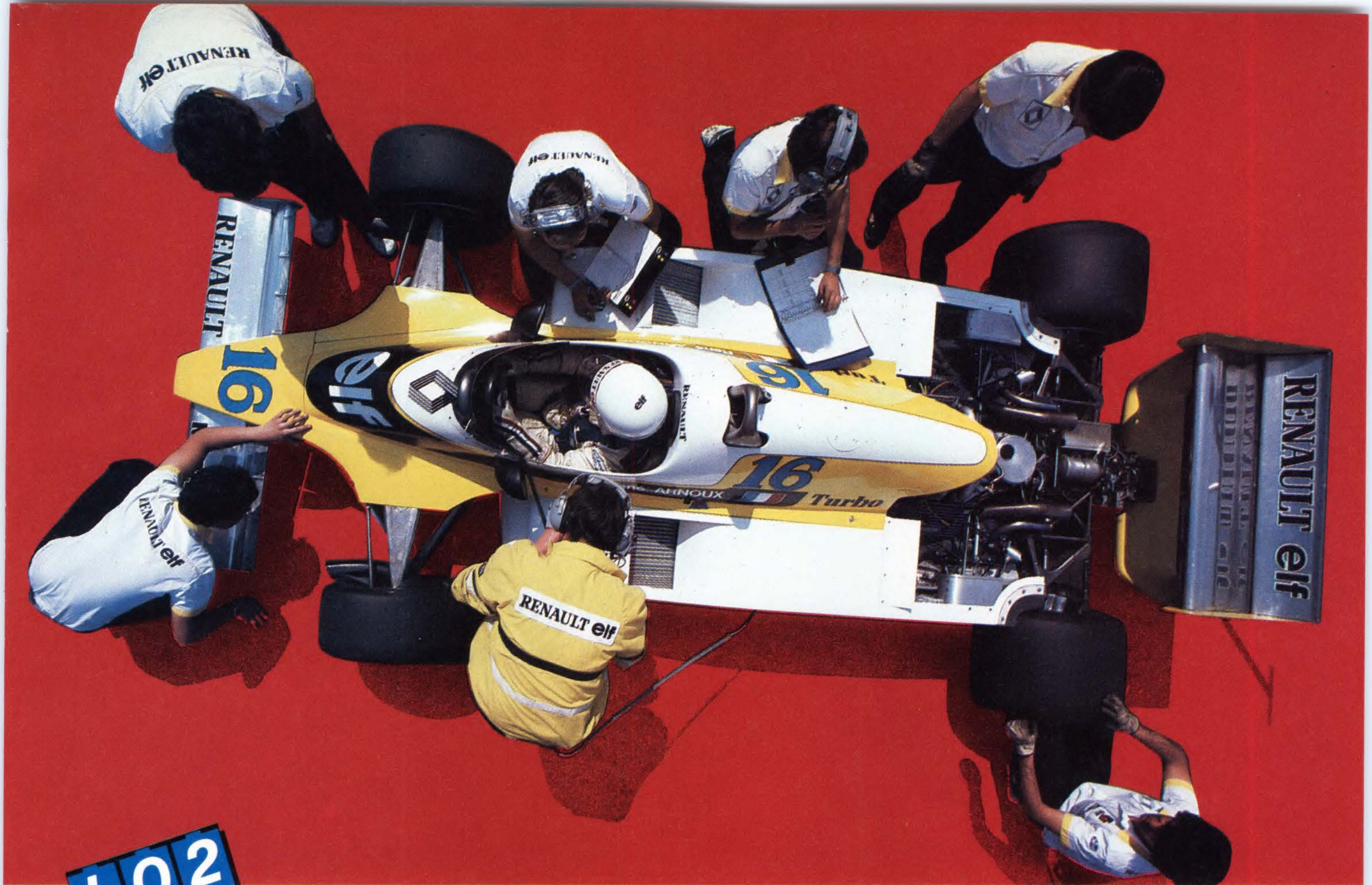
Note: The scaling factor of 1.5 (which is easier to calculate than the actual figure of $\sqrt{2}$) for the horizontal and vertical masks corrects for the greater weightings of the diagonal masks.

Price and availability

Samples of the PDSP16401 edge detector are now available, and the chip is slated for full production in July. In a 68-pin leadless ceramic chip carrier, it costs $365 in quantities of 100; in a pin-grid array package, it costs $342 in similar quantities.

Plessey Semiconductors, 3 Whatney, Irvine, CA 92718; (714) 951-5212. **CIRCLE 513**

Plessey Semiconductors Ltd., Cheney Manor, Swindon, Wilts., SN2 2QW, England; (+44) 793-36251; Telex: 449637. **CIRCLE 514**



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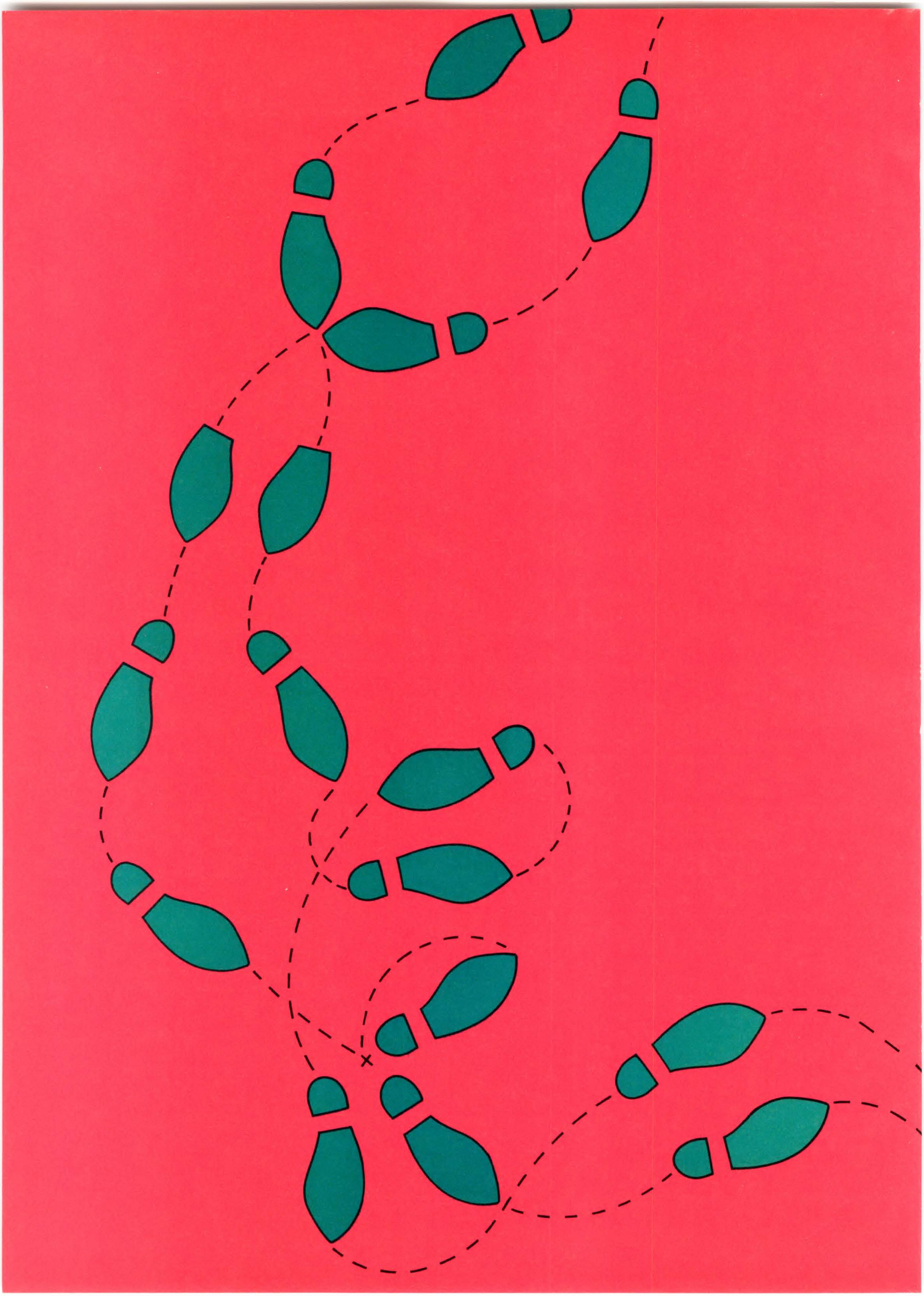
CIRCLE 38



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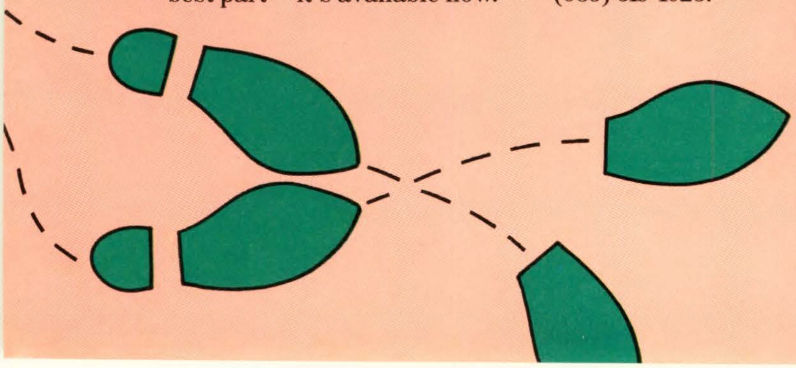
CIRCLE 39



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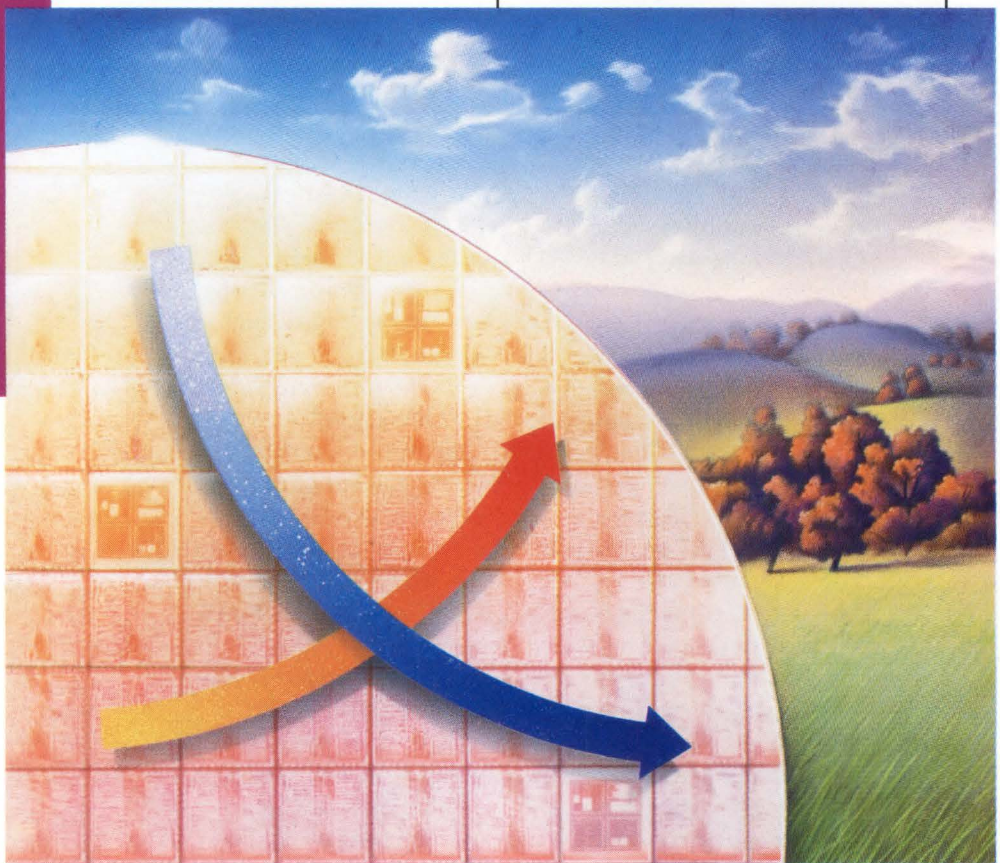

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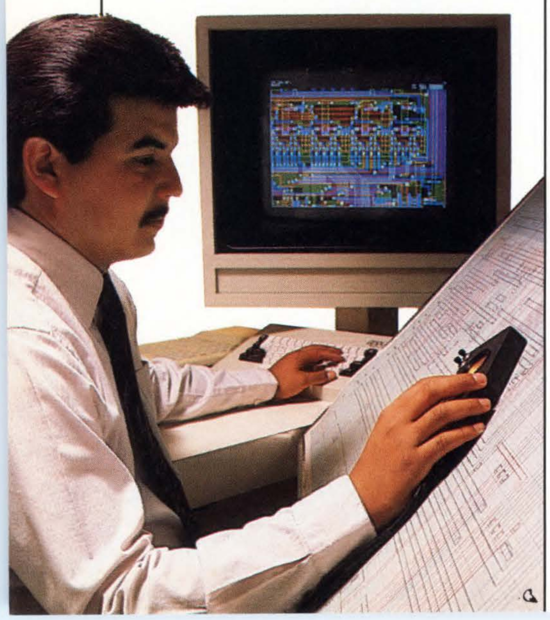

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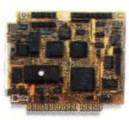

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chip controller that turns SCSI from scuzzy to sexy. A new QIC-36 streaming tape controller device. And an RLL hard disk controller with 56-bit ECC.

Our board engineers have been busy too. Integrating our new VLSI into solutions that address the emerging high performance disk markets of (2, 7) RLL and ESDI, as well as new technologies such as optical.

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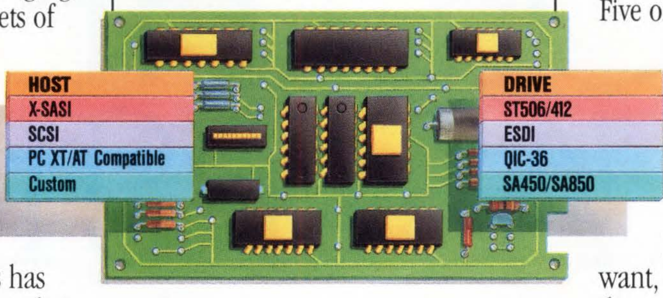

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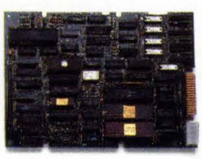

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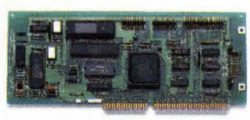


WD1003-WAH 100% PC AT compatible hard disk controller for up to two ST506 drives.

CIRCLE 100

ELECTRONIC DESIGN EXCLUSIVE

Flashy 8-bit ADC samples at 25 MHz

Nonlatching comparators permit a low-cost 8-bit flash converter to sample 12.5-MHz signals at their Nyquist rate of 25 MHz.

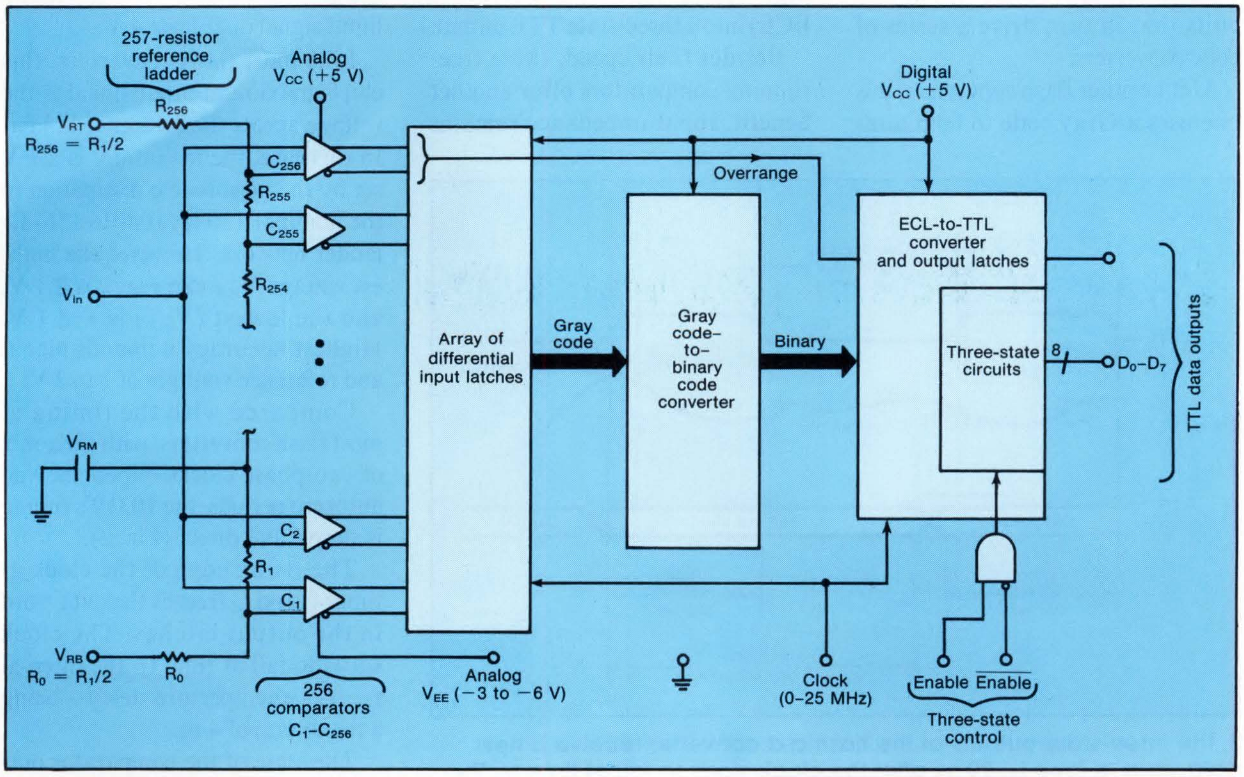
BY FRANK GOODENOUGH

Flash analog-to-digital converters are inherently faster than any other type, bar none. They confront their task and overpower it with a bank of comparators that match the input signal to a voltage along a reference voltage divider, instantly producing a digital representation of the signal's amplitude. Could anything be faster? A flash converter in which the comparators never saturate.

To ensure that their digital output stands still long enough to be grabbed by a microprocessor or memory, virtually all flash converters use comparators that are latched—that is, strobed by a clock pulse to a fixed state. Alternatively, an expensive hybrid sample-and-hold amplifier would be required at the signal input. However, the latched comparators are limited in speed by the time needed to unlatch them and get their transistors out of saturation.

Designers at Motorola Semiconductor take a different course: By allowing the comparators to run free, they get top speed from the transistors in their 8-bit, 25-MHz converter, the MC10319. Since the comparators neither latch nor saturate, they continuously change state as they track the variations in the input signal.

To avoid the now apparent demand for a sampling amplifier on the chip's input, two sets of latches are incorporated in the chip: The first set, the comparator output latches, tracks the comparators' state until strobed by the clock when they latch. The second set, the data output latches, holds the digital output still until the first set is latched. The digital word in the first set is



1. Motorola's MC10319, an 8-bit, 25-MHz flash a-d converter, owes its speed and accuracy to an architecture employing 256 free-running rather than strobed comparators.

then transferred to the second set.

The converter, a device built with a 3-GHz bipolar process, allows you to sample dc-to-12.5-MHz signals at the Nyquist rate of 25 MHz. (Input bandwidth is 50 MHz.) Priced at $19.97 in 1000 quantities (about one-third the going rate), the converter takes aim at instrumentation, television, and transient-capture systems with arrays of converters.

At first glance, the 10319 looks like nearly any other flash converter (Fig. 1). The signal drives the input of all 256 comparators, while their other inputs receive the 256 taps on the reference ladder (R_0-R_{256}).

But that is where the similarity ends. The comparators are built as current-steering circuits, running at maximum transistor speeds. Like ECL, they remain in a pseudolinear state and never saturate. They drive the comparator output latches, themselves differential-input circuits that in turn drive a series of code converters.

Unlike other flash converters, this one uses a Gray code to help minimize errors. This code has long been used in high-resolution optical shaft encoders and high-speed ripple-through a-d converters. It changes only one bit at each code transition. For example, in changing from decimal 127 to 128, binary code has to go from 0111 1111 to 1000 0000, flipping all eight bits. The Gray code, however, goes from 0100 0000 to 1100 0000, changing only one bit.

Gray code ensures that small errors (a few least significant bits) at the comparator's output—errors caused by crosstalk, feedthrough, or "race" conditions in the timing—will result in correspondingly small output errors, rather than the quarter- or even half-scale errors that arise with binary code.

The latches' output is converted from Gray code into binary and finally from ECL levels (most of the high-speed logic in the device is ECL) into a three-state TTL output.

Besides their speed, these free-running comparators offer another benefit. Input impedance remains constant, while that of most flash converters appears as a rapidly changing capacitance—which can make them a problem to drive.

The 10319's input, however, has the appearance of a fixed resistor and capacitor in parallel.

Input resistance is specified in terms of an input current that varies between -100 and $+150$ μA, depending both on the polarity and on the value of the signal as it ranges from zero to full scale. Input capacitance, which is partially related to junction capacitances, ranges between 35 and 55 pF, depending on the reference voltage.

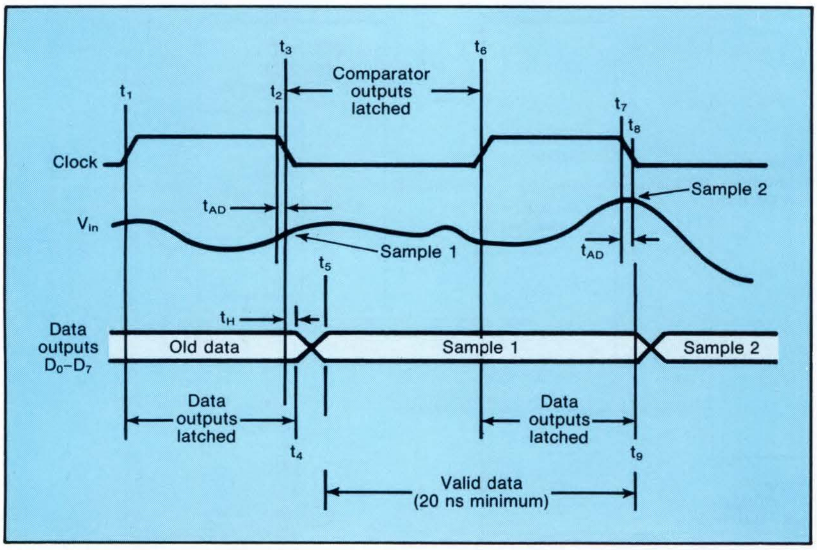
Driving this converter's input takes nothing more than an op amp or buffer capable of swinging a 1- to 2-V input signal into about 1-kΩ and 50 pF. Some of the earlier converters required an amplifier with a few ohms' output impedance at 10 times the clock frequency, along with an input signal of at least 4 V.

Like most flash converters, this chip's maximum input signal is the voltage across the reference ladder. In this case, the maximum is 2.1 V set by the permissible dissipation in the nominal 130 Ω (104- to 156- Ω) ladder network. However the highest voltage V_{RT} can reach is 2.1 V, and the lowest (V_{RB}) is -2.1 V. Highest accuracy demands signal and reference voltages of 1 to 2 V.

Compared with the timing of most flash converters, with their mix of two-phase clocks, pipelines, and autozero periods, the 10319's timing is simple and direct (Fig. 2).

The rising edge of the clock at times t_1 and t_6 freezes the data word in the output latches. The clock starts to fall at time t_3, the interval $t_2 - t_3$—the aperture delay—being a maximum of 4 ns.

The state of the comparator output latches represents the value of the analog input at that instant: 4 ns



2. The three-state outputs of the flash a-d converter receive a new data word at time t_5, 20 ns after the clock starts to fall at time t_2. The data remains valid except for the 14 ns between times t_4 and t_5, when the data word changes.

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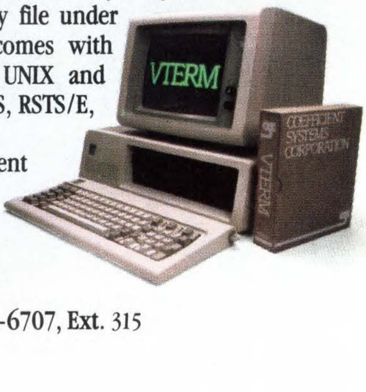

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CIRCLE 42

25-MHz flash ADC

± 100 ps after t_2. (Aperture uncertainty stands at 100 ps.) The output latches are released 6 ns later, at time t_4 (the end of the hold time, t_H; within 14 ns, at t_5, a new data word appears at outputs D_0 through D_7.

During the following period, when the clock is low, the comparator outputs are latched, while the data-output latches are released. When the clock goes high again at t_6, the data outputs are latched and the comparator latches are freed to track the input.

High and low clock times are a minimum of 5 and 15 ns, respectively. While some flash converters and some other sampling devices have a minimum clock rate, this one has none. To summarize the timing: Any time the clock is high, fresh data is available at the output 4 ns after the clock starts to fall.

That type of timing makes the converter especially suitable for applications that grab transient phenomena. A number of the devices can be used together to take sequential samples of the same signal.

The converter's typical $\pm 1/4$ LSB integral nonlinearity over the commercial temperature range (0° to 70°C) and its overrange output (the 256th comparator) lend it to a number of other jobs.

However, at commercial temperatures the converter needs to be linear only to within $\pm 1/2$ LSB. Thus, the extra $1/4$ LSB of linearity means it can be used at a far wider temperature range. In fact, Motorola is characterizing the device over the military temperature range.

The overrange output permits a pair of converters to be stacked in series to get 9-bit resolution; the $1/4$ LSB linearity indicates 9-bit accuracy is also possible, maybe without trimming.

Finally, the chip's low power, typically 600 mW, puts it in a class with hard-to-drive CMOS converters. □

Price and availability

In a 24-pin double-width ceramic DIP, the MC10319 flash a-d converter goes for $19.95 each in 1000-piece quantities. For 10,000, the unit cost falls to $16.50. Small quantities are available from stock.

Motorola Semiconductor Products Inc., 7402 South Price Rd., Tempe, AZ 85282; PR 340 Dennis Morgan (602) 897-3872. **CIRCLE 511**

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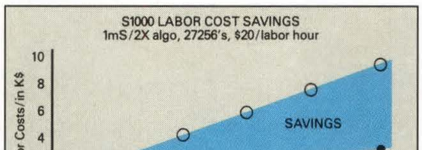

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CIRCLE 45

For the Technical Professional:

The story behind IBM's new 32-bit RISC PCs.

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The IBM RT PC 6150 Model 20
Floor-standing unit

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One of the key programs available for the IBM RT PC—attached to the IBM 5080 Graphics System—is Professional CADAM. And it's compatible with established host-based CADAM.

There's also Computer-Integrated Electrical Design Series (CIEDS), which allows for the schematic capture of integrated circuit designs.

And there is a growing list of applications available from software companies in the following fields: mechanical and electrical CAD/CAM, petroleum production, artificial intelligence, software engineering, project management and graphics.

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The primary operating system is derived from the UNIX System V—with some very important enhancements added by IBM. These enhancements make this operating system—Advanced Interactive Executive or AIX[3]—much easier to use, give it improved performance and reliability, and also add a virtual storage capability.

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There is also a full-function IBM SQL/RT relational data base management facility available.

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And as for general-purpose applications, you'll be able to run UNIRAS[4] (for engineering and business graphics), RS/1[5] (for data analysis and graphing functions), IMSL[6] (a library of Fortran subroutines), Interleaf's Workstation Publishing Software[7], Solomon III[8] (for accounting), SAMNA+[9] (for spreadsheet and word processing) and Applix IA[10] (for integrated office functions).

PC Compatible

The IBM RT PCs can incorporate as an optional feature an Intel 80286 coprocessor (in effect a PC AT on-a-board) that runs concurrently with the 32-bit RISC processor. That means the RT PCs can support many existing IBM PC applications and the interchange of their related data. It also means the RT PC I/O bus can accept standard PC cards.

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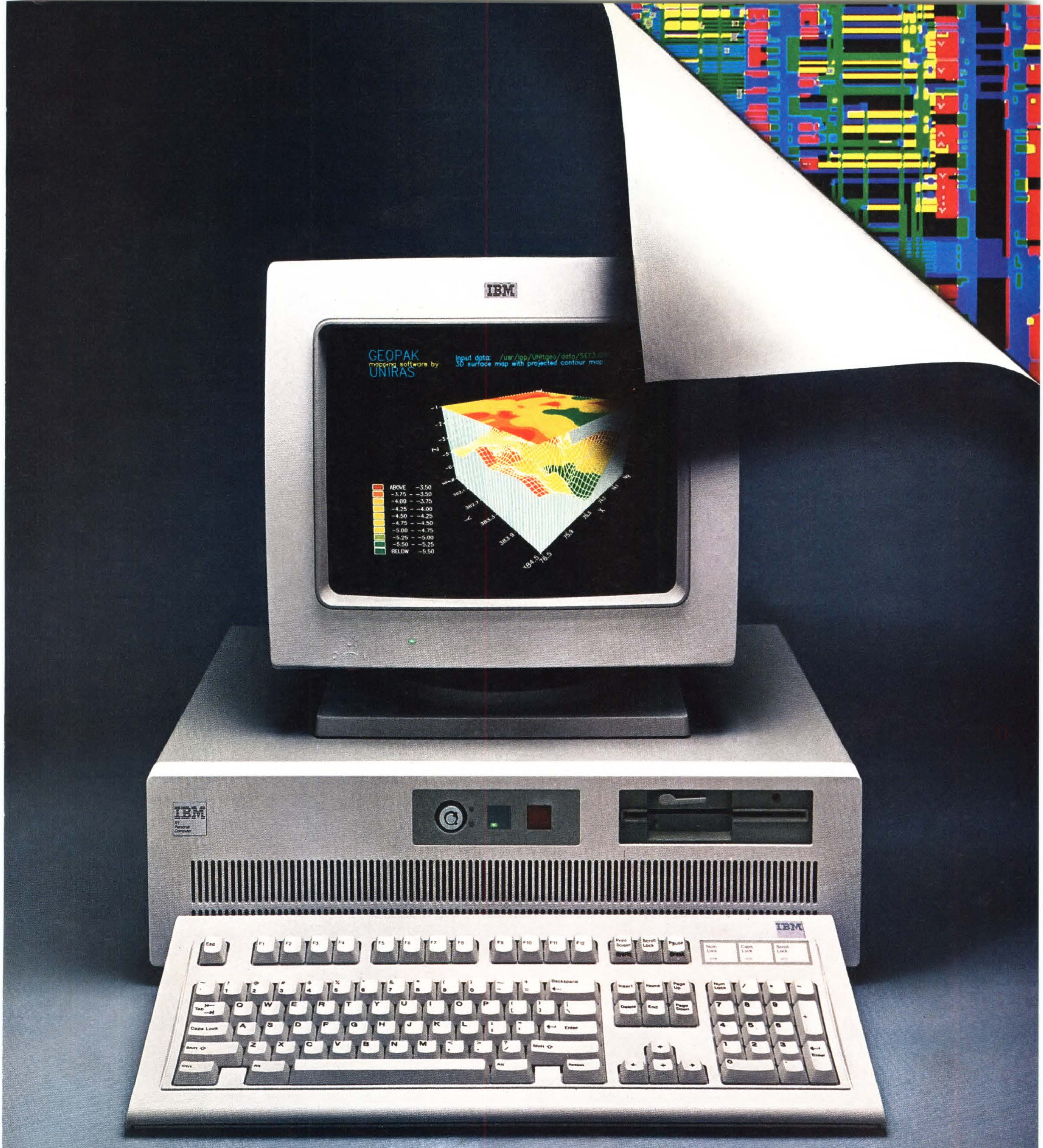
CIRCLE 46



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Desk-top unit**

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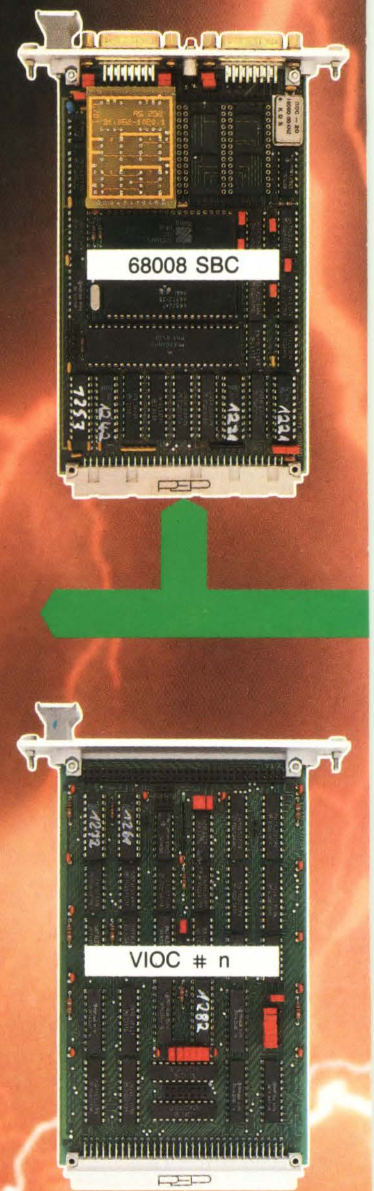

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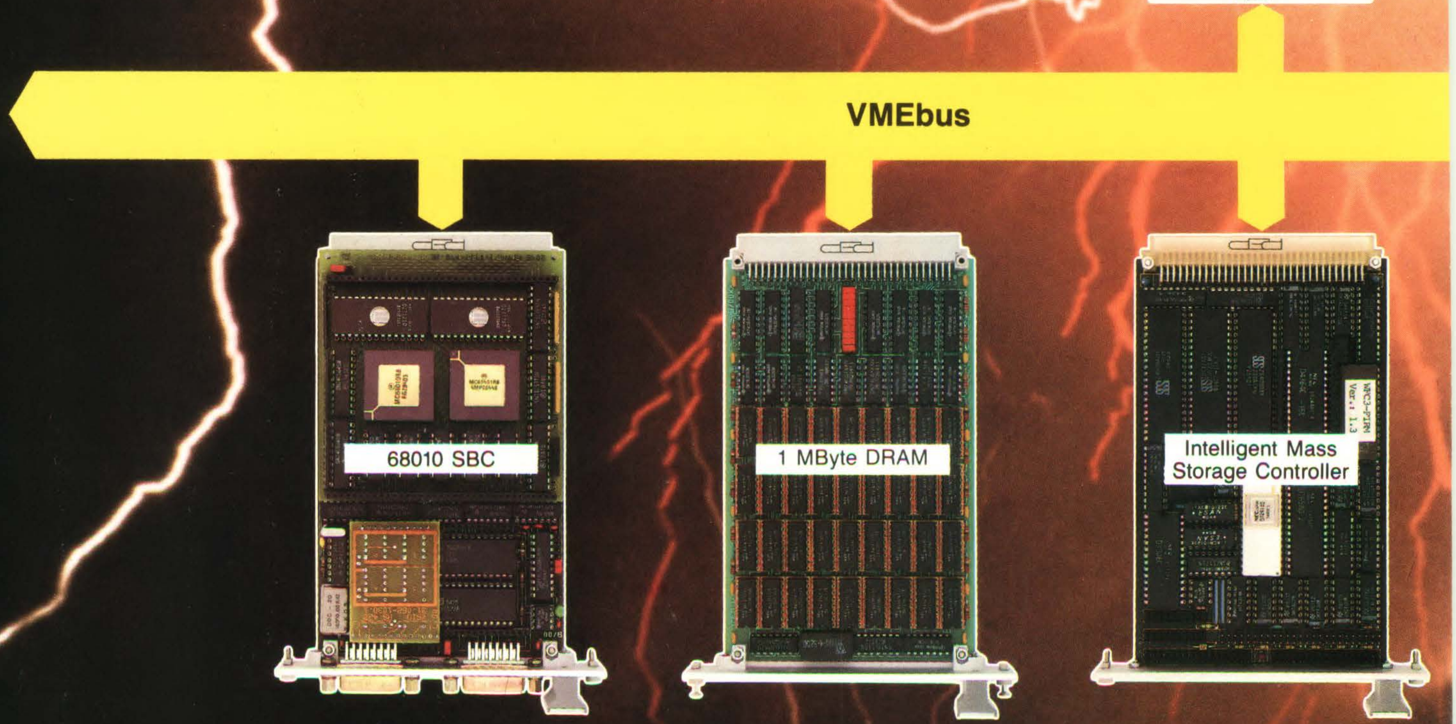

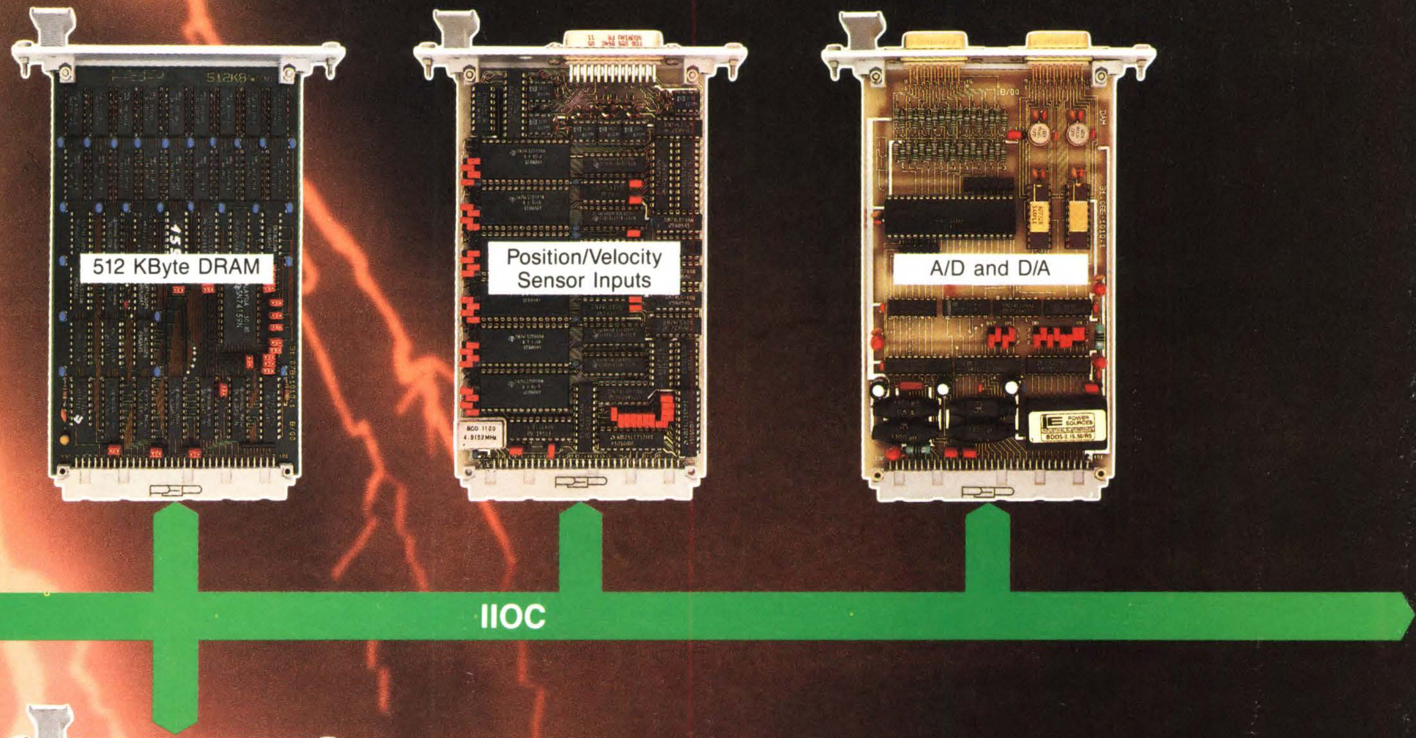

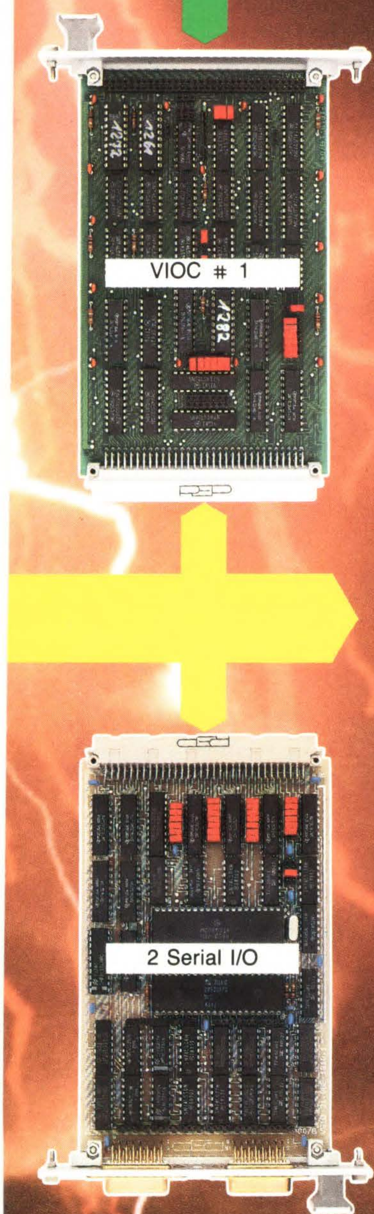

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CIRCLE 47

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HP-IB Interface: $400

Prices are U.S.A. list prices only.

Call 800-523-2121 ext. 961 for technical literature, and a new demonstration disc that simulates system operation. Or call your local HP sales office listed in the white pages of your telephone directory. Ask for the Electronic Instruments Department.

HEWLETT PACKARD

CIRCLE 48

HP—IB 3478 Voltmeter

AD 2115651

Powerful Unix-based workstations take on minicomputers, mainframes

Low-cost 32-bit microprocessors pair up with standard Unix operating systems to deliver heavy-duty processing to engineers' desktops.

BY RAY WEISS

Engineers are about to be freed from the frustrations of queuing up for computationally intensive projects. No longer will tasks like simulation, large-scale compilation, and modeling be the domain of minicomputers and mainframes alone. Desktop workstations, based on the Unix operating system, have arrived for full-scale 32-bit processing. Typically, they contain at least 2 Mbytes of memory as well as floating-point processors, virtual-memory–mapping hardware, and peripherals. Moreover, many stations include special hardware and software to deliver high-resolution color images and three-dimensional graphics.

Within the Unix environment, these new workstations put interactive computing into the hands of any engineer or programmer. Furthermore, they provide first-class user interfaces that match those of far more expensive systems. And at the heart of these powerful Unix-based workstations are 32-bit microprocessors like Motorola's 68020 and National's 32032.

Unix, primarily System V from AT&T Co. (Morristown, N.J.), is rapidly becoming the standard workstation operating system (see "The End of the Unix Wars," p. 76). Accordingly, a wide range of application programs is emerging to run under it. Those programs, along with user-written software, are truly portable: They can run on any Unix-based workstation with only minor modifications.

Thus, users are freed from dependence on a single workstation supplier, especially since some major manufacturers, like Digital Equipment Corp. (Fig. 1), have entered the fray. Users may buy workstations from various sources, aiming their purchases at specific applications. Furthermore, they need not worry about a vendor leaving the workstation arena or taking an unwanted product direction—they can simply move their software to another workstation.

Critical to the success of 32-bit workstations in the engineering world is their ability to fit into a network. Engineers and programmers rarely work alone; they need to gather information from others and to send their results off as well. Placing a full 32-bit processor onto an engineer's desk may ease the load on the organization's main processor, but it does not lessen the requirements for an integrated environment and a common data base.

Now, networking is becoming a reality for Unix-based workstations. Above the Ethernet and TCP/IP level, file system packages enable files to be accessed remotely and programs to be executed across a full network. The Network File System, developed by Sun Microsystems Inc. for its Unix workstations, has been placed in the public domain and is on its way to becoming an industry standard. Engineers can

1. Digital Equipment's VAXstation II/GPX sports two processors. The main processor is a 32-bit workstation version of the successful VAX architecture, the MicroVAX II. The graphics processor is in the display where it speeds up graphic processing.

use the system to access files across the network through a so-called stateless server, which carries no internal states and therefore recovers easily from system failures.

AT&T's System V.3 will contain a network file package based on the Berkeley 4.2 BSD remote file system. The package, which permits both file access and remote execution, is based on the International Standards Organization's Open Systems Interconnection model. Another network system, the Freedomnet, was developed by the Center for Digital Systems Research (Research Triangle Park, N.C.) and released by Butler & Curless Associates (Raleigh, N.C.). Built for a distributed Unix network, it permits remote program execution and device sharing. Moreover, it is transparent to the user and automatically handles differences in file and hardware formats.

The workstation world is no longer the province of the smaller, more innovative manufacturer. Some of the major computer companies, including Hewlett-Packard Co., IBM Corp., and DEC, have started to produce 32-bit Unix workstations.

HP (Palo Alto, Calif.) was the first to make a commitment with its version of Unix, called HP-UX, and a subsequent series of workstations. The company's latest stations include the HP9000 Model 320, which is based on the 68020 microprocessor, and the Model 550, which is built around a proprietary chip set. Both are directed toward engineering applications. HP is also fielding software packages for artificial intelligence development, including CAE and Lisp programming.

Both IBM and DEC have introduced Unix-based workstations this year. IBM's series of RT personal computers is based on the company's own 32-bit RISC architecture (Fig. 2). The 2-MIPS workstations run a variation of Unix, derived from the Berkeley 4.2 BSD, and are also compatible with System V. Although the machines are intended to serve as engineering workstations, many other application packages have already been ported to it.

DEC introduced a 32-bit graphics workstation called the VAXstation II/GPX (Fig. 1 again). Based on the MicroVAX II, the system includes a separate color graphics processor and features an advanced windowing package. Labeled X-Windows, the package comes with DEC's version of Unix—Ultrix 32W. With this combination, users can run remote graphic programs throughout a network.

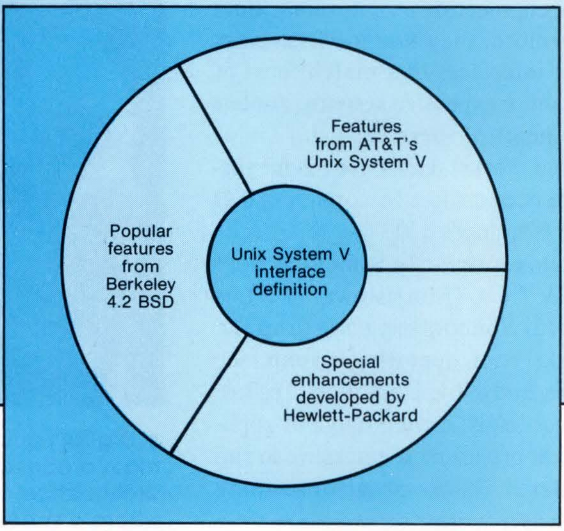
DEC brought out the MicroVAX II workstation last year. The machine runs under versions of Ultrix,

The end of the Unix wars

This year should mark the end of the Unix wars. The battle for supremacy is waning as the various Unix suppliers move their implementations toward compliance with the Unix System V releases from AT&T, meeting the compatibility standards set forth by the System V interface document. Thus, they will provide an application-portable base for Unix systems. Furthermore, by year's end their versions will have to pass the AT&T System V validation suite developed by Unisoft Inc. (Berkeley, Calif.), the 68000 Unix supplier.

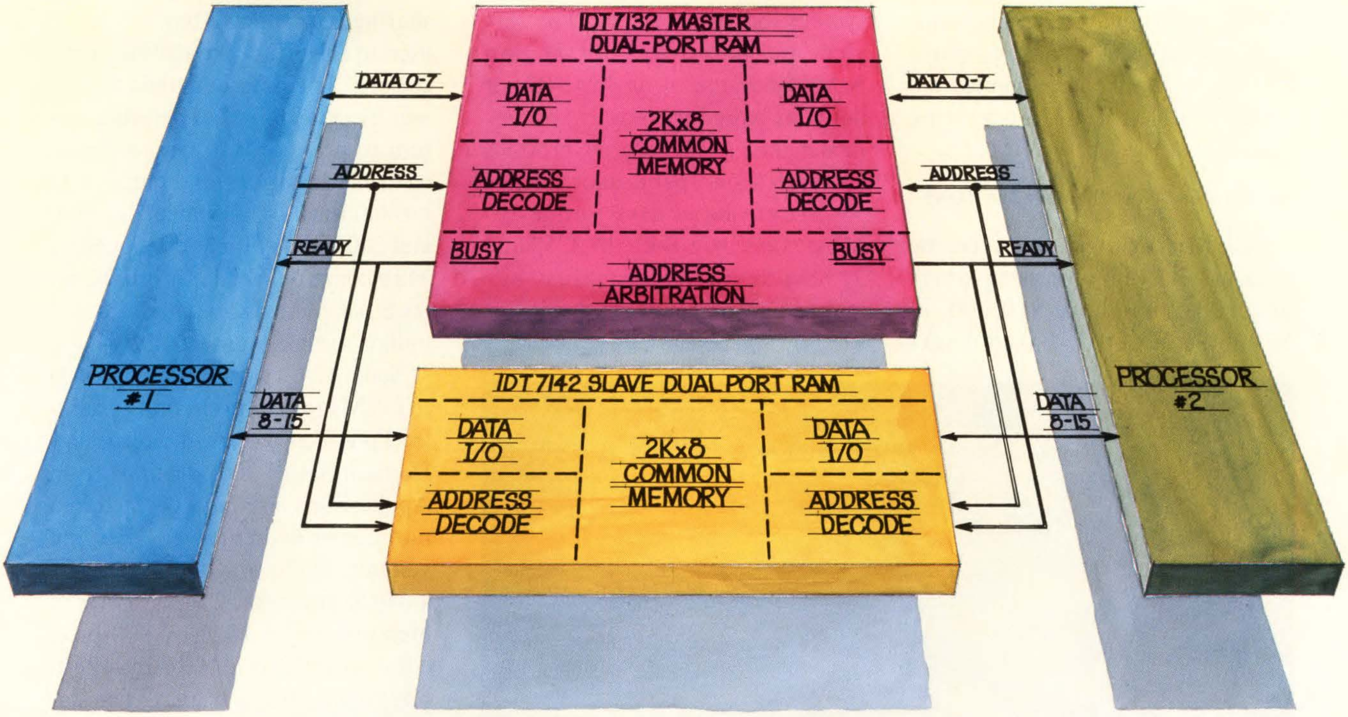
Though System V will undoubtedly become a system standard, it will not do so without change. AT&T has pledged to work with the Unix community to improve the system. Additionally, two standards committees are working on the problem: the IEEE P1003 and the Users Group Standards Committee.

All the Unix systems, though, will not become one. In fact, many workstation suppliers are developing proprietary versions of Unix. Those systems will need their own extensions to take advantage of hardware features, special interfaces, and software tools. For example, Hewlett-Packard's version of System V, the HP-UX (see the figure), employs features from the Berkeley 4.2 BSD and AT&T System V.



When Performance Counts

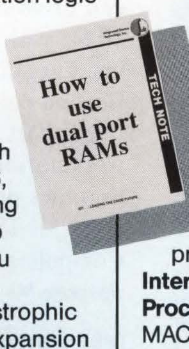
Expandable 55ns Dual Port CMOS Static RAMs



New "MASTER/SLAVE" combo is the only way to expand width and eliminate "system deadlock" without incurring a speed penalty due to extra logic.

We've led the market with the industry standard IDT7130 (1Kx8) and the IDT7132 (2Kx8) "MASTER" dual port RAMs. Used in multiprocessor systems, they provide fast, asynchronous, simultaneous access of a common memory from two totally independent data/address ports. On chip arbitration logic resolves conflicts when the addresses match.

Now we are introducing the IDT7140 (1Kx8) "SLAVE" and the IDT7142 (2Kx8) "SLAVE" dual port RAMs which permit width expansion to x16, x32 or greater while maintaining a 55ns access time. All you do is add as many SLAVES as you need to one MASTER.



A SLAVE eliminates catastrophic "system deadlock" in width expansion encountered when using dual port memories. Without a SLAVE you must use external logic for address arbitration to avoid deadlock—and that causes performance degradation.

Industry's fastest. All four of these dual port static RAMs have access times of 55ns.

Cascadable in depth. To 4K, 8K, 16K or more.

Low-power and battery backup. Typically 325mW active and 1mW standby, the low-power version permits battery backup at 200μW from a 2 volt battery.

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May we be of assistance: Call or fill in the bingo for a copy of our *Technical Note* explaining (1) how and when to use dual port static RAMs (2) how to avoid "deadlock."

Also ask for our *Product Selector Guide* on high-speed CEMOS™ **MICROSLICE**™ (bit-slice microprocessor products), **Subsystems, Memory Interface Logic, Digital Signal Processing Circuits** (multipliers, MACs, and FIFOs), and one of the fastest, broadest lines of **Static RAMs** in the world.

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Our Static RAM Family
(available now)

Size	P/N	Worst Case Comm'l Speed
16Ks		
16Kx1	IDT6167A	25ns
4Kx4	IDT6168A	25ns
4Kx4	IDT71681A*	25ns
4Kx4	IDT71682A**	25ns
2Kx8	IDT6116A	35ns
64Ks		
64Kx1	IDT7187	35ns
16Kx4	IDT7188	35ns
16Kx4	IDT7198***	35ns
16Kx4	IDT71981*	35ns
16Kx4	IDT71982**	35ns
Dual Port Static RAMs		
1Kx8	IDT7130 MASTER	55ns
2Kx8	IDT7132 MASTER	55ns
1Kx8	IDT7140 SLAVE	55ns
2Kx8	IDT7142 SLAVE	55ns

*Separate I/O—outputs ON at write
**Separate I/O—outputs 3-state at write
***Extra $\overline{OE}$ and $\overline{CS}$

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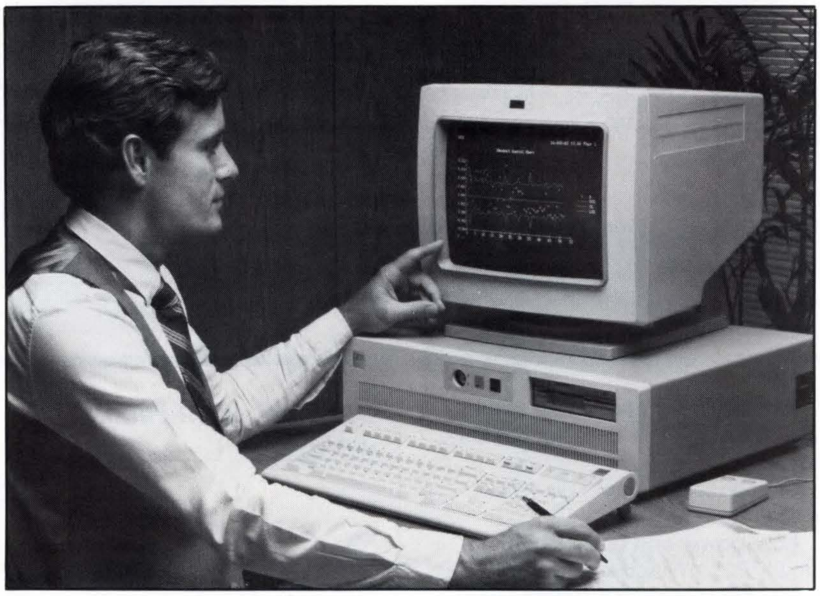
as well as under the company's VMS operating system. The company also devised a package called VNX, a Unix-like development environment for the VMS operating system.

MAINSTREAM 32-BIT WORKSTATIONS

Sun Microsystems reduced the price of full 32-bit processing, which generally ran above $10,000, to $7900 for a 68020-based workstation that relies on another Sun system for disk services. The services are not critical for the Sun 3/50M because of its 4 Mbytes of demand paged memory. Another model, the 3/52M (Fig. 3), provides a stand-alone processor with a 71-Mbyte hard disk and a 60-Mbyte tape unit. Both the 3/50 and 3/52M deliver high-quality, bit-mapped graphics with a display of 1152 by 960 pixels.



2. The first reduced-instruction-set computer targeted at the workstation market, the IBM RT PC sports a proprietary version of Unix that has been tamed for the engineering and casual user.

3. The Sun 3/52M is one of the least expensive, 32-bit stand-alone workstations. It also has a slightly slower, cheaper cousin, the 3/50M (see directory on the next page), that sells for $7900 without a disk but with a 68020 processor and 4 Mbytes of memory.

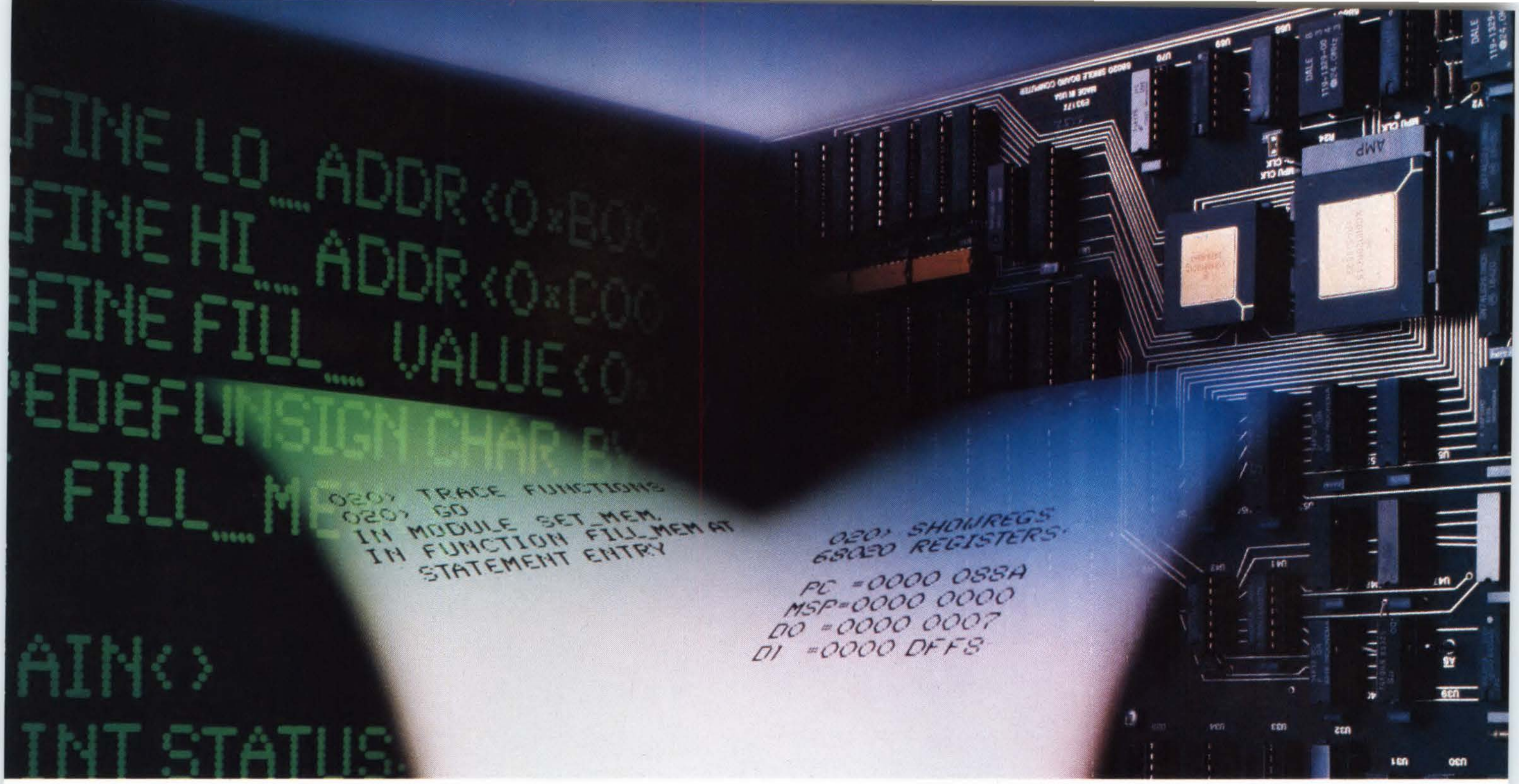
While Unix is primarily a time-sharing operating system, it can be used to drive data acquisition applications. The data demands can be met by extending the operating system to provide timing functions, controlled priorities, and special I/O mechanisms. For instance, the 5300 and 5400 workstations developed by Masscomp deliver both full 32-bit processing and a sampling rate of 1 million samples per second (Fig. 4).

Some 32-bit workstations are sold to OEMs for inclusion into system-level products. For example, the new Domain Series 3000 stations from Apollo Corp. are incorporated in a number of dedicated engineering systems. Each workstation features a 68020 processor, 2 to 4 Mbytes of memory, and a 1024-by-800-pixel color display or a 1024-by-1280-pixel monochrome display. The stations run under the Domain/IX operating system, which includes both System V and Berkeley 4.2 BSD running on top of the Aegis kernel.

High-end 32-bit workstations can deliver extremely effective graphics, including 2D and 3D transformations, scaling, and filling. By applying special hardware processors, such operations can be extremely fast. For instance, the Iris 3030 workstation from Silicon Graphics can drive a 32-bit plane (1024 by 1024) with 4096 simultaneous colors. The station rips through 83,300 floating-point operations per second to support the graphics. Another workstation aimed at heavy-duty graphics processing is the Edge-1 (Fig. 5). The machine, from Edge Computers, is supported by special-purpose VLSI chips.

THE PC ENTERS THE ACT

Engineers and programmers do not have to buy an expensive workstation to start out in 32-bit pro-

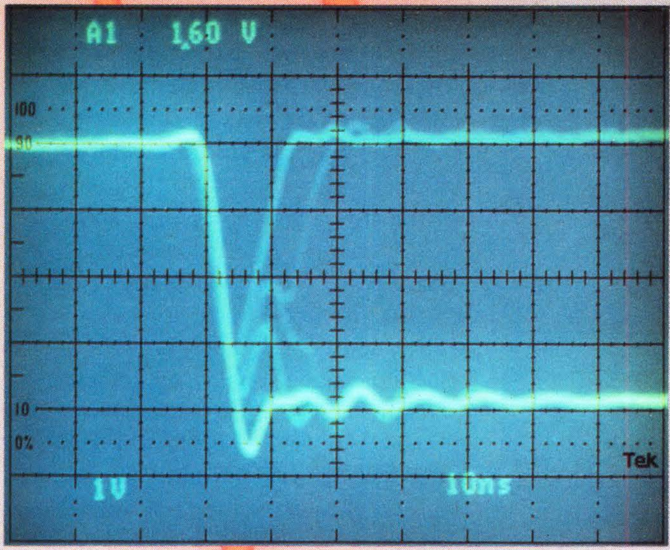

020> TRACE FUNCTIONS
020> GO
IN MODULE SET_MEM
IN FUNCTION FILL_MEM AT
STATEMENT ENTRY
020> SHOWREGS
68020 REGISTERS
PC =0000 088A
MSP=0000 0000
D0 =0000 0007
D1 =0000 DFF8

Directory of manufacturers of Unix-based workstations

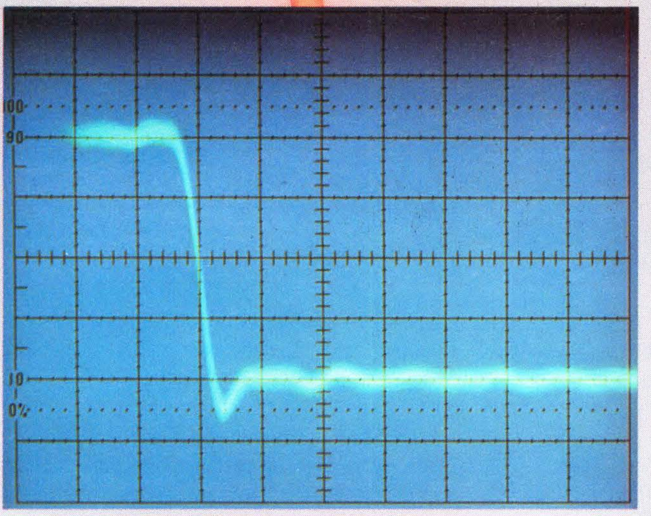
Company	Workstation	Processor	Clock rate (MHz)	Local memory (Mbytes)	Operating system	Hard disk (Mbytes)	Screen resolution	Hardware graphic support	Hardware floating-point support	Circle
Apollo Computer Inc. 330 Billerica Rd. Chelmsford, MA 01824 (617) 256-6600	Domain 3000	68020	16.6	2–4	Aegis Domain/IX (System V or Berkeley 4.2 BSD)	72	1024 by 1280	Yes	Yes	451
	DN570/580			2–64		50–2670				
Convergent Technologies Inc. 2700 N. First St. San Jose, CA 95134 (408) 435-3464	Mighty Frame/JWS	68020	16.6	1–16	CTIX (System V with enhancements)	50–2500	1280 by 1024	Yes	Yes	452
Definicon Systems Inc. 21042 Vintage St. Chatsworth, CA 91311 (818) 341-5654	Coprocessor system for IBM PC, PC AT, and PC XT	32032	10	1–2	ZAIAZ System V	N.a.	N.a.	N.a.	Yes	453
Digital Equipment Corp. 200 Baker Ave. Concord, MA 01742 (call local sales office)	VAXstation II	MicroVAX II	—	2–9	Ultrix 32M (4.2 BSD with System V compatibility)	33–213	1024 by 864	No	Yes	454
	VAXstation II GPX		—	3–9	Ultrix 32W (4.2 BSD with System V compatibility)			Yes		
Edge Computer Inc. 7273 East Butherus Scottsdale, AZ 85260 (602) 951-2020	Edge 1 Model 500	Proprietary with 680x0 instruction set	25	Up to 64	GSX (System V with enhancements)	168	1280 by 1024	Yes	Yes	455
Hewlett-Packard Co. Fort Collins System Division 3404 E. Harmony Rd. Fort Collins, CO 80525 (call local sales office)	9000 family Model 320	68020	16.6	1–7.5	HP-UX (System V with enhancements)	24–404	1024 by 768	Yes	Yes	456
	9000 family Model 550	Proprietary	18	1–10						
Intergraph One Madison Industrial Park Huntsville, AL 35807 (205) 772-2000	InterPro 32	32032 and 80186	10	2–4	Environ V (System V with enhancements)	39–127	884 by 1184	Yes	Yes	457
IBM Corp. Engineering Systems Products 472 Wheelers Farms Rd. Milford, CT 06460 (call local sales office)	RT-6150/1	RISC	5.8	1–4	AIX (System V with enhancements)	40–210	1024 by 764	No	Yes	458
Masscomp One Technology Park Westford, MA 01886 (617) 692-6200	5300	68020	12.5	2–4	RTU (System V with enhancements)	40	1152 by 910	No	Yes	459
	5400		16.6	2–10		71				
Opus Systems Inc. 20863 Stevens Creek, Bldg. B-4 Cupertino, CA 95014 (408) 446-2110	Coprocessor system for IBM PC, PC AT, and PC XT	32032	10	2–4	Opus5 (System V)	N.a.	N.a.	N.a.	Yes	460
Silicon Graphics Inc. 2011 Stierlin Rd. Mountain View, CA 94043 (415) 960-1980	Iris 3030	68020	16	2–4	System V with enhancements	170–240	1024 by 1024	Yes	Yes	461
Sritek Inc. 6615 W. Snowville Rd. Cleveland, OH 44141 (216) 526-9433	Coprocessor system for IBM PC AT	68020	16	2–4	System V/68	N.a.	N.a.	N.a.	Yes	462
Sun Microsystems Inc. 2510 Garcia Ave. Mountain View, CA 94043 (415) 960-1300	3/50 M	68020	12.5	4	SUN OS (4.2 BSD with System V compatibility	Optional	1152	No	Yes	463
	3/52 M		16.67	4		71-142	by	No		
	3/160 M		16.67	2-16		71-360	960	Yes		

Note: This is a representative sampling of manufacturers and is not meant to be a definitive list.
N.a. = not applicable

In a matter of seconds, the new Tek 2467 can save weeks of troubleshooting.



Now. See what you've always needed to see with a portable scope. (Above) Tek's new 2467 Transient Intensifying Oscilloscope, with its exclusive microchannel-plate CRT, highlights the infrequent metastability of a flip-flop output. (Below) The same metastability is invisible on a conventional high-speed scope.



Don't be stymied by elusive glitches, pulses and single-shot events.

Our new 350 MHz Transient Intensifying Oscilloscope reveals invisible signals that escape detection by any other portable instrument. An approximate 100-fold increase in *visual* writing rate translates high-speed, single-shot phenomena and low-repetition-rate signals into easily-seen displays—in normal room light and at sweep speeds as fast as 500 ps/div.

Discover marginal conditions you don't even know exist. Now designers and test engineers can quickly identify circuit or system faults caused by infrequent metastability, asynchronous noise, crosstalk or erratic timing-margin violations—even if they occur only once in a million normal operations.

Not only can you shorten time to market, you can deliver more reliable new products.

To see the Tek 2467 in action, or to order, contact your Tek Sales Engineer. Or call the Tek National Marketing Center, 1-800-426-2200. In Oregon, call collect, (503) 627-9000.

To rent a Tek 2467 for a trial evaluation, contact an authorized Tektronix rental company:

Continental Resources, Inc.
(800) 323-2401 Nationwide
(312) 860-5991 Illinois

Electro Rent Corporation
(800) 423-2337 Nationwide
(800) 232-2173 California

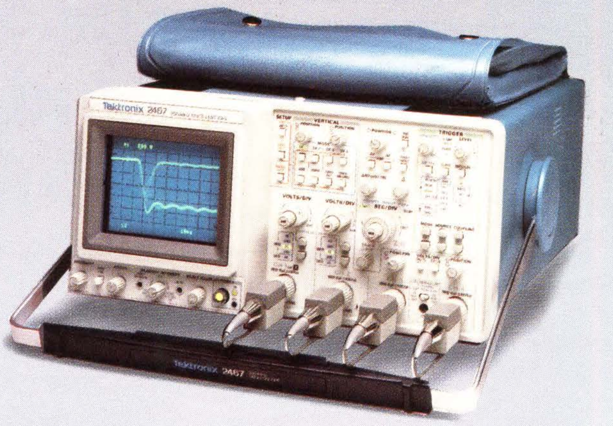
General Electric Company
(800) GE-RENTS

GENSTAR Rental Electronics, Inc.
(800) 227-8409 Nationwide
(800) 331-3440 California

McGrath RentCorp
(415) 568-8866

Telogy, Inc.
(800) T-E-L-O-G-Y-Inc.

U.S. Instrument Rentals, Inc.
(800) 824-2873



Tektronix
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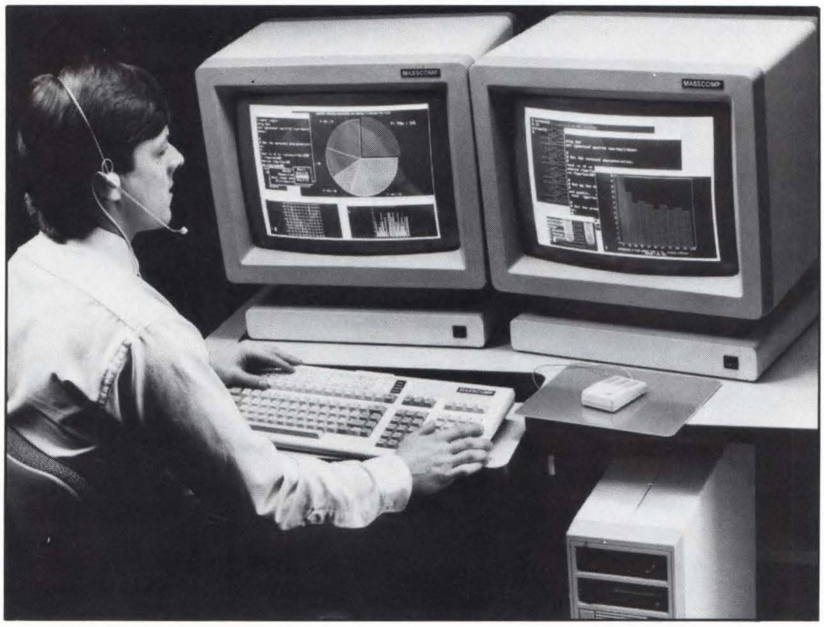
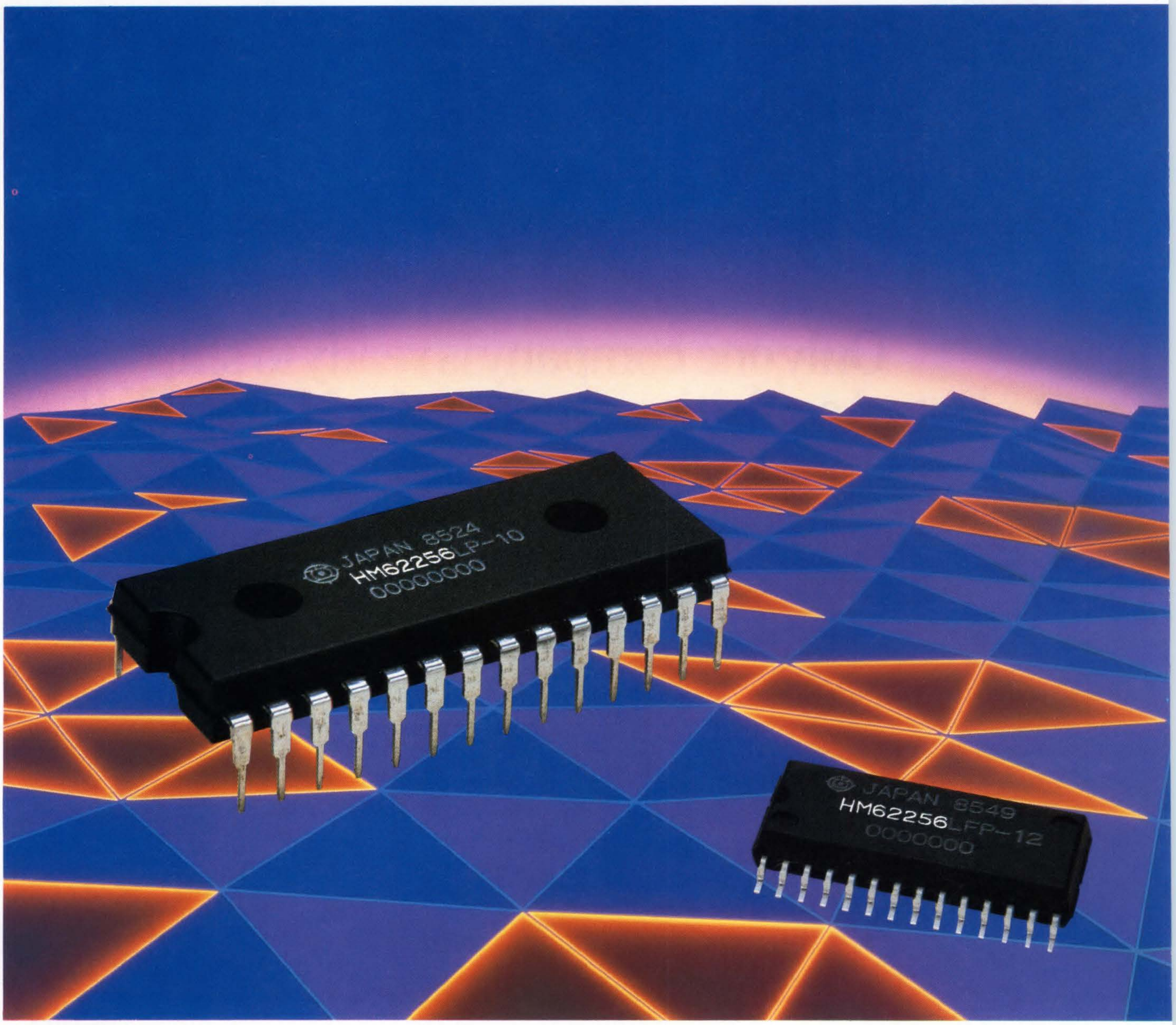


4. While the Masscomp 5300 is a moderate-cost 32-bit workstation, it is also a base station for data acquisition. With hardware additions, it can handle up to 1 million samples per second.

cessing. IBM PC personal computers and compatibles can be adapted to computationally intensive work that does not need an extensive I/O subsystem. The conversion can be made by adding coprocessor-based subsystems, such as Unix-based 32032 and 68020 coprocessor cards. The 32-bit boards carry both floating-point and virtual-memory control chips. For compilation, simulation, or memory-intensive processing they deliver the necessary power at a reasonable cost—\$2500 and up. The coprocessor subsystems generally carry VAX-class language compilers and other software tools. They work with variations of System V. Suppliers of the boards include Definicon Systems Inc., Opus Systems Inc., and Sritek Inc.□



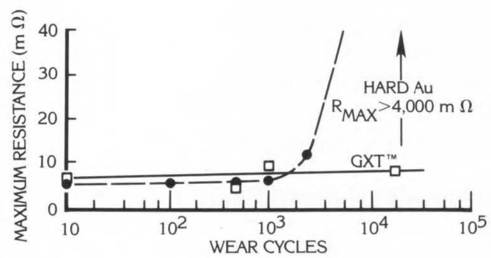
The new age of the microchip is dawning with the advent of the Hitachi HM62256 256K SRAM, fabricated using the exclusive 1.3-micron Hi-CMOS III process.

Cutaways of pins (shown in these microphotographs) prove GXT plating resists wear better than gold. After 25,000 mating cycles, note the minimal deterioration of the Du Pont coating. With GXT, a cycle life greater than 25,000 cycles is possible.

Tests also show the GXT plating system is better than gold in solderability, porosity, bend ductility, and corrosion resistance. Yet GXT can reduce costs as much as 20%.

Independent testing laboratories have proved that the Du Pont GXT plating system is *superior to gold* in wear resistance, solderability, porosity, environmental corrosion resistance and bend ductility. And is as *good as gold* in contact resistance and wire-wrapping performance.

Moreover, connectors protected by this remarkable new coating system frequently cost considerably less than comparable parts plated with gold. For example, savings of up to 20% are possible on pins plated with GXT. (Savings depend on the price of gold and upon the amount of gold being replaced.)



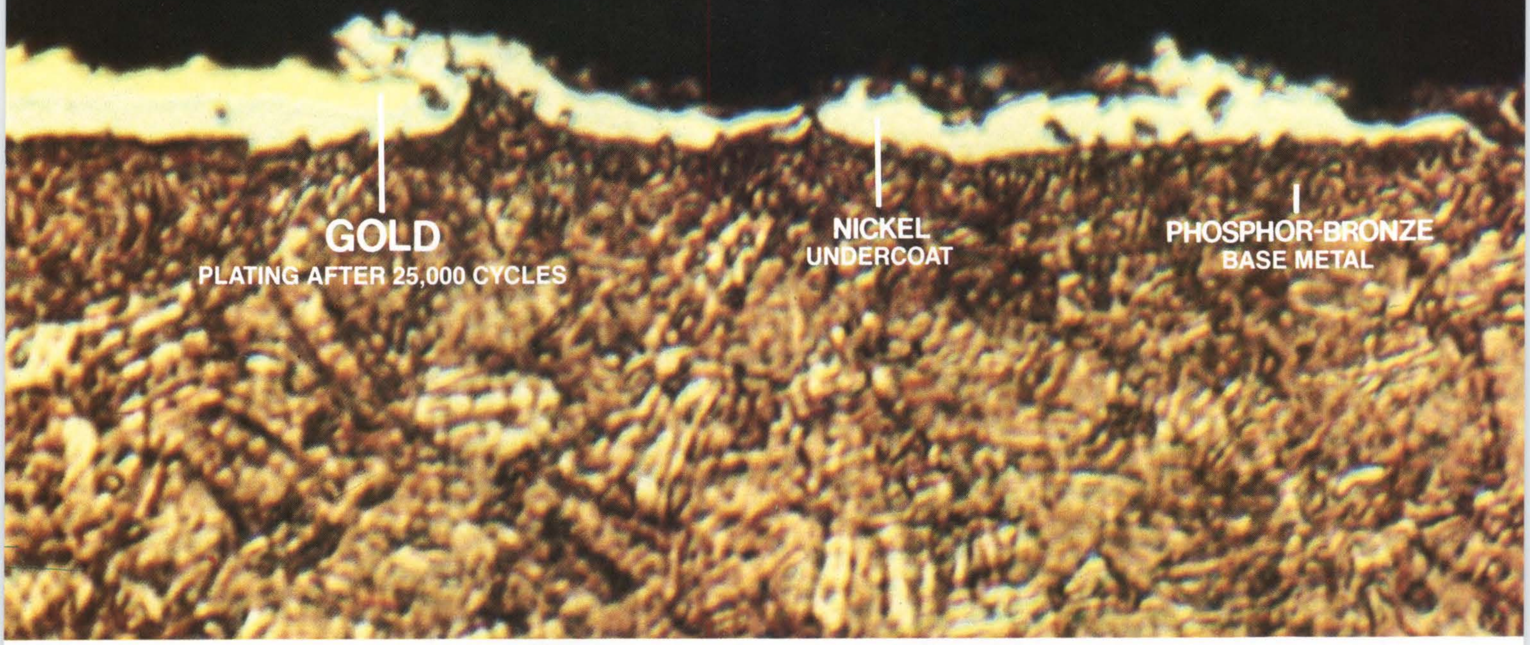
GXT assures minimum contact resistance after wear and exposure to H_2S

By 25,000 cycles, gold shows contact resistance increases to 4,000 milliohms or higher. In contrast, GXT shows excellent electrical performance even after 25,000 cycles.

GXT is a trademark of the Du Pont Company.

Berg Electronics is now

outwears, outperforms gold. connector pins prove it.



In these tests, other gold substitutes didn't measure up to GXT, either. In porosity, solderability, intermetallic growth, bend ductility, internal stress, and manufacturing process stability, the GXT plating system clearly outperformed all other gold alternatives including other palladium-nickel and pure palladium coatings.

In fact, in no test did any gold substitute—or gold itself—outperform GXT.

GXT plating, an exclusive Du Pont development, is now available on Du Pont's 0.025″ square pins, including BergStik™ headers, BergPost™ and BergPin™ terminals, and compliant press-fit pins. Some industry leaders already have switched from gold to GXT to help improve the reliability of their products.

If you require high reliability connectors, you're sure to want complete test results. They're yours for the asking...along with sample pins for your own tests/inspection.

Get all the facts! Order this free GXT Convincer Kit.

Review results from independent test laboratories. Proof positive that GXT palladium-nickel plating outwears, outperforms gold. To request kit...

Make the "Du Pont Connection" Call (800) 237-2374

Or write The Du Pont Company, Du Pont Connector Systems, 30 Hunter Lane, Camp Hill, PA 17011.

DU PONT CONNECTOR SYSTEMS

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READER FEEDBACK

An open letter to U.S. chip makers

As a component engineer, I've seen U.S. manufacturers of ICs make some costly mistakes in packaging. Over the last several years the most common has been memories in DIPs that were unnecessarily long, too long to allow us to fit everything we needed to on the printed circuit board. Instead of a 0.045-in. maximum overhang from the center line of the end pins to the edge of the package (half-lead style), which would allow maximum packing of memory arrays, manufacturers used a longer package with a 0.050-in. overhang or greater. We found the short package memories we needed, though—made in Japan.

It looks like we're ready to hand Japan another victory. Many, and especially the largest of the U.S. manufacturers, are refusing our requests for a new package with obvious benefits, while the Japanese are responding positively.

High-performance applications are often the proving ground for the latest ICs, and periodically the latest packaging. Pin-grid arrays and especially surface-mounted devices have been much discussed lately, but a new package is poised to steal many of the SMD's applications. The ZIP (Zigzag in-line package) is offering greater density and a cheaper, easier implementation than SMDs.

When pcb area is at a premium, and it usually is in high-performance applications, the area needed by each device is important. SMDs save considerable area compared with DIPs, but ZIPs save even more. An added bonus for pcb designers is the easy straight-line routing of ZIP memory arrays.

High-performance systems are often manufactured in quantities that make the payoff of new manufacturing equipment long term. ZIPs use traditional soldering equipment and existing or modified SIP insertion equipment. SMDs, on the other hand, require new equipment for both operations.

The only drawback for ZIPs appears to be the pin count, which will probably peak at 24 or 28 pins. This really isn't much of a limitation, since high-performance DRAM, SRAM, PROM, PLD, and glue parts, consisting mostly of 8-, 9-, or 10-bit-wide parts for bus applications, will fit easily.

The ZIP is a definite winner in high-performance applications. U.S. manufacturers of ICs had better wake up to that fact before they lose another proving ground, and the revenue that goes with it.

M. Tony Young
Intergraph Corp.
Huntsville, Alabama

Star Wars satire

I found Terry Costlow's Editor's Beat in the Feb. 20 issue ("Funding Fuels Fantasies of Star Wars and Personal Computers," p. 33] to be ludicrous at best. The first thing I did was check if I was reading an April Fool's edition. I still am not sure if we are supposed to take this editorial seriously.

Costlow claims that "Uncle Sam, in effect, created the personal computer," and that by covert funding, the U.S. government supported small computer firms, which "created scores of jobs." The pur-

(continued on p. 254)

UPCOMING MEETINGS

Expotronica '86, Professional Electronics, Equipment and Components Show, May 13–17. Barcelona Fair, Barcelona, Spain. Barcelona Fair, Av. Reina M. Cristina, s/n. 08004 Barcelona-Espana; (93) 223 31 60-22399 00.

1st Lasers in Manufacturing: Selection/Planning of Lasers Systems, Opportunity for Applications Growth and Latest Technology (S.P.O.T '86) Conference & Exposition, May 19–22. Philadelphia Dunfey-City Line Hotel, Philadelphia, PA. S.P.O.T. '86 Conference, Kathleen Warren, Society of Manufacturing Engineers, 1 SME Dr., P.O. Box 930, Dearborn, MI 48121; (313) 271-1500, ext. 317.

5th Beama International Electrical Insulation Conference, May 19–22. Metropole Hotel, Brighton, England. Mike Cavanagh, Beama Ltd., 8 Leicester St., London WC2H 7BN England; (01) 437-0678.

SEMICON/West '86, May 19–22. San Mateo Fairgrounds and Bay Meadows Race Course, San Mateo, CA. SEMICON/West '86, Mathews & Clark Communications, 410 Cambridge Ave., Palo Alto, CA 94306; (415) 327-3721.

6th International Conference on Distributed Computing Systems, May 19–23. Hyatt Regency Cambridge, Cambridge, MA. DCS-6, IEEE Computer Society, 1730 Massachusetts Ave. N.W., Washington, D.C. 20036; (202) 371-0101.

38th Annual National Aerospace and Electronics (NAECON '86) Conference & Exhibition, May 19–23. Dayton Convention Center, Dayton, OH. NAECON '86, William R. Baker, IEEE, 655 Ridgedale Rd., Dayton, OH 45406; (513) 255-6548.

2nd International Computer Applications in Production and Engineering (CAPE '86) Conference & Exhibition, May 20–23. Bella Center, Copenhagen, Denmark. Peter Falster, Conference Chairman, CAPE '86, DIS Congress Service, 48 Linde Alle, DK-2720 Vanlose, Denmark; 45-1-71 22 44.

Techex '86 Americas, Technical Developments Exposition, May 20–23. Expo Center, Orlando, FL. Anne E. Klenner, Dr. Dvorkovitz & Associates, P.O. Box 1748, Ormond Beach, FL 32075; (904) 677-7033.

1986 International Symposium on Multiple-Valued Logic, May 26–28. Virginia Polytechnic Institute and State University, Blacksburg, VA. Dr. Joseph G. Tront, Symposium Chairman, ISMVL-86, Dept. of Electrical Engineering, Virginia Polytechnic Institute, Blacksburg, VA 24061; (703) 961-5067.

AUTOMACH Australia '86, Automated Integrated Factory Focus Conference & Exhibition, May 26–29. Hilton International Sydney and the Royal Hall of Industries on the RAS Showgrounds, Sydney, Australia. AUTOMACH Australia '86, Adolph Greco, A. Greco & Associates Ltd., Integrated Project Management Services, P.O. Box 68, Pennant Hills, 2120 N.S.W., Australia; (02) 875-2377.

1st Annual High Frequency Power Conversion Conference & Exhibition, May 28–30. The Cavalier Resort, Virginia Beach, VA. Sam Davis, Conference Director, c/o Intertec Communications, 2472 Eastman Ave., Bldg. 34, Ventura, CA 93003; (805) 658-0933.

40th Annual Frequency Control Symposium, May 28–30. Marriott Hotel, Philadelphia, PA. Dr. J. Vig, U.S. Army Electronics Technology & Devices Lab, ATTN: SLCET-EQ, Fort Monmouth, NJ 07703; (201) 544-1510.

1986 VLSI Technology Symposium, May 28–30. Hotel Intercontinental, San Diego, CA. Moiz M. Beguwala, Program Chairman, Rockwell International, MS 501-369, Semiconductor Products Division, 4311 Jamboree Rd., P.O. Box C, Newport Beach, CA 92660; (714) 833-4712.

1986 International Summer Consumer Electronics Show, June 1–4. McCormick Place, Chicago, IL. Allan Schlosser, Staff Vice President, Consumer Electronics Group, 2001 Eye St. N.W., Washington, D.C. 20006; (202) 457-4919.

(continued on p. 92)

UPCOMING MEETINGS

(continued from p. 91)

Vision '86 Applied Machine Vision Conference & Exposition, June 2–5. Cobo Hall, Detroit, MI. Machine Vision Assoc. of the Society of Manufacturing Engineers, 1 SME Dr., P.O. Box 930, Dearborn, MI 48121; (313) 271-1500.

Advanced Infrared Detectors and Systems Conference, June 3–5. London, England. Conference Services, Institution of Electrical Engineers, Savoy Place, London WC2R 0BL, England; (+44) 1 240 1871.

Circuit Expo '86 West, June 3–5. Long Beach Convention Center, Long Beach, CA. Mary Burns Sheridan, Worldwide Convention Management Co., P.O. Box 159, Libertyville, IL 60048; (312) 362-8711.

6th International Conference on Robot Vision & Sensory Controls (RoViSeC-6), June 3–5. Paris, France. IFS Conferences Ltd., 35-39 High St., Kempston, Bedford MK42 7BT England; (+44) 234 853605.

3rd International Conference on Lasers in Manufacturing (LIM-3), June 3–5. Paris, France. IFS Conferences Ltd., 35-39 High St., Kempston, Bedford MK42 7BT, England; (+44) 234 853605.

3rd International VLSI Multilevel Interconnection (V-MIC) Conference, June 9–11. Santa Clara Marriott Hotel, Santa Clara, CA. Dr. Thomas E. Wade, General Chairman, IEEE VLSI Mutlilevel Interconnection Conference, College of Engineering, University of South Florida, Tampa, FL 33620; (813) 974-3786.

Conference on Lasers and Electro-Optics (CLEO '86), June 9–13. Moscone Convention Center, San Francisco, CA. CLEO '86, Optical Society of America, 1816 Jefferson Pl. N.W., Washington, D.C. 20036; (202) 223-0920.

14th International Conference on Quantum Electronics (IQEC '86), June 9–13. Moscone Convention Center, San Francisco, CA. IQEC '86, Optical Society of America, 1816 Jefferson Pl. N.W., Washington, D.C. 20036; (202) 223-0920.

NEPCON East '86 Electronics Packaging, Production and Testing Conference & Exposition, June 10–12. Bayside Exposition Center, Boston, MA. NEPCON East '86, Cahners Exposition Group, 1350 E. Touhy Ave., P.O. Box 5060, Des Plaines, IL 60017; (312) 299-9311.

1986 National Computer Conference & Exhibition (NCC '86), June 16-19. Las Vegas Convention Center, Las Vegas, NV. NCC '86, American Federation of Information Processing Societies (AFIPS), 1899 Preston White Dr., Reston, VA 22091; (800) NCC-1986.

1986 IEEE Computer Vision and Pattern Recognition Conference & Exhibition, June 22–26. Fontainbleau Hilton Hotel, Miami Beach, FL. Dr. Linda Shapiro, Conference Chairman, Machine Vision International, 325 E. Eisenhower Pkwy., Ann Arbor, MI 48104; or IEEE Computer Society, 1730 Massachusetts Ave. N.W., Washington, D.C. 20036; (202) 371-0101.

7th Power Modulator Symposium, June 23–25. Hyatt Seattle, Seattle, WA. Leslie Gallo, Program Secretary, Palisades Institute for Research Services Inc., 2011 Crystal Dr., 1 Crystal Pk., Ste. 307, Arlington, VA 22202; (703) 769-5580.

Automatic Test Equipment (ATE) East '86 Conference & Exhibition, June 23–26. World Trade Center, Boston, MA. Morgan-Grampian Expositions Group, 1050 Commonwealth Ave., Boston, MA 02215; (617) 232-3976.

CPEM '86, Conference on Precision Electro-Magnetic Measurements, June 23–27. National Bureau of Standards, Gaithersburg, MD. CPEM'86 Technical Program Chairman, Norman B. Belecki, National Bureau of Standards, B146, Metrology, Gaithersburg, MD 20899; (301) 921-2715.

23rd Design Automation Conference & Exhibition (DAC '86), June 29–July 2. Las Vegas Hilton, Las Vegas, NV. DAC '86. Donald E. Thomas, Program Chairman, IBM Thomas J. Watson Research Center, P.O. Box 218, Yorktown Heights, NY 10598.

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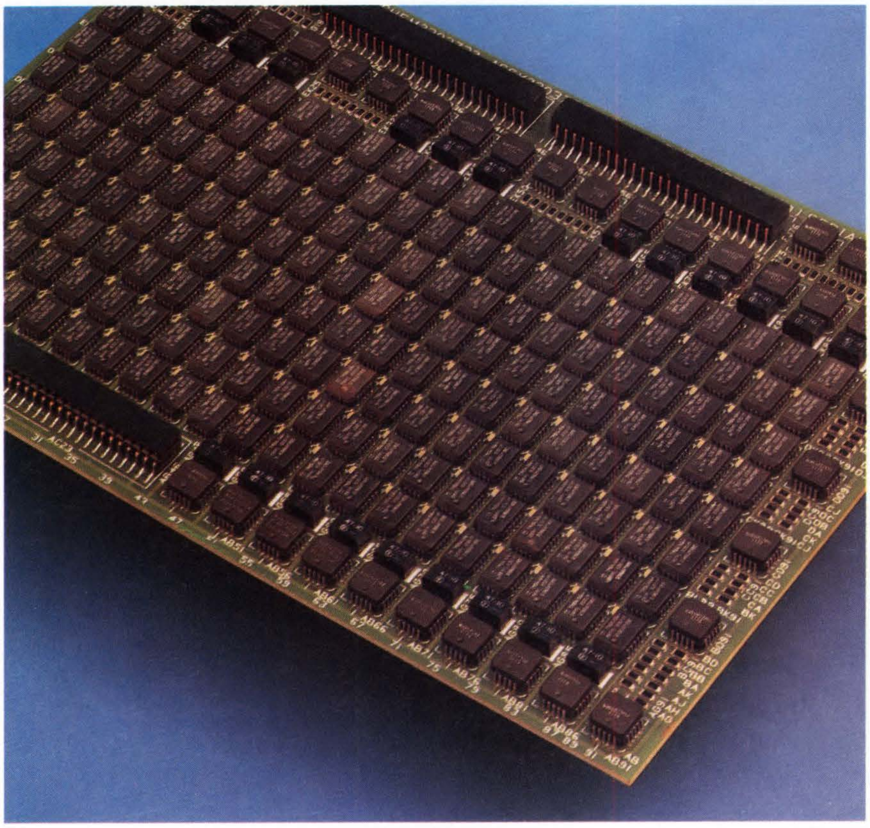


Avoiding stress in surface-mounting MLC chips

The most critical factor in surface mounting multilayer ceramic chip capacitors, thermal shock, can be avoided by preheating the capacitors before they contact the solder. Figure 1 indicates the ideal temperature profile for wave soldering MLC chips.

Temperature Guidelines

As the chart shows, the ideal guideline for preheating is to raise the chip temperature at a rate of approximately 2°C per second to within 100°C of the solder bath. Although the preheat rate is important, the more critical parameter is the differential between chip and solder temperatures when the two meet. The closer these two temperatures, the less likely there will be thermal shock.

Wave Soldering

Figure 2 charts the internal temperature of an MLC chip during a single-wave-soldering operation. The ceramic chip is mounted on the bottom side of the board with an imbedded thermocouple. Although the rate of increase in the capacitor temperature is 4.5°C/sec., no thermal shock is observed, since the capacitor is brought to within 50°C of its peak temperature in the solder wave.

Preferred Wave Solder Profile for Ceramic Chip Capacitors

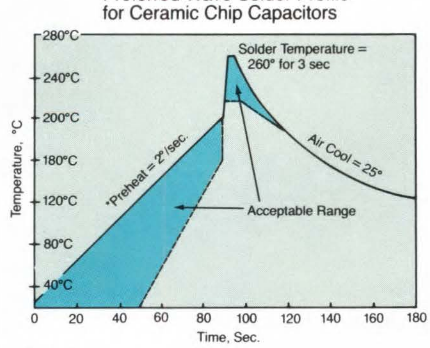
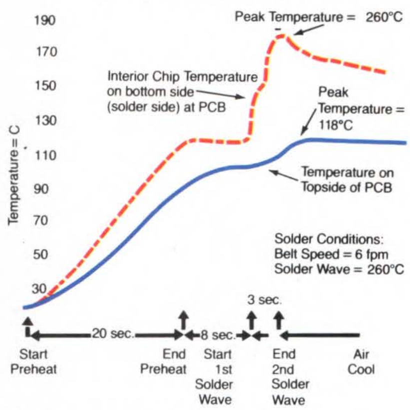


Fig. 1

Fig. 2 Internal MLC Chip Temperature During Wave Soldering to PCB



Discussion

Bottom-sided (solder-side) soldering results in critical temperature differentials between PC board and chip, as shown by comparing chip with board temperature using an additional thermocouple mounted on a copper runner on the top side of the board. Here peak board temperature was 118°C versus a chip temperature of 173°C when coming into contact with a 260°C solder wave for 3 sec.

AVX results show that the cooling cycle is as important as the preheat cycle. Gradual cooling not only avoids thermal shocking of the capacitor, but also allows relaxation of thermal stress in the solder and boards.

For a technical paper discussing the critical aspects of surface mounting ceramic chip capacitors, complete and return the coupon below.

- ☐ Please send me the AVX Technical Paper "Chip Capacitors Relating to Surface Mounting Technology"
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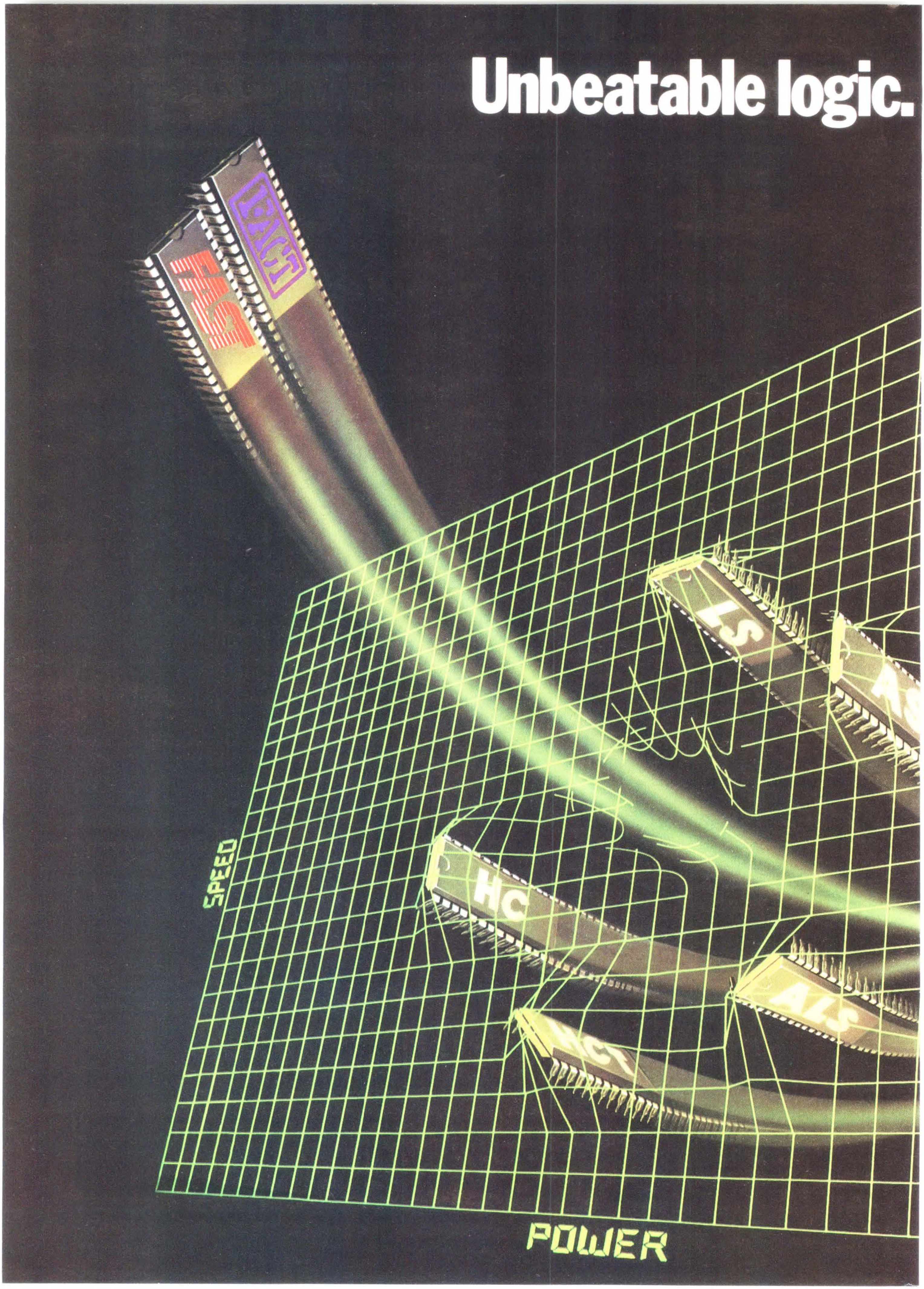
AVX Technology For The Times

ED 5/15/86

Photo: This experimental circuit board from Texas Instruments shows the surface mounting technique. The board is not an available commercial product.

CIRCLE 61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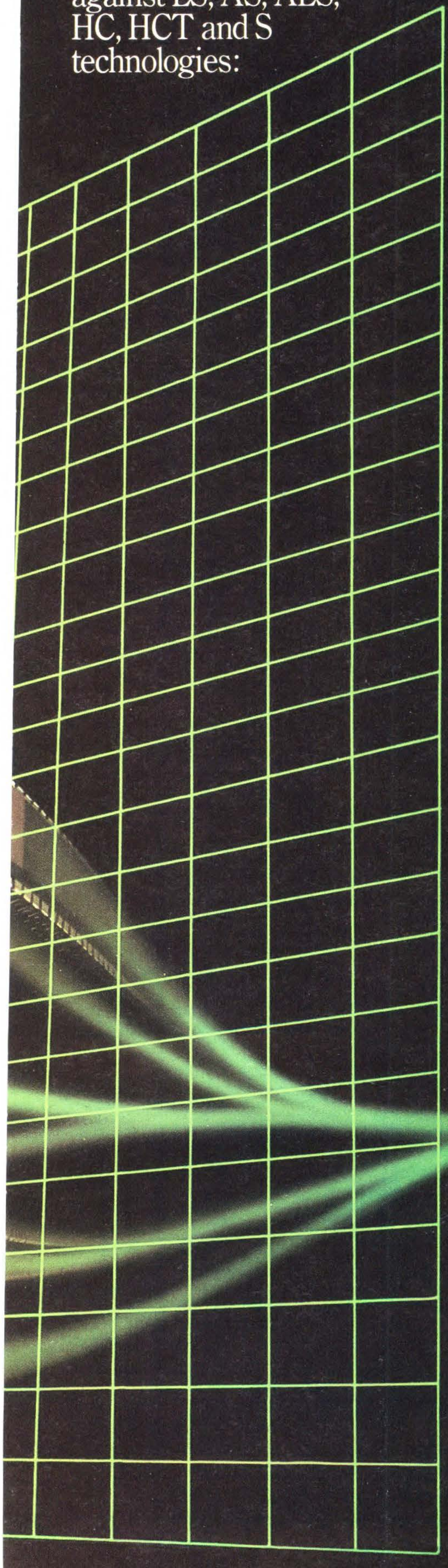

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CIRCLE 62

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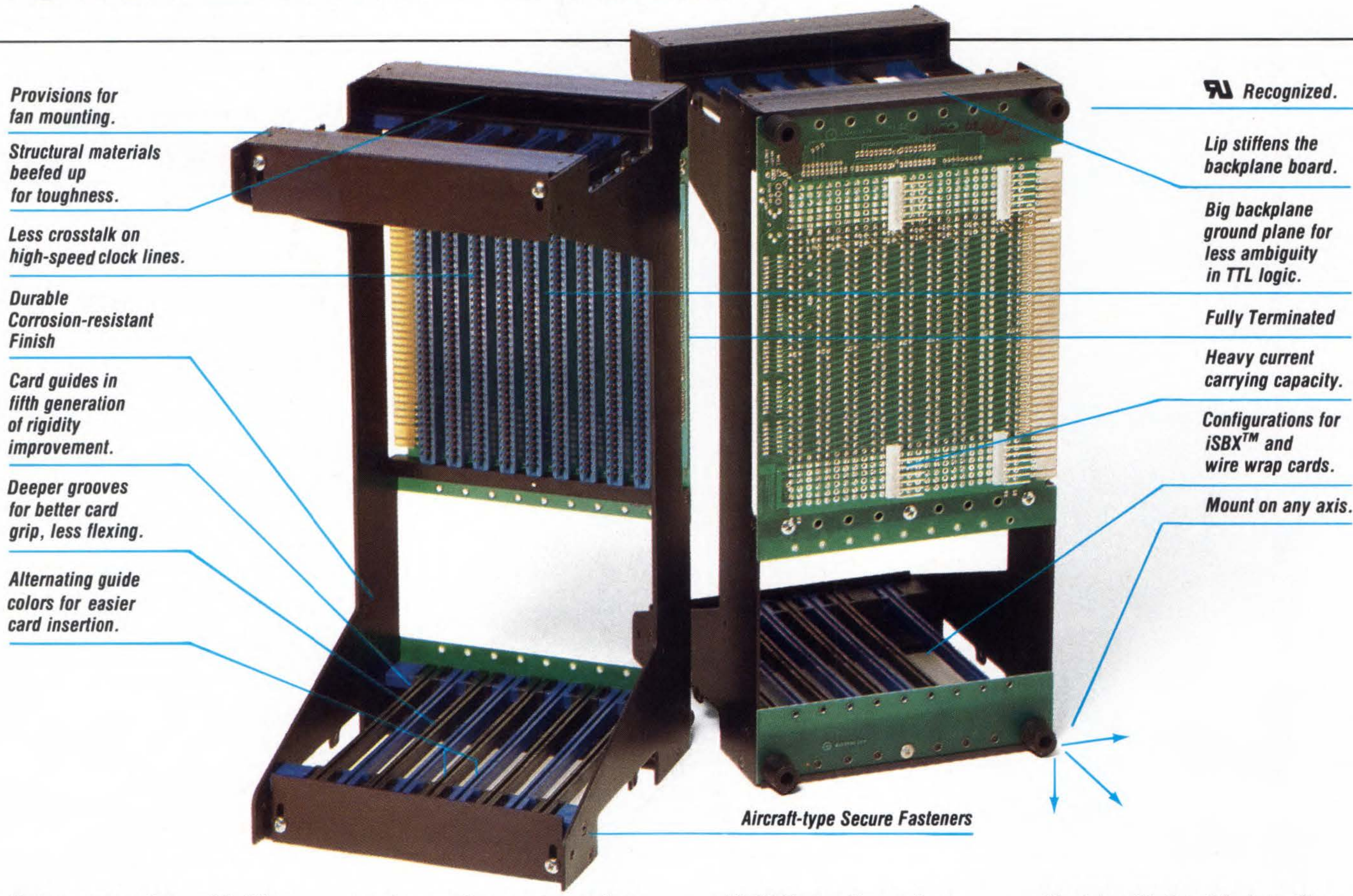

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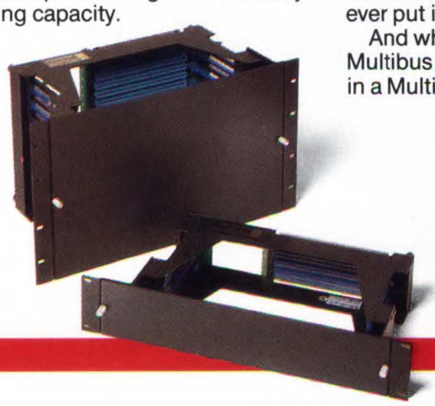

Multi-Cages through an evolutionary process have been made more and more rigid. So cards stay put better under shock and vibration conditions. Special aircraft-type fasteners never loosen their grip. And the brushed anodized aluminum finish has developed into one of the most corrosion resistant ever put into a card cage.

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CIRCLE 63

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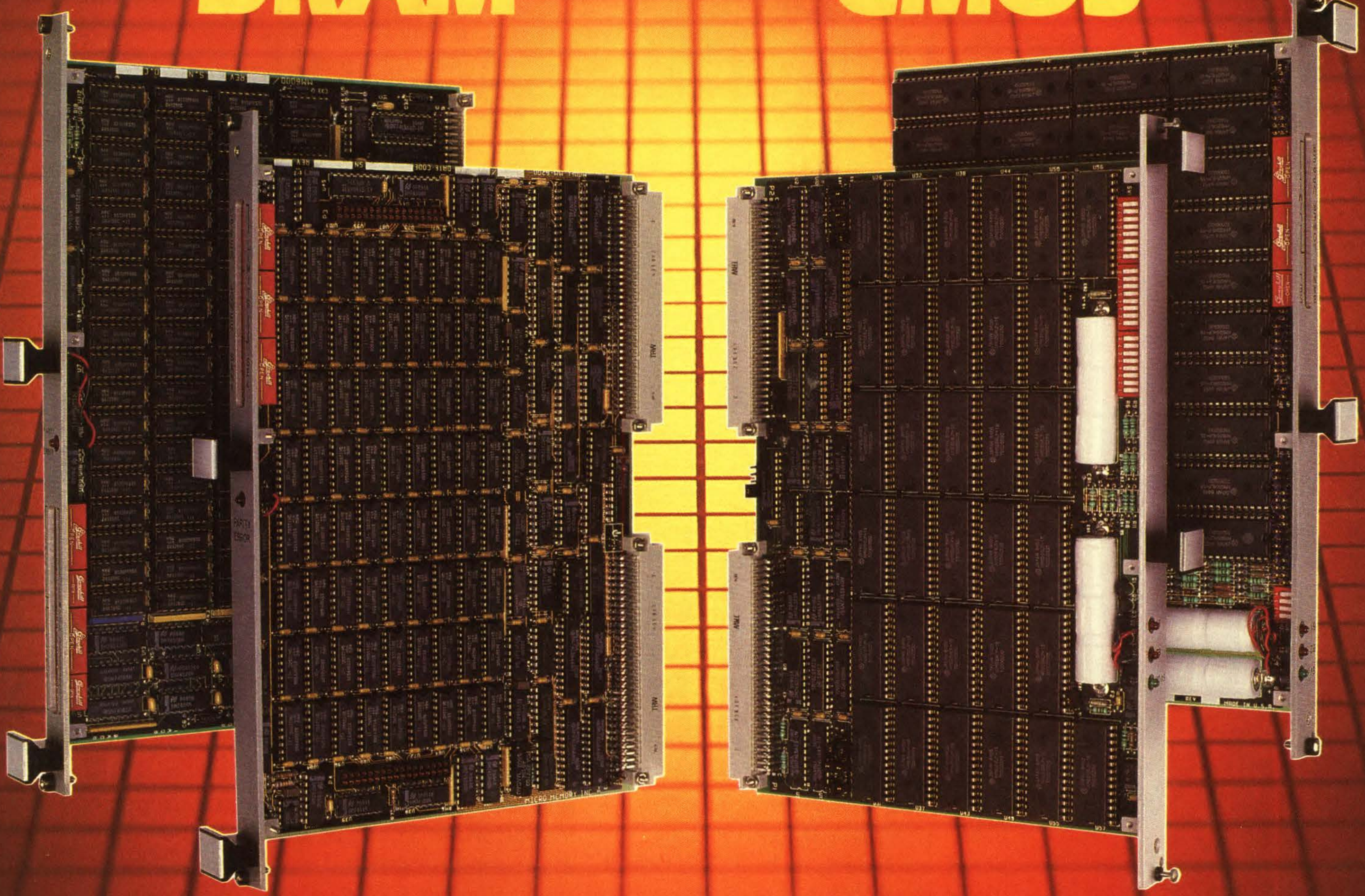

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If space is limited and you need a lot of memory, there's the MM-6200D (DRAM), which has a 4 Mbyte capacity and 32-bit word length. For 2 Mbytes and 16 bits, there's the MM-6000D (DRAM).

Furthermore, reliability is ensured by fully-operational burn-in and temperature cycling. And, there is a one-year warranty on parts and labor.

Model No.	Capacity	Cycle/Access (nsec)	Type	Word Length
MM-6000D	256K, 512K, 1M, 2M	330/210	64K or 256K DRAM	16-bit
MM-6200D	512K, 1M, 2M, 4M	350/220	64K or 256K DRAM	32-bit
MM-6500C	32K, 64K, 128K	200/200	CMOS (Calendar-Clock)	16-bit
MM-6600C	64K, 128K, 256K, 512K, 1M	200/200	64K or 256K CMOS	16-bit
MM-6700C	**64K, 128K, 256K, 512K, 1M**	**150/150**	**64K or 256K CMOS**	**32-bit**

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CIRCLE 64

ELECTRONIC DESIGN REPORTS

Factory communication: MAP promises to pull the pieces together

Communications, the key roadblock to large-scale automation of the factory floor, is falling to the onslaught of the Manufacturing Automation Protocol. A set of factory networking guidelines set forth by General Motors Corp. (Detroit, Mich.), MAP aims to let intelligent factory entities like robots, computers, machine tools, and programmable controllers communicate painlessly and with true plug-in compatibility — regardless of what company made which piece. MAP is GM's answer to moving from fixed to flexible automation, a move necessary to keep it — and many other companies — competitive.

In fact, corporate giants worldwide view MAP as a necessity. Some see themselves as users of MAP equipment, some as suppliers, and many as both. No doubt the names have a familiar ring: Allen-Bradley, AT&T, Bethlehem Steel, Boeing, Chrysler, Digital Equipment, Dow Chemical, Dupont, Ford, General Electric, Hewlett-Packard, Honeywell, IBM, Intel, Kodak, Motorola, Olivetti, Philips, Renault, Siemens, Texas Instruments, 3M, Westinghouse Electric, and Xerox.

The momentum behind MAP reaches beyond the factory floor and into engineering labs and management offices. In fact, MAP has spawned the Technical Office Protocol, or TOP, which Boeing Computer Services Co. (Seattle) developed to interconnect engineering workstations, computers, and peripherals. Naturally, MAP and TOP backers are uniting to devise a common specification that will ensure compatibility between the engineering office and the factory floor.

The MAP specifications themselves are suited to both batch manufacturing and real-time continuous process control. In fact, many have already been accepted as standards, encouraging the development of chip, board, and box level interface electronics; in addition, more MAP gear is on the drawing boards. Yet the hustle and bustle also underscores some particularly needy areas, namely, network management, interoperability, and conformance testing — critical issues now being addressed by MAP manufacturers, MAP users, and independent testing and standards organizations. Interoperability, the ability of two pieces of equipment to actually work together, is an issue of particular importance. There is sufficient room for interpretation within the various MAP standards that two pieces of gear can meet the standards and yet not work together.

Given the pace of MAP standards development and the international support backing it, fully automated MAP plants could conceivably come on stream within two or three years. In fact, GM is now debugging several "fully MAP-ped"

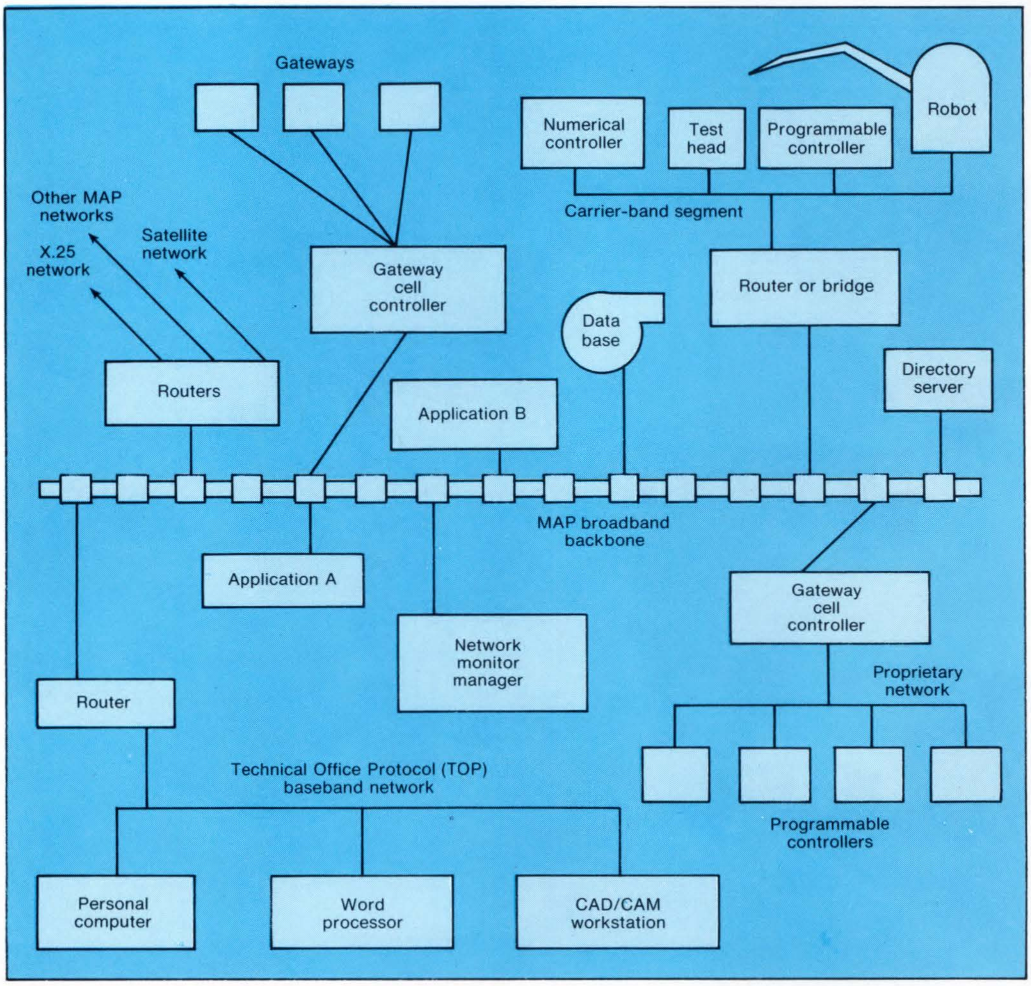
Roger Allan

plants in the U.S. and Canada, hoping to meet the 1988 projected time frame for operations (see "Steering Factories into the Future," p. 106).

The protocol draws largely on the International Standards Organization's seven-layer Open System Interconnection reference model. But it also pulls standards from other groups, including the Institute of Electrical and Electronic Engineers, the American National Standards Institute, the Instrument Society of America, the Electronic Industries Association, the National Bureau of Standards, and the International Consultative Committee for Telegraphy and Telephony.

At the lowest of the seven MAP layers, the physical layer calls for broadband coaxial cable (Fig. 1) based on the 10-Mbit/s IEEE-802.4 token-passing bus standard (see the table, p. 112). Broadband technology allows data, voice, and video signals to be transmitted simultaneously, and thanks to relatively high carrier frequencies of 300 to 400 MHz, it is highly immune to noise—clearly a critical factor in the plant. As for token passing, its deterministic nature plays an important part in discrete and continuous process-control systems, where the uncertainties in response time of other approaches cannot be tolerated. Moreover, the scheme also accepts message priorities.

The broadband backbone ties into both MAP and non-MAP networks through bridges, routers, or gateways (Fig. 2). A bridge permits two IEEE-802 networks—either identical or dissimilar—to communicate through the bottom two layers of the OSI model. Routers, which encompass the first three layers of the model, link several networks at a common point. Finally, gateways are the most complex of the three, as they provide the most com-



1. A broadband coaxial-cable backbone will link diverse factory and nonfactory networks, including proprietary and non-MAP systems, both inside and outside the plant. The Manufacturing Automation Protocol, or MAP, is based on the IEEE-802.4 token-passing bus protocol at the first two layers.

munication functions. Moreover, they use all seven layers of the OSI model.

MAP's data-link layer includes the IEEE-802.2 logical-link control sublayer and the IEEE-802.4 media-access control sublayer—which are independent of one another. The former manages message frame transmissions and detects and corrects errors, the latter arbitrates control of the cable through ownership of the token. Many experts feel that the combination of 802.2 and 802.4 sublayers lends itself to VLSI implementation, a heartening step toward low-cost node connections.

The IEEE-802.2 protocol spells out connectionless class 1 service with a 48-bit address field. Thus two networks can exchange data without a formal data-link connection. Unlike connection-oriented service, 802.2 can stretch to internetwork communication and to routing between subnetworks.

MIDDLE GROUND

At the network layer, MAP specifies the OSI's connectionless-oriented protocol for routing messages and exchanging information between networks. GM has added its own routing algorithm, which differs slightly from the one in the ISO reference model. The layer encompasses protocols supported by the IEEE and the NBS, as well as an X.25 protocol for communication with other networks.

The transport layer deals with end-to-end data reliability through the ISO-compatible subset of the NBS class 4 transport protocol. Unlike the ISO class 4 protocol, the NBS version supports datagram service (the transmission of individual data packets), so that data can be transferred without a specific point-to-point connection.

Following the transport layer is the session layer, which calls for the ISO OSI session kernel. This layer translates and synchronizes names and addresses.

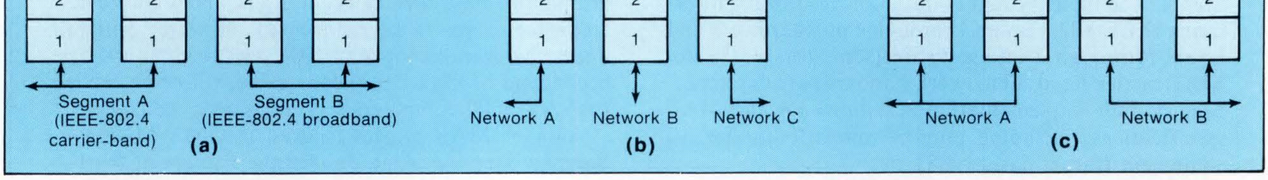
The functions in MAP layers 6 and 7—the presentation and application layers, respectively—are highly interrelated; the protocols defined within each one's realm affects the other level. Right now, MAP carries no specifications for the presentation layer, which negotiates a syntax for the application layer. The reason: No syntax explicit enough has been agreed on, though efforts continue.

The application layer comprises several protocols: a subset of the ISO's common application service elements (CASE) protocol; directory services; file transfer, access, and management (FTAM); a subset of the reference OSI model's manufacturing management format standard (MMFS); and GM network management protocols.

The CASE protocol defines services that allow an application to set up an association with a named remote peer application—that is, one neither subordinate to it nor above it—and to transfer information between applications. Within the bounds of this protocol fall the directory services, including a data base that MAP network nodes can use to locate other systems.

The FTAM protocol allows users to move files in bulk and to perform simple management functions. File accessing and more sophisticated file-management routines are now in development; the latter include diagnostics and control of installations interconnecting several networks.

The roughest road lies under the application layer's current MMFS protocol, which has no clear-cut, unambiguous message syntax defined. As a result, manufacturers may produce MMFS-compatible equipment, but



2. Three basic types of structures will hook other networks into the MAP backbone. Bridges tie similar and dissimilar IEEE-802 networks through the first two layers of the ISO OSI reference model (a). Routers require the first three layers to bring together several MAP and non-MAP networks at a common point (b). Gateways encompass the seven layers, so that MAP, non-MAP, and proprietary networks can communicate (c).

their machines may be unable to communicate with other MMFS-compatible gear. FTAM can fill in some gaps, but it is too general and too complex; moreover, many plant-floor machines have no file system of their own.

In the meantime, the GM Programmable Devices Working Group, a MAP task force, is attempting to clear up the MMFS ambiguity. Cooperating with Working Group 1393 of the Electronic Industries Association, it has produced a real-time protocol, designated EIA RS-511, that will be debated and voted on later this year. GM expects most of layers 6 and 7 to reach draft international standard status by late this year. At that stage, no major changes can be made to their technical content. The protocols would then be eligible for international standard status.

RS-511 satisfies the real-time demands of process- and cell-control networks. These system segments, which adhere to IEEE-802.4 standard and serve as subnetworks to the MAP broadband backbone, are known as MAP's enhanced performance architecture (EPA) options. The carrier-band subnets (single-frequency subnets) are expected to connect a large number of factory devices and will likely make up the majority of local networks on the plant floor. There they will direct, monitor, and maintain machines and controllers in islands of automation.

Carrier-band subnets will be connected to the MAP backbone via three-layer routers, and can include MAP/EPA, as well as mini-MAP nodes (Fig. 3). Devices residing on a MAP/EPA node may communicate over the MAP backbone with other peer entities via the MAP/EPA node using all seven MAP layers. Alternatively, layers 3 through 6 may be skipped, for real-time responses. Mini-MAP nodes allow communication between entities residing in the control segment only, using the first two layers of MAP.

Carrier-band protocols for the EPA subnets are moving closer to those of the Instrument Society of America's Proway. Like that network, they specify phase-coherent frequency-shift keying for modulation and have similar transmitter and receiver specifications. Whereas Proway has a 1-Mbit/s data rate, the IEEE-802.4 carrier-band data rate is specified at 5 or 10 Mbits/s (ELECTRONIC DESIGN, Feb. 20, 1986, p. 31).

For time-critical factory operations, carrier-band subnets have several advantages, not the least of them being cost. Their simpler modems and interface circuits translate into much lower node connection costs than for broadband networks. In addition, carrier-band networks

Steering factories into the future

Recognizing the large base of incompatible factory equipment, as well as the time that goes into developing software, hardware, and standards, General Motors has come up with a plan for gracefully implementing its Manufacturing Automation Protocol, or MAP. The strategy encompasses five steps:

Step 1: Incompatible computers talk to one another via an IBM minicomputer (completed in 1984)

Step 2: Computers from different vendors tie into a distributed local network, with specially selected programmable controllers accessing a MAP network (completed in 1984)

Step 3: Network functions are enhanced for MAP and TOP (Technical Office Protocol) through network management, directory services, internetworking, a transport protocol, and a file transfer protocol (demonstrated at 1985's Autofact Convention)

Step 4: The industry makes initial moves toward translating IEEE-802.4 layers 1 through 4 into hardware and layers 5 through 7 into software (some time in 1986); MAP carrier-band subnetwork standards are developed.

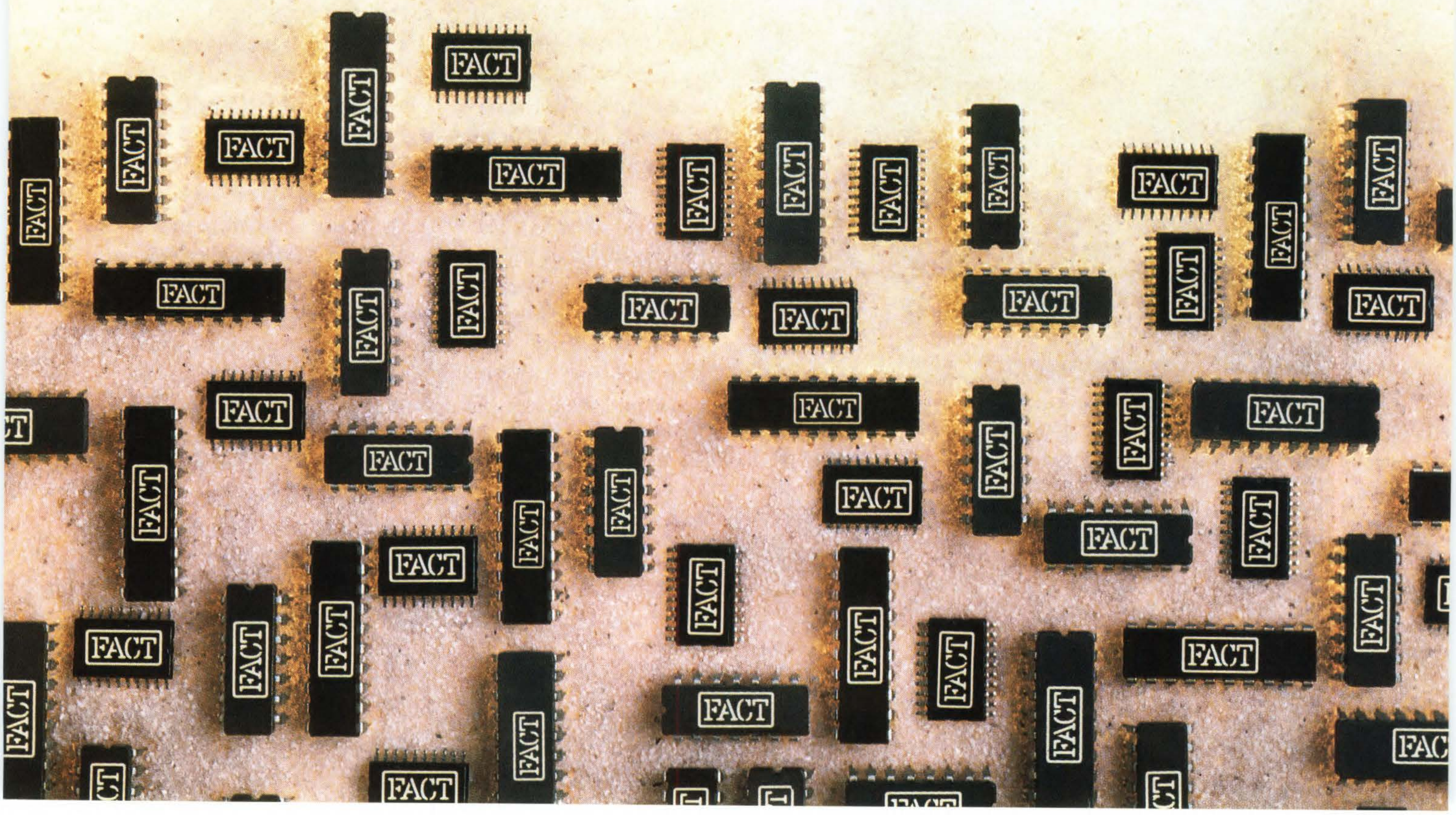
Step 5: Full implementation scheduled for the MAP specifications, including plug-in compatibility for all equipment (target date, 1988).

To General Motors, bringing orderly communication to the factory floor is a prerequisite to automating its plants. Consider the Spring Hill, Ky. plant for manufacturing the Saturn automobiles. With an MAP/TOP network, the facility will turn out a projected 500,000 cars a year—double the output of existing GM plants.

Going a step further GM anticipates that within a few years, customers will be able to order a Saturn car—complete with all desired features—through a computer terminal at the car dealership. The order will be relayed to the plant, which customizes and ships the car to the customer within a week. Down the road GM sees customers placing their orders directly through their home computer.

The automotive giant has ambitious ideas for other divisions as well. Its GMT400 project, geared to redesigning and redeveloping the CK series of light-duty trucks, dictates a 40% increase in plant automation. Each of the five factory facilities involved will have 1000 to 2000 intelligent devices on the floor—from programmable controller, cell controllers, and robots to new technologies yet to be named—all of which will fall under the overall control of IBM 4300 computers. The broadband MAP 2.1 backbone cable will be controlled by VAX 8600 computers serving as area managers.

Another MAP project focuses on GM's Michigan-Saginaw Steering plant, dubbed the Factory of the Future. The plant, which manufactures front-wheel drive axles, will set aside some 100,000 ft^2 for refurbishing as a totally MAP-ped plant.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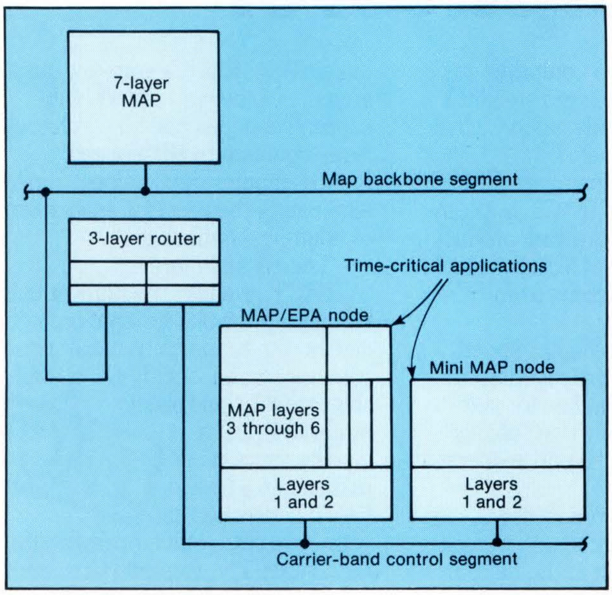
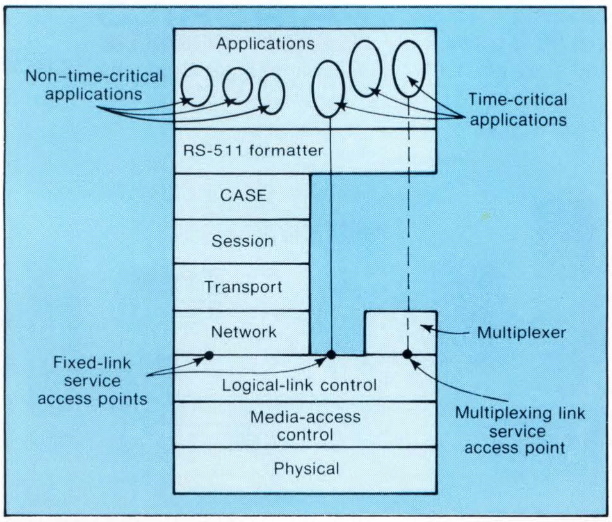


3. Through the protocol's enhanced performance architecture (EPA) options, a MAP carrier-band control subnetwork can meet real-time response needs. This can be done either through a MAP/EPA node, which delivers some application layer support while skipping layers 3 through 6, or through a mini-MAP node that uses only the first two layers. The mini-MAP node, though, restricts communication to the control segment only.



4. MAP carrier-band subnetworks can communicate with the MAP backbone using link-access service points in one of three ways: by skipping layers 3 through 7 (mini-MAP node); by linking parts of layer three to the application layer directly; or through a multiplexer.

need no head-end remodulator, which broadband networks need to translate frequencies between transmitted and received signals. Carrier-band networks also are more conductive to redundant cabling, which lifts their reliability above that of their broadband counterparts. Still they do have drawbacks: For instance, they are limited to one single-frequency channel (broadband systems, several) and are somewhat noisier.

The EPA subnets will build on a collapsed architecture that uses only layers 1 and 2 of the ISO OSI model, plus parts of layers 3 and 7 (Fig. 4). Collapsing the reference model bypasses much of the software code that resides in the upper layers, thereby speeding up response time. Some experts estimate that a message packet could travel through the collapsed architecture in a snappy 0.5 ms, a far cry from the 40 ms estimated for a packet to travel through all seven OSI layers.

A MATTER OF SILICON

Amid all this spec talk, all eyes focus on the efforts of top semiconductor manufacturers to reel out VLSI interfaces, most at the chip or board level. Motorola Semiconductor Products Inc. (Austin, Texas) was the first to produce a single-chip implementation of the IEEE-802.4 media-access control sublayer. Its MC68824 token-bus controller chip, fabricated wtih a 2-μm HCMOS process, works with 1-, 5-, and 10-Mbit/s carrier-band and broadband networks at the first two MAP layers. Internal registers allow it to accept broadcast messages without microprocessor intervention. Moreover, it handles the immediate-response (that is, the real-time-response) option of MAP's EPA and has four classes of message priority. Controlled by a local 68000 microprocessor, the device connects to the MAP coaxial cable through either a carrier-band or a broadband modem.

Motorola has already placed the chip on a 68020-based VME interface board that satisfies all seven layers of MAP 2.1. The MVME372 module uses hardware to fulfill the first two layers and Motorola's MicroMap software for the upper layers. The software can be downloaded into 640 kbytes of on-board dynamic RAM.

For 10-Mbit/s MAP broadband networks, a two-board set from Motorola puts a broadband modem on one board and the token-bus controller chip on the other. The MVME370 module satisfies the first four layers of MAP 2.1; here too, software can be put into on-board RAM.

Accompanying these boards is a MAP developer's kit that includes a head-end remodulator and coaxial cable taps. Some time this year Motorola expects to introduce an interface controller IC, designed with a macrocell array and built for the 10-Mbit/s MAP backbone. An-

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other IC expected this year, a bipolar carrier-band modem, works at 1 and 5 Mbits/s.

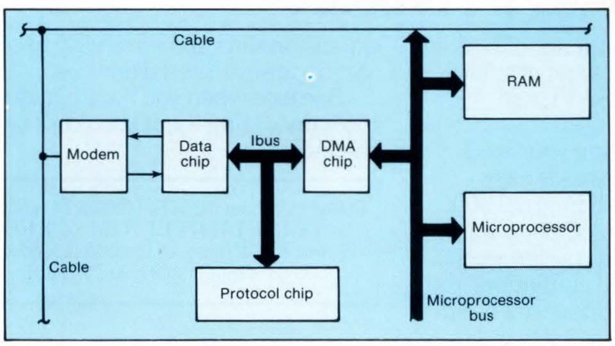
For top flexibility, designers can turn to the Token/Net interface chip set, the joint work of Concord Data Systems Corp. (Marlboro, Mass.) and Gould AMI Semiconductors Inc. (Santa Clara, Calif.). The three chips—one for data, one for DMA control, one for protocols—are fabricated with 2-μm design rules, an HCMOS standard cell, and custom arrays (which make up 30% to 40% of the design). They target carrier-band and broadband systems that move data at 1, 5, and 10 Mbits/s.

The data chip processes serial information flowing from or to a modem over coaxial cable. In addition, it frames messages, checks errors, converts data between serial and parallel formats, and synchronizes the modem to a system clock. The DMA chip, which connects the data chip to a microprocessor bus, manages the buffer data. Unlike other MAP interface chips, it can tie into both Intel and Motorola 8- and 16-bit microprocessors, and it can be upgraded for upcoming 32-bit devices.

The protocol chip, the brains of the threesome, implements the media-access control sublayer and portions of the logical-link control sublayer. An immediate-response option can be called on to satisfy the MAP enhanced performance architecture.

Like Motorola's token bus controller, the protocol chip contains registers that eliminate the need for microprocessor intervention. All three token/net interface devices are linked through the proprietary Ibus (Fig. 5).

For now, Concord Data Systems uses the chip set in its MAPware carrier-band and broadband modems, board-level subsystems for Multibus I setups. Together with supplied software, the boards handle all layers of MAP



5. Distributing MAP interface functions among three separate chips—one each for data, DMA, and protocols—gives designers greater flexibility than does a single-chip approach. The key to the chip set, developed by Concord Data Systems and Gould AMI, is the high-performance Ibus, which consists of eight data lines, a control line, a common-clock line, and three bus request lines.

2.1. In the future, Gould AMI might supply the chips separately to the merchant market on a limited basis.

Concord Data also makes box-level MAP items, including two MAPserver front-end processors for carrier-band and broadband networks. One of those processors also provides RS-232-C terminal connections. Finally, a terminal server connects asynchronous and synchronous terminals, personal computers, and RS-232-C devices to MAP networks.

A MAP interface board from Intel Corp. (Santa Clara) handles the first four layers of MAP 2.1 and is designed to hook MAP systems into Multibus systems. The iSXM554 Commengine revolves around an 80186 microprocessor, a token-passing bus handler, iSXM and Multibus interface circuitry, and a broadband modem. MAP-Net software for layers 5 through 7 can be downloaded into 256 kbytes of on-board RAM. The board runs Intel's iNA961 (release 2.0) transport- and network-layer software.

A PROPRIETARY DESIGN

The 80186 microprocessor also forms the heart of the MAP/One interface board from Industrial Networking Inc. (Santa Clara). On the board is a pair of proprietary CMOS gate-array chips, designed by Industrial Networking and built by Toshiba Corp. (Tokyo), as well as 512 kbytes of RAM. The hardware meets the first two layers of MAP 2.1, while software covers the upper five layers. Teamed with a VLSI-based broadband modem board, the board establishes an interface with 10-Mbit/s MAP networks. Variations of the two-board set aim at general-purpose buses, the IBM PC bus, the VMEbus, and the Multibus. To supplement the board set, Industrial Networking offers a head-end remodulator, a network monitor, and a network traffic analyzer. It is also working on a VLSI chip carrier-band modem.

Two other firms working together on a MAP interface chip set are Western Digital Corp. (Newport Beach, Calif.) and Siemens AG (Munich, W. Germany). At this time, no details are available.

Two other manufacturers, Fairchild Data Corp. (Scottsdale, Ariz.) and the Communications Division of Allen-Bradley Co. (Ann Arbor, Mich.) lend their names to 10-Mbit/s broadband MAP modems. Fairchild's M8024 MAP-Link is compatible with the VMEbus, Multibus, Q-bus, and Unibus and satisfies only the IEEE-802.4 physical layer. By this summer it will be priced aggressively for OEMs at about $500—one of the least expensive broadband modems. Yet even that price cannot compare with the $25 to $50 tags on baseband modems, one more reason that carrier-band networks are gaining

favor in the MAP environment.

Despite the proliferation of MAP hardware and software, large challenges loom. For one thing, all this sophisticated electronic equipment in an automated plant means more complicated maintenance. Plant electricians, accustomed to servicing electromechanical and relatively simple equipment, will now face more formidable machines. The inclusion of self-diagnostic mechanisms can circumvent the problem, but not without network management tools, something sorely lacking for MAP.

Servicing difficulties pale beside two more pressing problems: interoperability and conformance testing. Just because two pieces of equipment are compatible with the protocol does not guarantee their interoperability, as all MAP specifications are subject to interpretation. In some demonstrations, so-called MAP-compatible pieces had to undergo much debugging before they went on stream. Testament to the confusion, makers of MAP modems can't even agree on what interoperability means.

Still, there have been important steps toward interoperability. Earlier this year, Concord Data Systems and Motorola successfully demonstrated their carrier-band equipment over MAP's first two layers. Included in the test were Concord's Token/Net interface modules and Token/Scope network analyzer and Motorola's token-bus controller, carrier-band modem, and software (ELECTRONIC DESIGN, March 6, 1986, p. 12). But these tests were limited to the first two layers only. Moreover, they did not take place in a fully operational MAP network or on a real-life factory floor.

A noteworthy element in the quest for interoperability is the first and only MAP simulator-analyzer from Tekelec Inc. (Calabasas, Calif.). The portable benchtop unit allows simulation and preconformance testing of MAP layers 3 and 4. Software for layers 5 and 7 will be available in the future.

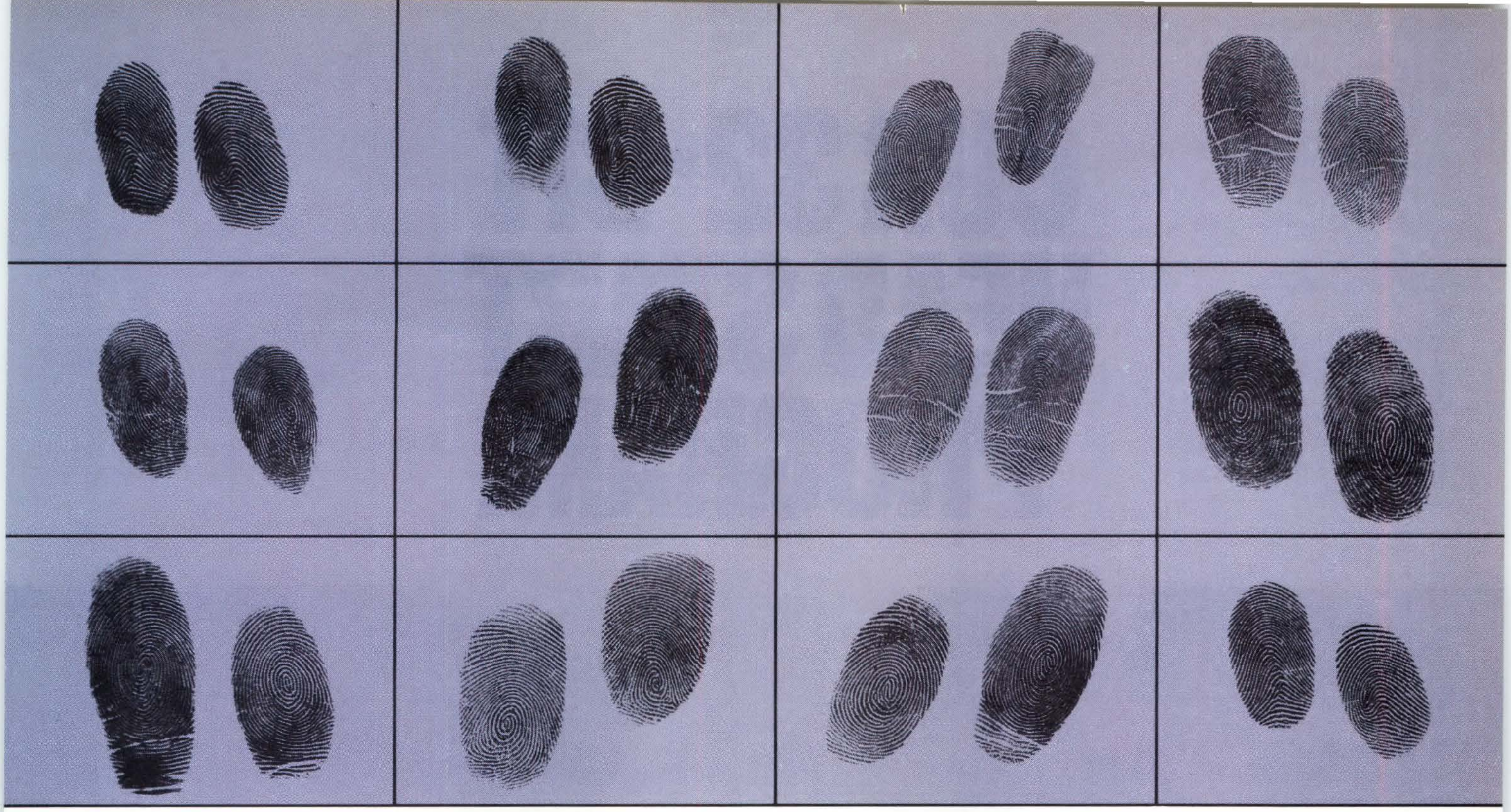
The Industrial Technology Institute (Ann Arbor, Mich.), a nonprofit organization funded by the state of Michigan, knows all about interoperability problems. Last September it began conducting conformance tests on MAP-compatible equipment. It reports that most of the equipment failed the initial testing, largely because of software problems. The institute has devised test software that evaluates possible fault conditions. MAP vendors now have the means to test their own products, with the institute interpreting the test results and releasing them to equipment users at the vendor's request.

The organization also plans to develop hardware tests for lower-layer MAP products. Whereas software faults can be remedied once they are detected, hardware faults may prove too costly to fix unless the tests are run at the early design stages. ITI expects to implement tests for broadband modems this year, following definition by the IEEE 802.4J-1 Committee. The National Bureau of Standards (Gaithersburg, Md.) is getting into the act too. It is developing a MAP test for IEEE-802.4 broadband modems that should be out by July.

How often must a conformance test be run on a product? After one engineering change or after several? With totally new equipment models? The ITI, the NBS, and other organizations are weighing the questions. But one thing is clear: Given the ambitious nature of MAP, the man-years of hardware and software efforts involved, and the level of complexity, many MAP backers agree with GM that conformance testing and assurance of interoperability should be compulsory. □

Specifications for MAP 2.1 and TOP 1.0

Layer	Manufacturing Automation Protocol	Technical Office Protocol
7—Application	Network management Directory services MMFS (manufacturing management format standard); migrating to EIA RS-511 ISO OSI kernel for CASE (common application service elements) ISO OSI FTAM (file transfer, access, and management)	ISO OSI FTAM (file transfer, access, and management)
6—Presentation	Not specified	Same as MAP
5—Session	ISO OSI session kernel	Same as MAP
4—Transport	ISO OSI-compatible subset of NBS class 4 transport	Same as MAP
3—Network	ISO OSI connectionless service (supported by IEEE and NBS) CCITT X.25 GM routing algorithms	ISO OSI connectionless service (supported by IEEE and NBS) CCITT X.25
2—Data link	IEEE-802.2 logical link control with immediate-response option of ANSI's Proway (connectionless class 1) IEEE-802.4 token-passing media-access control	Same as MAP
1—Physical	IEEE-802.4 token-passing access to broadband medium IEEE-802.4 token-passing carrier-band options	IEEE-802.3 CSMA/CD access to baseband medium



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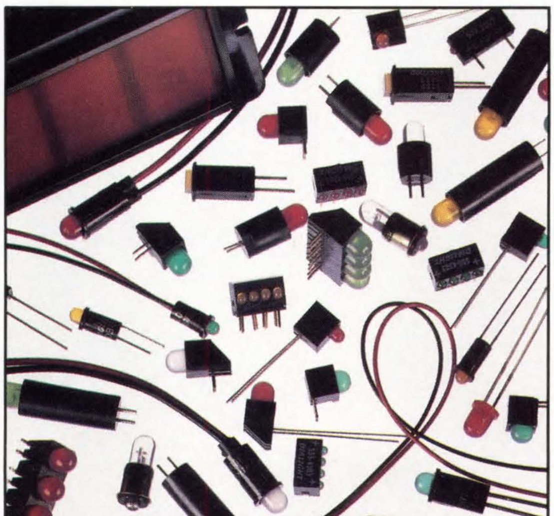

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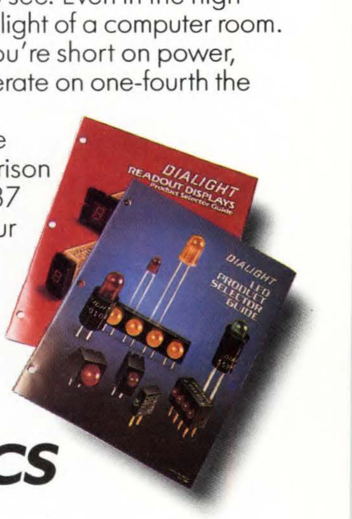

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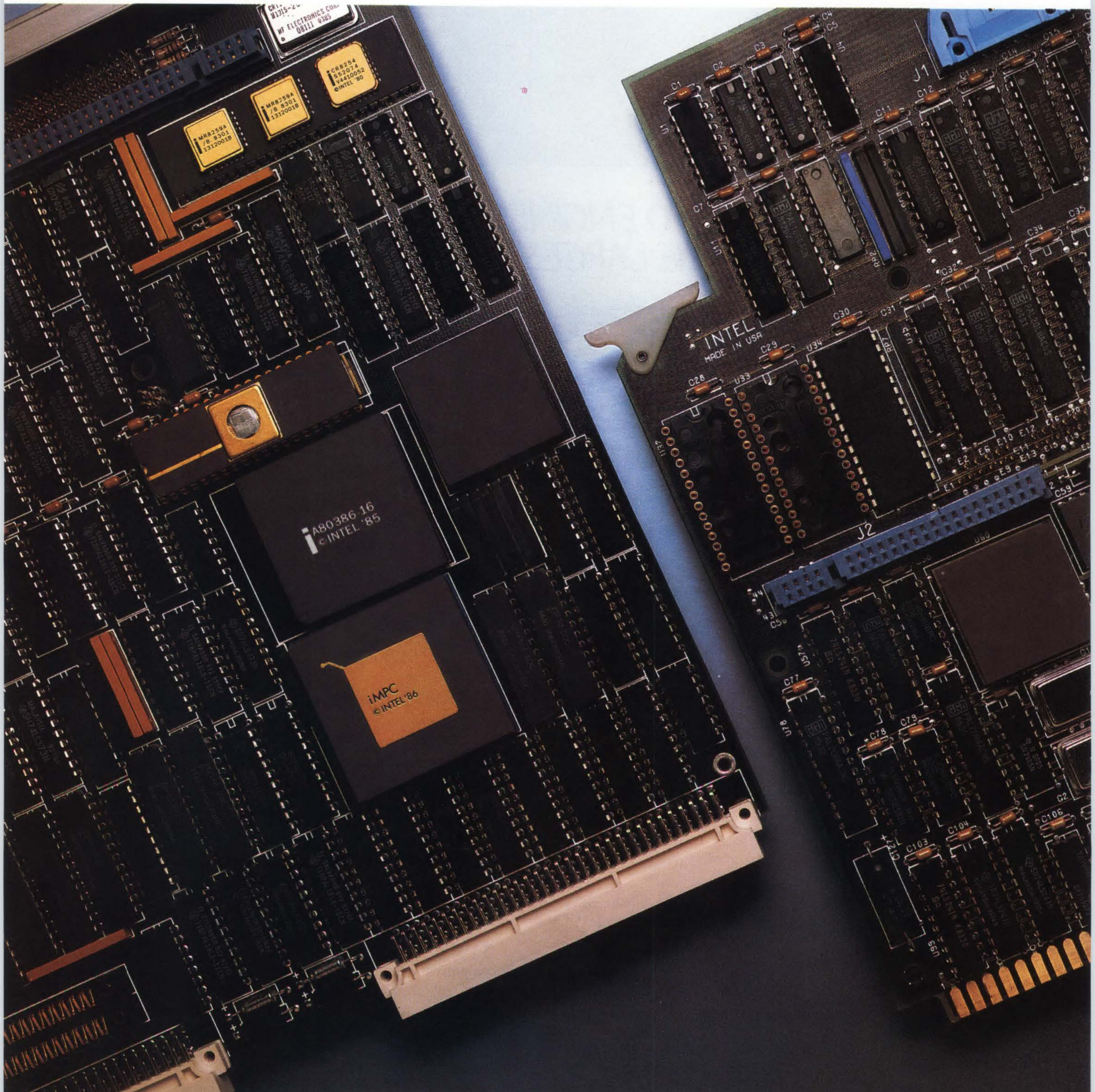

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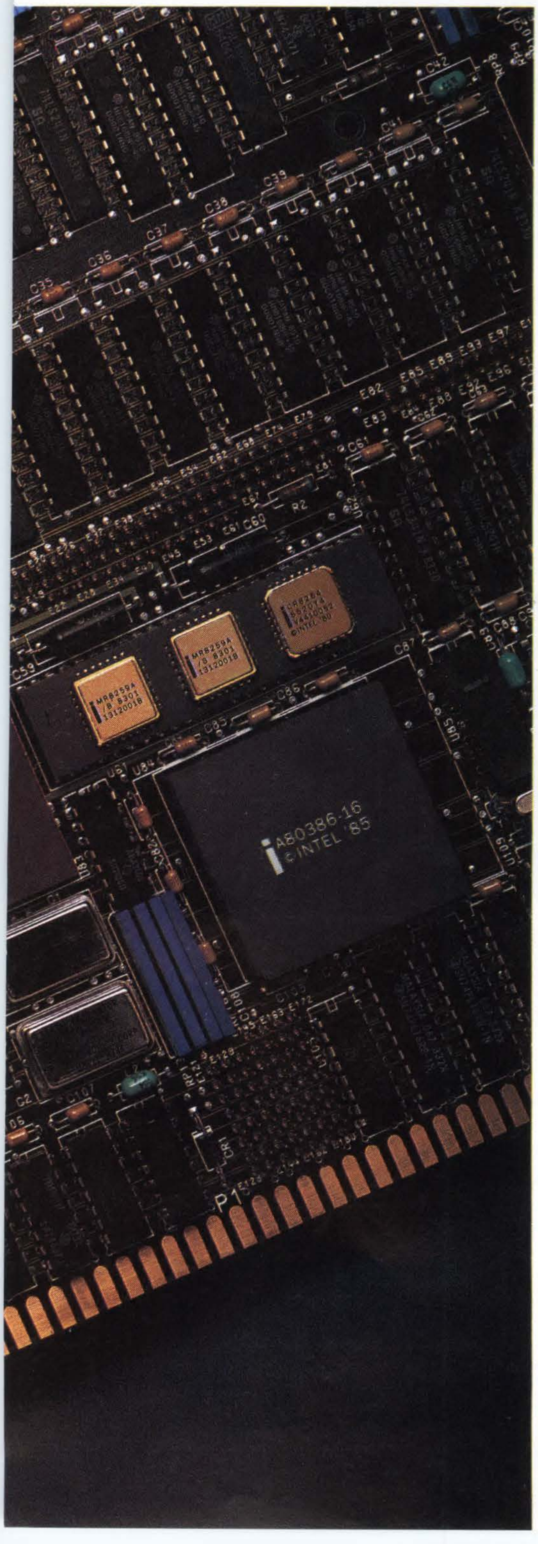

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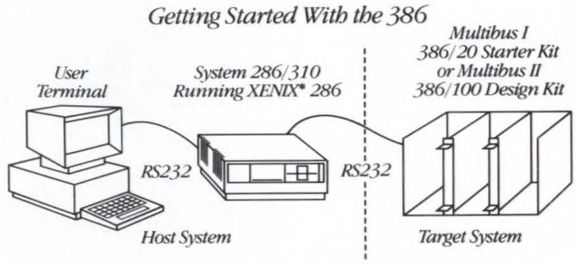

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CIRCLE 69

ELECTRONIC DESIGN EXCLUSIVE

When bit slices team up with ECL, 32-bit computers rise to superpower status

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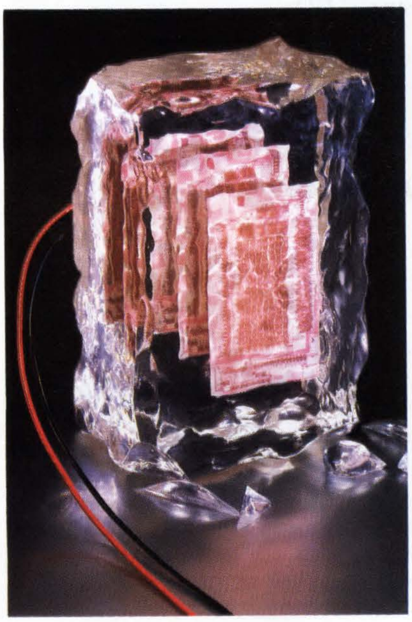


This is the first in a two-part series about a brand-new family of ECL bit-slice chips. The second article, to appear in a subsequent issue, will detail how to design an actual system using the chips.

When it comes to speed in a CPU, nothing surpasses a bit-slice design, and when it comes to silicon, nothing beats emitter-coupled logic. Now the two approaches have joined. A new family of 8-bit devices will give designers the tools to build the fastest 32-bit computers possible under existing technology—with instruction execution rates of 50 MIPS or better. As impressive, the chips can dramatically upgrade the performance of even the most powerful minicomputers.

The new chip set revolves around an 8-bit-slice processor, essentially a register-equipped ALU. Two versions of the chip, the TIE10H888GB and the TIE100888GB, are fabricated with 10KH and 100K ECL, respectively; the last version, the TIET888GB, uses ECL internally and TTL for the I/O circuitry. All three models deliver 50-MIPS performance—for a 20-ns instruction cycle—and dissipate less than 5 W. Moreover, they run four times faster than STL devices in the same application.

The ECL bit-slice processors spring from an innovative bipolar semiconductor process called Impact. Already the process has spawned bit-slice chips in Schottky transistor logic (STL) that set new standards for speed and power consumption. The Impact process enables STL circuitry to match conventional ECL gate delays but at a thirtieth the power. And when it is applied to ECL circuitry, Impact cuts gate delay three to four times, yet power dissipation is that of conventional ECL.

Designers gain another advantage: Both families, Schottky and ECL, incorporate the same hardware functions and are fully compatible right down to their microcode instructions. In fact, a system development cycle might begin by designing the initial hardware with STL components, since they are more easily managed. That way designers can develop and debug microcode and root out logic problems before coming to grips with the more exacting demands of

Cover: First ECL bit-slice family

ECL devices. Then they have two options for gaining speed: Either substitute the ECL-TTL components for the STL devices or wring out top performance by redoing the pc board for purely ECL components and design rules.

In operation, the ECL processor naturally needs support, primarily from a microprogram sequencer (controller) and a 16-bit expandable barrel shifter. With a 14-bit address width, the 890 microsequencer can address up to 16 kbytes of control-store memory. In addition, it handles multiway branching, real-time interrupts, and nested-loop operations. The 897 barrel shifter takes care of the extensive data-shifting operations found in graphics and artificial intelligence. Moreover, it speeds digital signal-processing computations, since its internal bit-reversal circuitry offloads the ALU from the address generation tasks needed to compute fast Fourier transforms. Like the processor slice itself, the sequencer and shifter chips are available in 10KH, 100K, and ECL-TTL versions (with similar, comparable part numbers).

An ECL bit-slice computer requires yet a fourth element, high-speed static RAM, both for the processor's register files and for control-store memory. The RAMs must run faster than 50 MHz (a 20-ns cycle time) to keep up with the processing speed of the ALU. Indeed, a family of high-speed ECL static RAMs sporting access times of 5 and 10 ns is in the works; they will be organized as 16k by 1 and 4k by 4 bits.

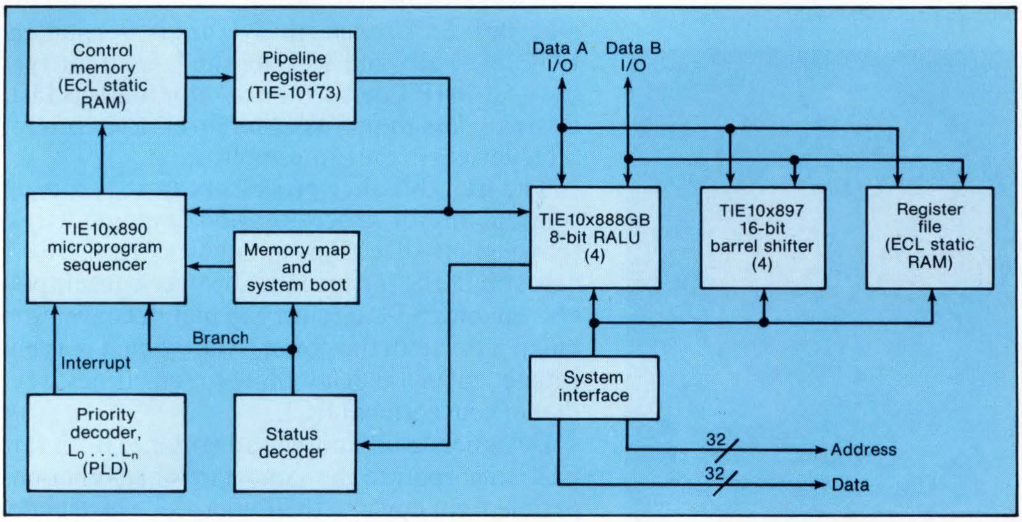
Besides the four main elements, a full 32-bit, high-performance computer needs programmable logic devices for priority-encoding, condition-code logic, and other circuitry (Fig. 1). PLDs having propagation delays of 3 and 5 ns will likewise spring from Impact Technology. With a complete family of ECL chips at their disposal, designers will no longer be labeling hardware as the limiting factor in computer performance. In fact, the chips hold out the possibility of desktop computers with extremely fast instruction execution and data processing.

Consider how ECL 888 devices could improve the instruction rate of several well-known high-performance minicomputers (Fig. 2), using the Cray-1 super-mainframe as a reference. By switching to the ECL family, three superminis could move into the Cray-1 class. Even workhorses like Digital Equipment's VAX-11/780 could run substantially faster with the ECL chips.

TWO-WAY HARDWARE

As noted, the different versions of the ECL 888 bit-slice devices accommodate various system performance requirements and cost goals. The performance level of the ECL-TTL devices, for example, is slightly lower than that of the purely ECL models, but designers have the convenience of simple interfacing with TTL circuits at the system level.

The ECL-TTL devices operate from the standard 5-V supply, whereas the purely ECL chips operate from a −5.3-V supply, as in standard ECL systems. Users accustomed to designing with the well-known ECL 10KH and 100K series of logic can treat the appropriate purely ECL versions as if they were members of those families.



1. The key processing elements of a high-speed 32-bit computer based on the ECL 888 bit-slice family are the microsequencer, four 8-bit-slice registered ALUs, four 16-bit barrel shifters, and a register file built with high-speed ECL static RAMs. For the fastest operation, 50 MIPS or higher, support components such as the control memory, status decoder, and pipeline register must also be built with ECL technology.

Whether ECL alone or ECL-TTL, no device—processor, microsequencer, or barrel shifter—consumes more than 5 W. Moreover, all three versions offer the same drive capability, 8 mA on the A and B data buses and 24 mA on the Y data bus. All three buses are bidirectional; each can serve as an input or output, depending on the particular processing situation.

To make pc board layout particularly efficient, the devices are packaged in pin-grid arrays. The standard 84-lead package has the same dimensions as the 68-lead grid array used for the STL family. The greater number of leads in the ECL version provides extra power-supply and ground leads, giving designers the flexibility to lay out pc boards according to the design rules of ECL technology. Despite the difference in pin count, sockets laid out for the ECL chips also accept the STL types.

Since the pin-grid array is designed to dissipate heat efficiently, neither heat sinking nor exotic cooling schemes are needed. Conventional fans suffice in any application.

OPTIMIZING SYSTEM THROUGHPUT

As mentioned earlier, both the ECL 888 processor and the 890 microsequencer are designed with a three-bus, flow-through architecture (Fig. 3). The architecture significantly raises throughput over existing bit-slice processors because the processor can read an address, perform an ALU operation, and shift and write—all in the space of a single clock cycle.

Operands flow into the processor—actually a register-equipped ALU, or RALU—either from an internal 16-by-8-bit register file or directly though the processor's two bidirectional I/O ports. Hence the register file can be expanded without limit, a valuable feature in digital signal processing (DSP) and AI applications.

ECL control-store memories with access times of 5 ns can be used in the control path so that it matches the data path's speed. However, a more cost-effective alternative uses the 890 microsequencer to provide very fast, balanced cycle times with the registered ALU. Because of its next-address generation time of 10 ns, the microsequencer effectively creates extra time in the timing cycle for slower memory devices; in the process it lowers the cost of the control-store RAMs without compromising performance.

Suppose that a 10-ns control-store memory has been added to a purely ECL system with a pipelined architecture (Fig. 4). The 890's next-address generation time is 10 ns, and the ECL processor cycles in 13 ns. While the processing portion of the system—pipeline, data path, and status-decoding blocks—manipulates data in 20 ns (2 + 13 + 5 ns), the microsequencer and control store generate the next address, also in 20 ns (10 + 10 ns).

Price and availability

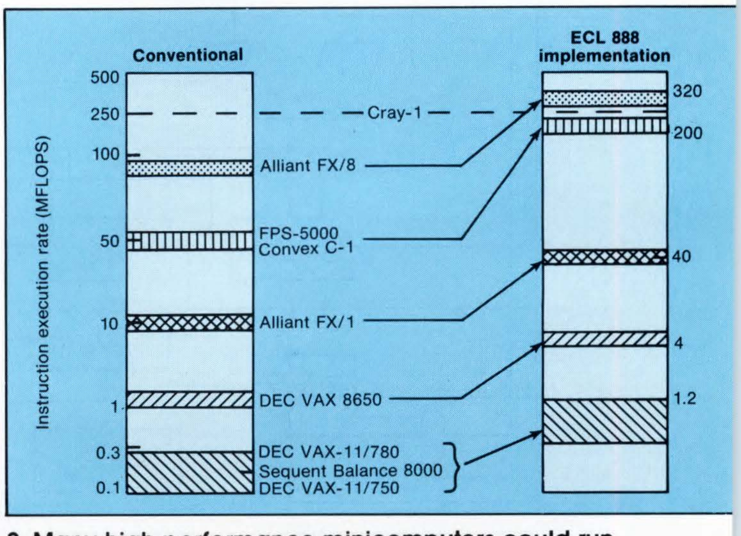
All the ECL bit-slice parts mentioned here will be available through distributors in the second half. The price structure has not yet been set.

CIRCLE 501

With the pipelined architecture, the data manipulation and next-address generation cycles fully overlap, and since the time for each is identical, they are balanced. Thus, what first appears to be a 40-ns cycle time is in reality a 20-ns cycle.

Mixing ECL and STL components within the same architecture may also prove to be advantageous. Such an approach reduces the expense of control-store RAMs, the major cost factor in high-speed designs. With TTL processors (and with the STL family), this alternative would traditionally be implemented through double pipelining: In addition to the customary pipeline register in the data path, a second is inserted in the address generation path. Double pipelining allows a designer to split the cycle time of the control portion of the system and thus use slower static RAMs. In effect, the address-generation pipeline register folds the control section into two parallel paths.

Nevertheless, the tactic is far from optimum, because the two-cycle delay between the ALU and control paths



2. Many high performance minicomputers could run faster and cover broader application bases if they were upgraded to the ECL 8-bit-slice family. Top-of-the-line superminis approach and even exceed the performance level of a Cray-1 supercomputer when built with 888 bit-slice processors.

heightens microcode complexity. For example, if the system executes a branch operation or services an interrupt, both pipeline registers must first be cleared, or flushed; the additional time lowers system throughput.

Rather than designing around the difficulties of a double-level pipeline, the ECL-TTL microsequencer can be used with relatively slow (35 ns) CMOS control-store RAMs and still deliver a balanced cycle time with the STL ALU path. System cost falls, since 35-ns static RAMs not only are readily available but are less expensive than 5- and 10-ns types. Moreover, the combination of an ECL-TTL microsequencer and STL ALU yields a powerful 49-ns instruction cycle time as a result of the microsequencer maintaining a 14-ns address-generation time.

As computers push into advanced application areas, changes in high-performance system architectures represent a natural evolutionary step. Yesterday's minicomputers are today's superminis, and personal computers are transformed daily into engineering workstations through advances in the chip-making art. As machines grow in capability, they are able to tackle a more demanding class of applications.

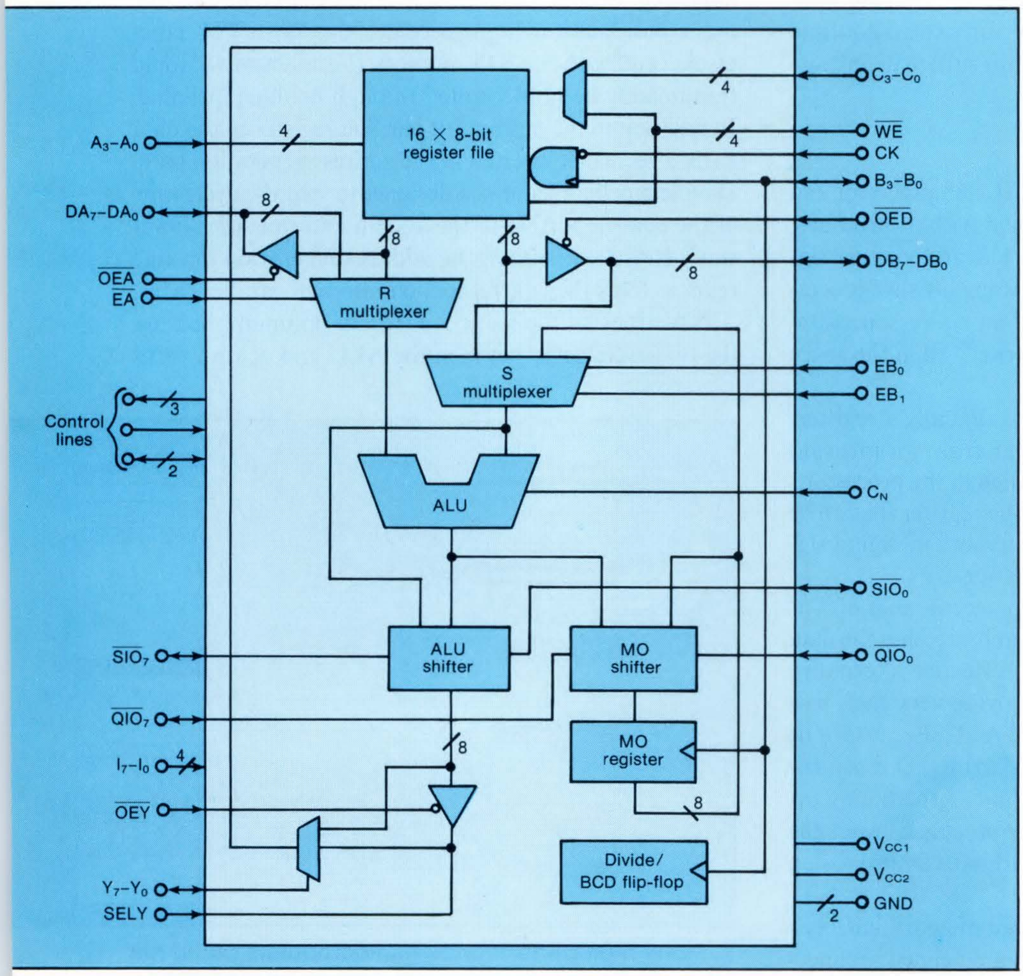
THE APPLICATION SPECTRUM

DSP for spectral analysis and digital filtering is one such class. Here the parameter of primary importance is the rate at which the computer system can sample, or process, signals. Clearly if a computer employs digital devices that operate four times faster than at present, its sampling rate might conceivably climb by the same amount. Designers can then analyze significantly higher frequency signals, extending the application spectrum for DSP.

A more subtle benefit accrues from the high-performance ECL family, namely, trade-offs between precision and bandwidth. In spectral analysis, for example, a designer can now obtain better resolution in analyzing signals within the same frequency band as earlier or move up to a higher band.

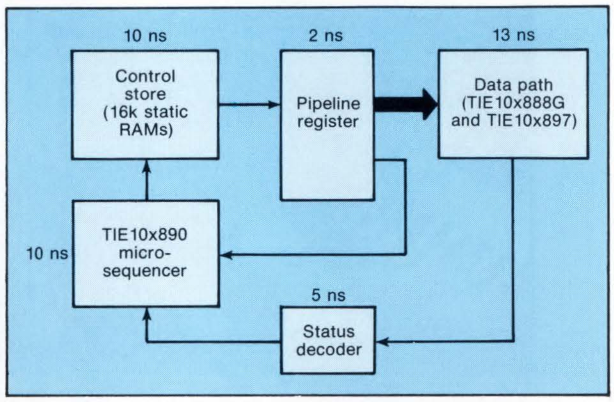
Computer graphics systems emerge as another beneficiary of the ECL devices. With bit-mapped techniques dominating virtually all graphics processing, the double-barrel challenge of accessing the bit map while refreshing the screen overwhelms conventional semiconductor logic. The ECL chips, with their vastly higher speeds, represent a first step in increasing system speed without making architectural alterations.

On the other hand, simply forcing a conventional processor system to run faster with higher-performance semiconductors proves insufficient for some new applications. Improvements in processor ar-



3. The processor, in reality an 8-bit-slice registered ALU, is the centerpiece of the bit-slice family. Its three-bus, flow-through architecture promises fast and accurate computations. The ALU and its support devices—barrel shifter and register file—execute an instruction in about 13 ns.

Cover: First ECL bit-slice family



4. The fastest computer systems might use the pipelined, purely ECL design shown. However, ECL 888 bit-slice devices can be mixed with STL or TTL logic to trade performance for cost.

chitecture may be necessary to guarantee flexibility and throughput. One method is to employ pipelining in systems that process information in an iterative sequence; to execute random algorithms, however, the flow-through approach works better than pipelining. But in some complex processing applications, the computer must be flexible enough to switch between the two approaches—from pipelining to flow-through on the fly. Another approach —used in array processors—is parallelism in the form of a single-instruction, multiple–data stream (SIMD) architecture.

The new family can operate in either a pipelined or a parallel mode by designating that the processor portion perform in a specific manner. In an array processor, for example, both parallel and pipelined architectures can be implemented, each with its own set of hardware. This approach translates into far simpler programming and faster operation than possible with a single hardware unit that works in both modes under software control.□

Chris DeMonico is strategic marketing manager for TI's processor slice products. He holds a BSEE from the University of Dayton and received an MBA from Southern Methodist University.

Frank Laczko is manager of system engineering for the TI VLSI Logic Division. He received a Bachelor of Science in physics from Sir George Williams University in Montreal.

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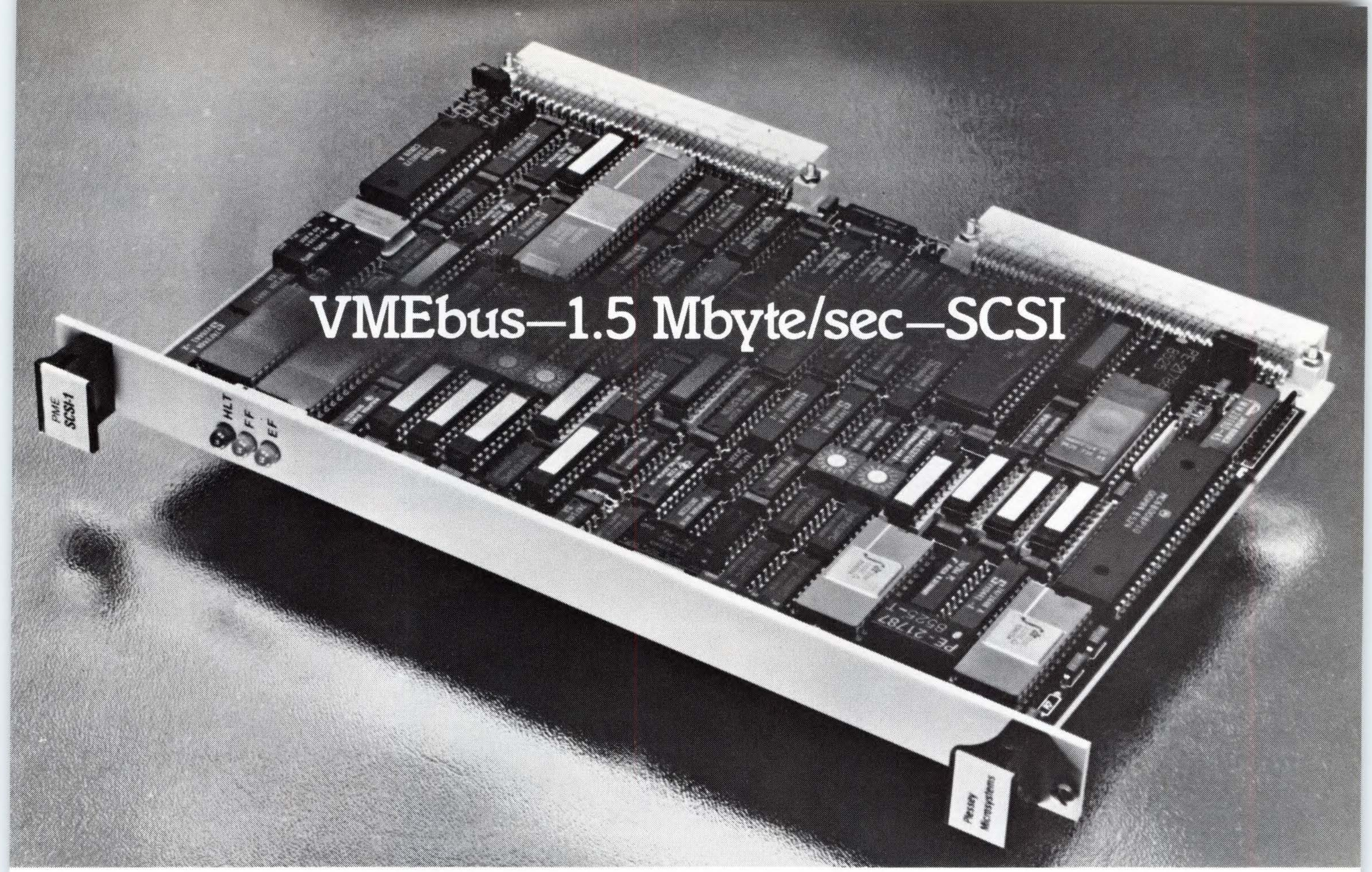

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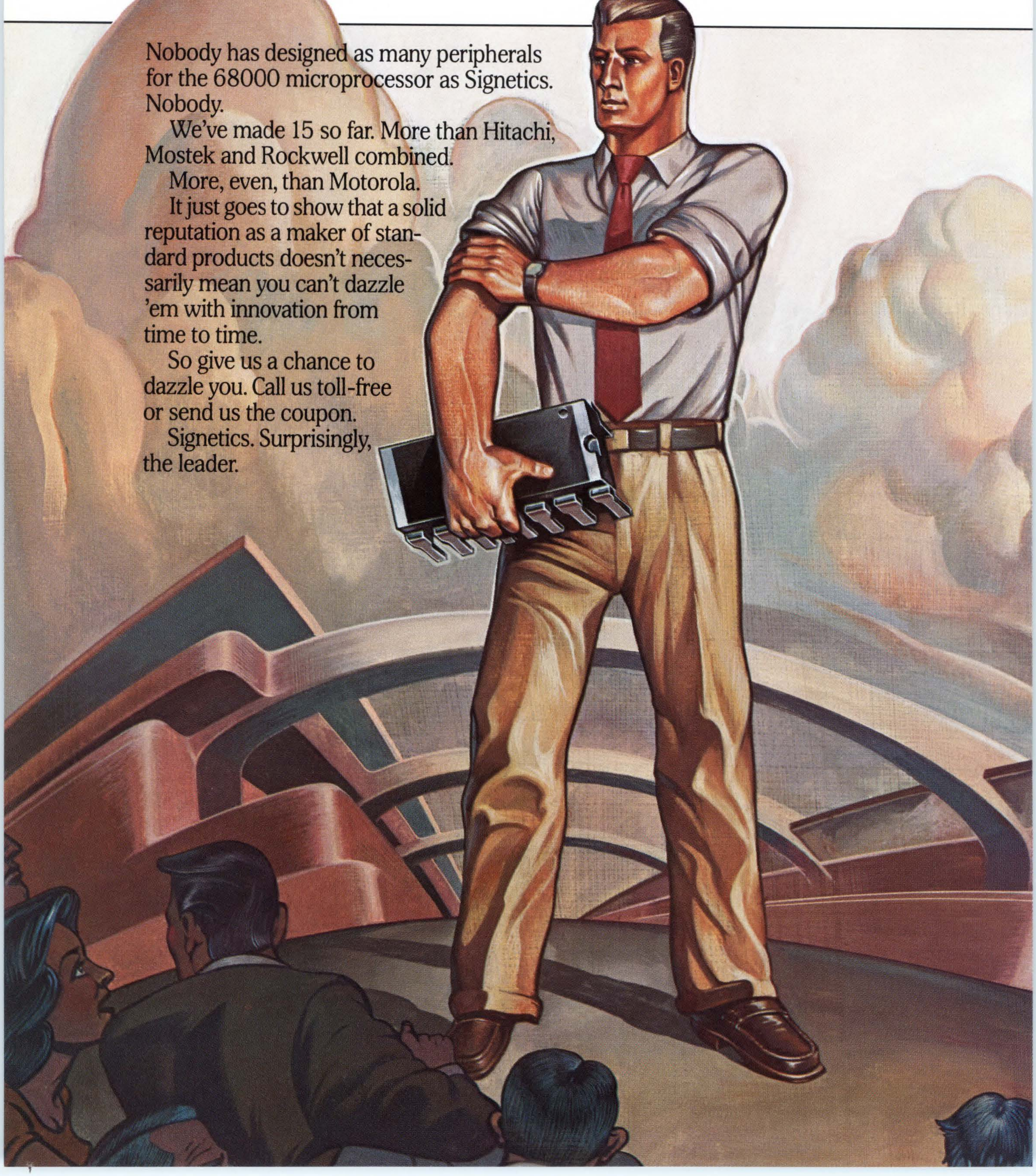

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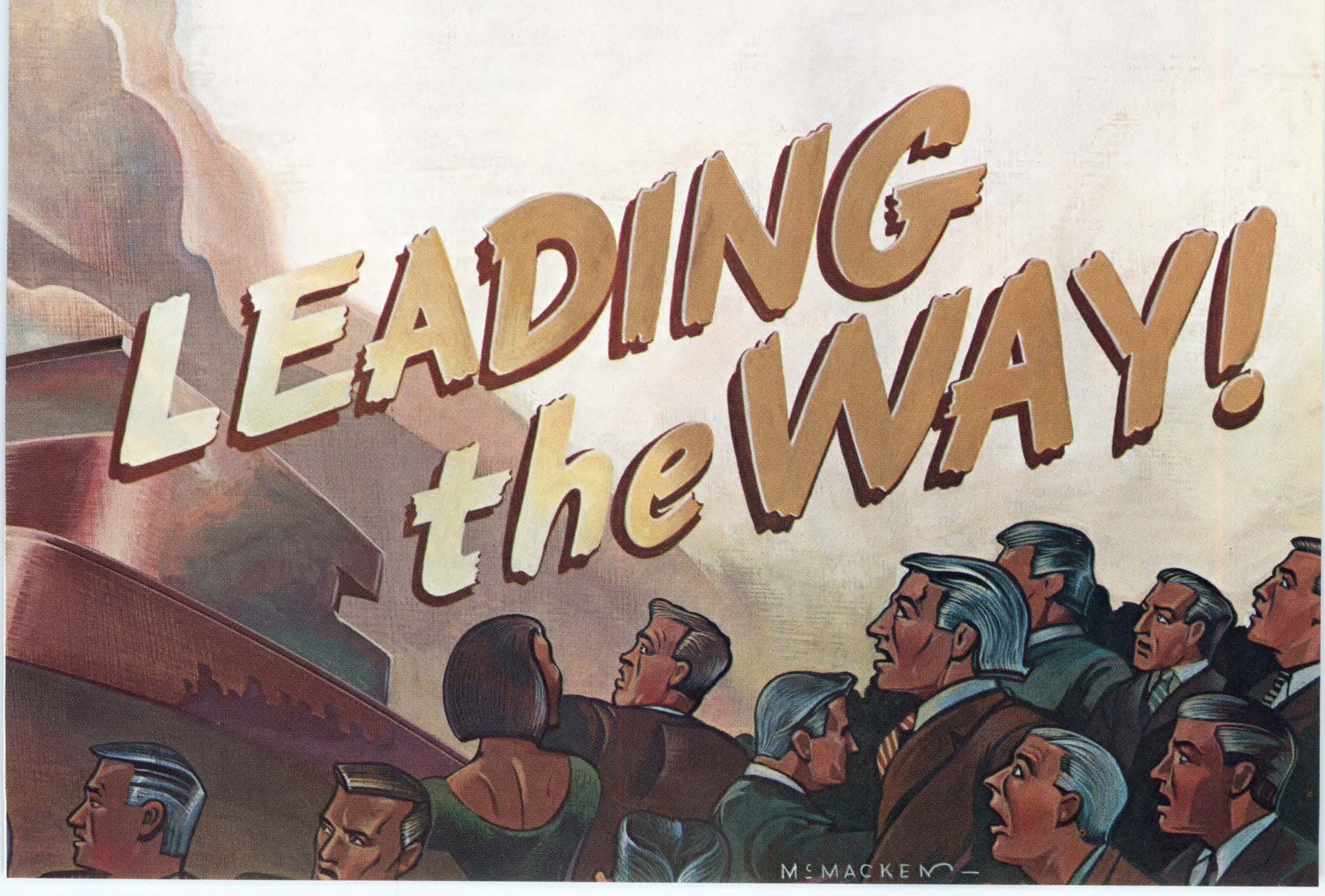

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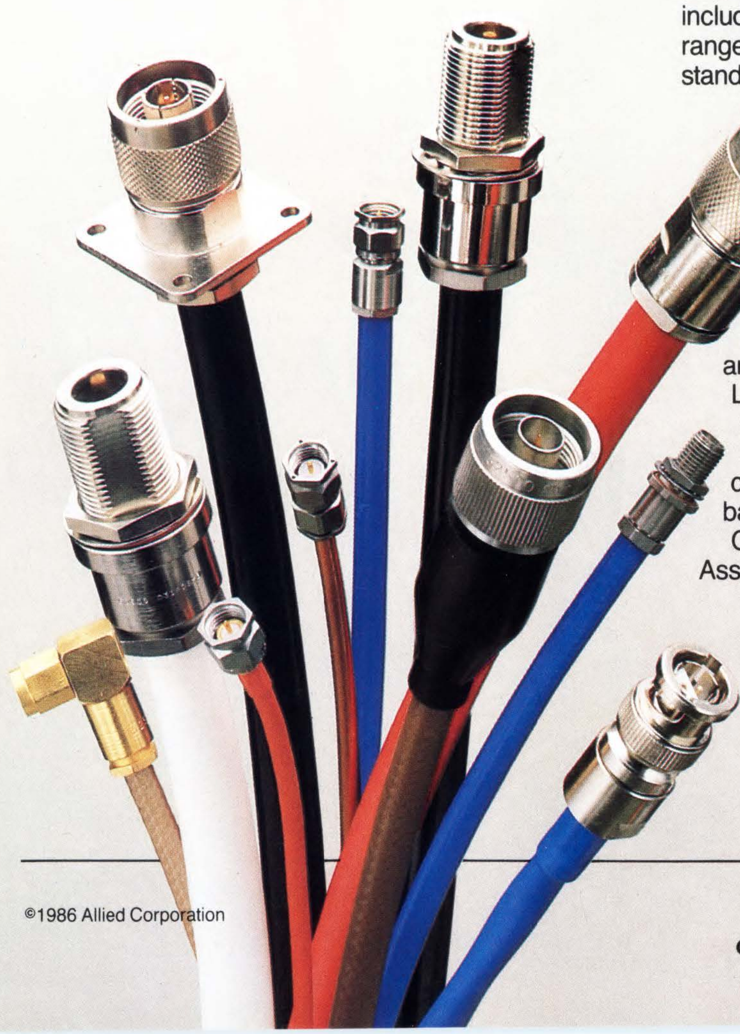

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CIRCLE 76

ELECTRONIC DESIGN EXCLUSIVE

High-power hybrid op amp dissipates up to 500 W and guards against burnout

Withstanding four times the heat of all previous hybrid circuits, a power op amp competes with bridge and parallel IC networks, power transistors, amplifiers, and other high-current schemes.

Granger Scofield
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Convenience, versatility, reliability, and accuracy attract designers to IC power op amps. But some tasks, particularly in motion control and robotics, demand higher current than today's monolithic or even hybrid op amps can deliver. Consider that right now, hybrid ICs can dissipate up to 125 W and drive loads of 250 W; monolithics can handle only a tenth that. To meet higher peak power requirements, op amps must be connected in parallel or bridge networks, or use external booster transistors or a power amplifier must be added. But those choices can increase a design's complexity, cost, size, and weight while cutting into reliability and linearity.

A new hybrid IC lifts the power limits. Owing in part to a specially developed package, the PA03 dissipates up to 500 W, four times that of the largest op amp now available. That rating means that the hybrid can drive 500-W linear motors, 1000-W passive resistive loads, and 2000-W loads in the switching mode. Furthermore, the op amp drives up to 30 A and operates from supplies of ± 75 V (ELECTRONIC DESIGN, Dec. 12, 1985, p. 164).

Besides having a high continuous power rating, the hybrid's thermal protection circuits enable it to operate anywhere within a 2400-W, 1-ms safe operating area. If an overload occurs, the circuits shut down the amplifier. Thus, the single amplifier is not only more economical than four separate ones in parallel, but it is also safer under abnormal conditions. In addition, by including its own current-limiting resistors, the circuit eliminates the bulky and expensive external current-limiting devices normally required for competitive power op amps.

The output stage, a common-collector complementary configuration (Fig. 1), can swing to within 4 V of the supply rail at 12 A and to within 6 V at 30 A. Furthermore, with a shutdown control, designers can protect sensitive loads or conserve power during battery operation. By dismissing external power transistors, the amplifier also casts off any emitter-follower oscillations. What's more, in class AB operation, it achieves low crossover distortion—a benefit of the thermal tracking of a one-package device.

The laser-trimmed FET input stage exhibits 10-μV/°C drift, 0.5-mV offset, and low thermal tail (the effect of heat flow on input offset voltage). Since an external balance control further improves those parameters, the hybrid can connect directly to devices such as a photodiode. It also can work in programmable power supplies with 12-bit resolution, as well as in integrators with long time periods.

PACKAGED FOR POWER

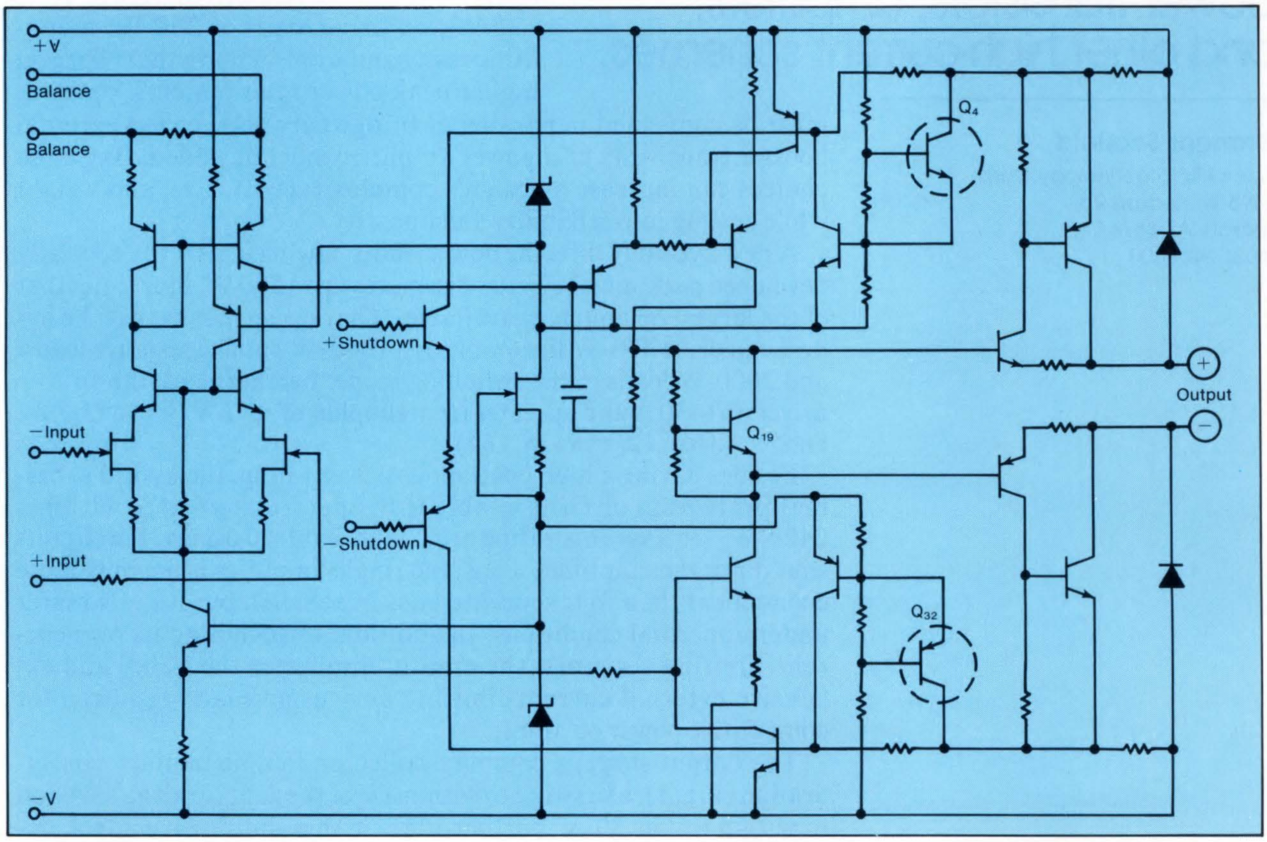
To help it accommodate high currents, the hybrid is housed in a copper DIP. Pins are 0.060 in. wide and spaced 0.200 in. apart to simplify layout on a standard 0.100-in. grid. Conventionally, power op amps occupy a TO-3 container with 0.040-in. pins on 0.170-in. centers.

In general, the op amp will find its way into single-ended circuits that must deliver as much as 1000 W to a resistive load and 2000 W peak to a bridge-motor servo system. Specifically, the hybrid will operate in linear and magnetic deflection circuits, and programmable power supplies.

The amplifier's high power dissipation suits it to linear control, especially in robots, lasers, and other high-speed jobs. The op amp is also desirable in motor controls that stop or reverse dynamically. High efficiency, switching motor controls can take advantage of the amplifier's high slew rate to modulate pulse width at frequencies up to 50 kHz.

The hybrid's slew rate and voltage rating equip it for high-power deflection circuits with fast write and retrace speeds. In power supplies, the amplifier's overload features improve its chances of surviving a short circuit. In addition, phased-array transmitters and high-powered transducers, akin to those in sonar, can exploit the amplifier's accurate phase response and its linearity in class AB operation.

The PA03 functions most efficiently at the minimum power-supply voltage needed to produce the required output. For example, a ±45-V, 12-A output requires



1. The PA03 power op amp's common-collector output stage dissipates up to 500 W of power while remaining within 6 V of the power supply at 30 A. Moreover, low crossover distortion marks the hybrid because it operates in class AB. The op amp also features shutdown control and a laser-trimmed FET input stage with drift, for the A version, of only 10-μV/°C and 0.5-mV offset.

the power supply to reach ± 50 V, which accounts for a 5-V supply-to-output differential. The power op amp works wtih symmetrical dual supplies of up to ± 75 V or single voltage supplies of 150 V or less rail to rail. The supply voltage must exceed input voltages by at least 10 V.

SHOWING HEAT THE DOOR

Because the op amp must dissipate high levels of power, its thermal path plays an especially critical role. A heat sink rated at 1 °C/W may effectively remove up to 50 W, but of course cannot handle 500 W. As a result, the higher power dictates a heat sink rated at 0.1 °C/W —a large heat-radiating surface cooled by forced air or even water. (Fortunately, insufficient cooling causes the hybrid to shut down rather than destroy itself.)

In a dc circuit, the internal power dissipation, P, is:

$$P = (V_S - V_O)\, I_O + (|V_S| + |-V_S|)\, I_Q$$

where I_O and I_Q are the output and quiescent currents and V_Q and V_S are the output and supply voltages, respectively. In calculating internal dissipation, V_S must represent the value at the supply that is the source or sink of the corresponding current. In addition, the designer must determine whether the worst-case condition is a short circuit to ground or to the power supply.

When the op amp drives a reactive load, power dissipation becomes a function of the phase difference between the output voltage and current. For the same values of voltage and current, the actual dissipation may be several times higher than for a resistive load. In this case, $P = P_I - P_O$, where P_I is the power drawn from the supply and P_O is the power delivered to the load. Thus, in purely reactive loads, all the power drawn from a supply is dissipated in the op amp.

CALCULATING THE OPERATING LIMITS

As determined through standard methods, the op amp's absolute maximum power-dissipation rating is 500 W, assuming a case temperature, T_C, of 25 °C and a maximum junction temperature, T_J, of 150 °C. Given the power dissipation and the maximum ambient temperature, T_A, the op amp's case and output transistor-junction temperature, T_J, can be found. Specifically, $T_C = T_A + P\Theta_{HS}$, and $T_J = T_C + P\Theta_{JC}$, where Θ_{HS} is the thermal resistance between the heat sink and the ambient air, and Θ_{JC} is the internal thermal resistance between the junction and the case.

To find the required thermal resistance of the heat sink, first calculate internal power dissipation P. Then, given the maximum recommended junction temperature, determine the junction's increase above the ambient temperature, denoted as $T_J - T_A$. The heat sink should have a thermal resistance of no greater than $\theta_{HS} = [(T_J - T_A)/P] - \theta_{JC}$.

For example, a circuit that dissipates 300 W at a 30 °C ambient temperature requires a heat sink whose thermal resistance is no more than $\theta_{HS} = [(150-30)/300] - 0.3 = 0.1$ °C/W.

Price and availability

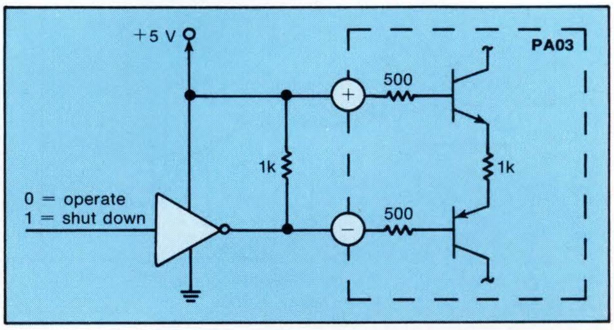
The PA03 power op amp is available now and sells for $190 each in quantities of 100. For applications requiring up to 10 pA of input bias current, the PA03A sells for $247, also in quantities of 100. CIRCLE 502

SIMPLE TO SHUT DOWN

When the op amp's output needs to be turned off, at least 3.5 V is applied between its shutdown pins. When TTL circuits activate the pins, the plus shutdown pin should connect to the +5 V of the logic supply voltage and the minus shutdown pin driven by the TTL logic gate (Fig. 2). In addition, a resistor pulls up the TTL gate to at least 3.5 V to ensure normal operation when the op amp's output stage is active.

CMOS logic can activate the shutdown mechanism as well, since only 100 μA is needed. Either pin can be switched, but a high logic level exceeding 5 V requires a resistive ladder to limit the voltage differential to 5 V between the pins.

To nullify the input voltage offset with the op amp's balance control, a 100- to 200-Ω potentiometer fits be-



2. Either TTL or CMOS logic circuits operate the op amp's shutdown mechanism. For TTL, the plus pin connects to the 5-V logic supply, and a gate activates the minus pin. A pull-up resistor (highlighted) also is recommended. On the other hand, a CMOS gate can drive either shutdown input pin, since 100 μA is sufficient and no pull-up resistor is needed.

tween the IC's balance pins. The potentiometer's wiper arm, which connects to the positive supply voltage, should be separate from the main current-carrying path to prevent any ripple from coupling into the balance circuit. If balance control is not needed, both pins link to the positive supply, again by a separate connection.

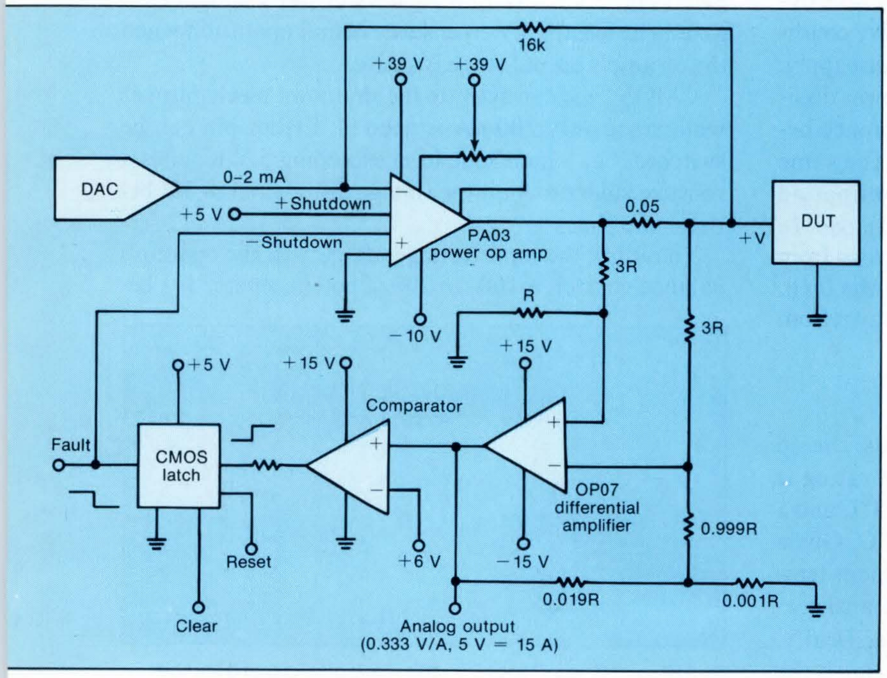
All high-current op amps can succumb to unwanted current feedback from electromagnetic radiation and voltage drops in wiring. The high current and speed ratings of the PA03 emphasize those effects. To prevent feedback, all supply and output leads must be fabricated from 12-gauge or thicker conductors. (The op amp's current capacity exceeds that of most residential wiring branch circuits.) In addition, external bypass capacitors prevent feedback through the power supplies. One capacitor, a 0.47-μF ceramic or low-impedance foil type, should parallel a low-frequency bypass capacitor of 10 μF for every ampere of peak output current—up to 300 μF. Both should be mounted no more than 1.5 in. from the amplifier's supply pins.

The op amp can go to work in a simple programmable power supply (Fig. 3). The supply tests dc-dc power modules, which draw up to 15 A at 28 V. For 0.5 seconds each, a low-voltage of 18.5 V and high-voltage of 32 V are applied; the normal 28-V test is performed as well. The module outputs must achieve accuracy to within 0.5% and be able to survive momentary short circuits to ground.

The programmable supply requires little calibration, because the power op amp changes the output current of a highly accurate d-a converter into a voltage. A circuit built around a differential amplifier (OP07) and four terminal shunt resistors senses the current drawn by the dc-dc module, the device under test (DUT). The circuit drives a comparator with a voltage equaling 0.333 V/A. If the DUT current exceeds 18 A, a CMOS latch shuts down the power op amp, and a pulse to the latch resets the circuit when the malfunction clears.

STRONG SENSOR

When the d-a converter's output is set to 2 mA, a 16-Ω feedback resistor yields the 32-V full-scale output to drive the DUT. At the same time, a 0.05-Ω current-sensing resistor develops 0.75 V when the supply's output current reaches 15 A. The relatively low 0.75-V full-scale voltage keeps the sensing resistor from dissipating excessively high power. Nevertheless, the resistor must be mounted on a heat sink: At 15 A it produces 11.25 W, and at the supply's current limit of 42 A, it throws off 88 W.



3. A high-power op amp goes to work in a test system as a simple programmable power supply. In this case, the supply tests dc-dc modules by applying 18.5, 28, and 32 V at 15 A across them and the test system checks their output voltage for accuracy. Under normal conditions, the op amp must dissipate up to 306 W peak. A short circuit in the test fixture pushes the power in the op amp to over 1.5 kW.

The programmable supply requires positive and negative power sources. For the positive source to generate the correct output voltage, the sense resistor's 0.75-V drop must be included in the power op amp's supply-to-output differential. Since the op amp's specifications indicate a 7-V drop at 30 A and a 5-V drop at 12 A, a maximum drop of 6 V can be assumed at 15 A. Choosing an output of 39 V leaves a 5.25-V margin. The overall approach, though conservative, is justified given the IR drop at high current and the lack of remote sensing circuits. The 10-V negative supply satisfies the power op amp's common-mode voltage specification.

A HANDLE ON POWER DISSIPATION

Determining the op amp's maximum power dissipation depends on an examination of four different power levels. Three of the levels apply the different output voltages to the DUT when it draws its 15-A maximum normal operating current. The fourth case covers abnormal

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situations that may arise from faulty timing or defective test units.

Calculating the power levels for the three normal voltage ranges shows the 18.5-V output to be the worst case. An output of 18.5 V added to 0.75 V across the sense resistor leaves 19.75 V across the power op amp's output stage. At 15 A, the internal power dissipation is 306 W, including a quiescent 9.8 W. Therefore, the junction-to-case temperature rises 92°C. In the other two normal testing levels, the power at 28 V is 163.6 W, and at the 32-V output level, the op amp dissipates the least power: 103.6 W.

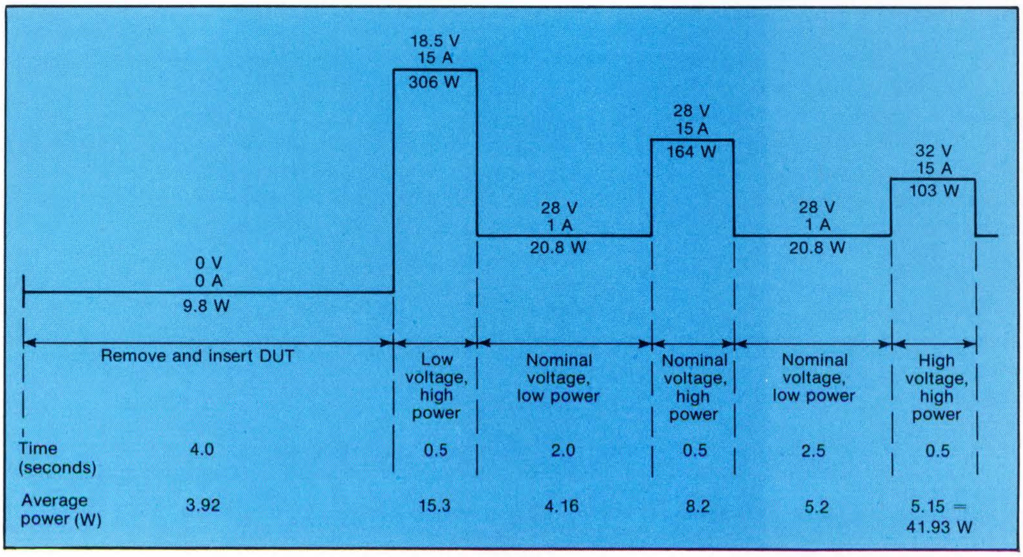
The actual heat sink values must take into account the general test plan or test sequence timing (Fig. 4). Since the three high-power tests last only 0.5 seconds apiece, examining thermal time constants and average power can reduce the heat sink requirements. During the 4.5 seconds of the test, the current is 1 A and the power is 20.8 W. In addition, removing and inserting the DUT takes at least 4 seconds, when only 9.8 W of quiescent power is dissipated. Thus, the average power dissipated is 41.93 W.

Assuming a heat sink time constant of 10 seconds, the highest power peak of 306 W for 0.5 seconds amounts to 5% of the time constant. That power, in turn, increases the temperature only 4.9% compared with dissipating 306 W continuously. The result equates to a 15-W spike. Thus, the peak short-term equivalent power is 57.2 W.

For a peak junction temperature of 150°C and a maximum of 38°C for ambient air, the heat sink can rise 18°C. Then, to dissipate the peak short-term equivalent power of 57.2 W, the heat sink rating must be 0.35°C/W. An HS06 heat sink with a 0.6°C/W rating in free air does the job if air is forced past it at 500 ft/min.

The final power calculation covers faulty test timing or a defective DUT. Prolonged operation at the 306-W level, however, will not destroy the power op amp because its thermal shutoff limits the temperature rise. The worst case actually occurs from a short circuit in the test socket. When that happens, the power op amp limits the current to 42 A, the sense-resistor voltage rises to 2.1 V, and 36.9 V develops across the amplifier. The resulting voltage and current levels, although producing 1.55 kW, are well within the amplifier's 2.4-kW, 1-ms secondary breakdown line on its safe operating-area curve. Therefore, the thermal shutoff circuit's fast response protects the amplifier.

Granger Scofield, vice president of marketing for Apex, previously worked as a senior application engineer assisting customers and giving seminars on power op amps. He has also designed products for Apex, as well as for Burr-Brown's test equipment and product development groups.



4. The test cycle sets the op amp's average power, which in turn determines the thermal resistance of the op amp's heat sink. Of the three supply-voltage tests, the low voltage demands the most dissipation from the op amp, a total of 306 W. Because each of the voltage tests lasts only 0.5 seconds, however, the power averages about 41.93 W.

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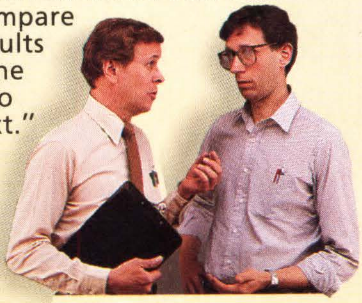

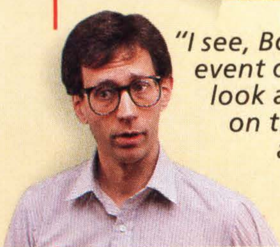

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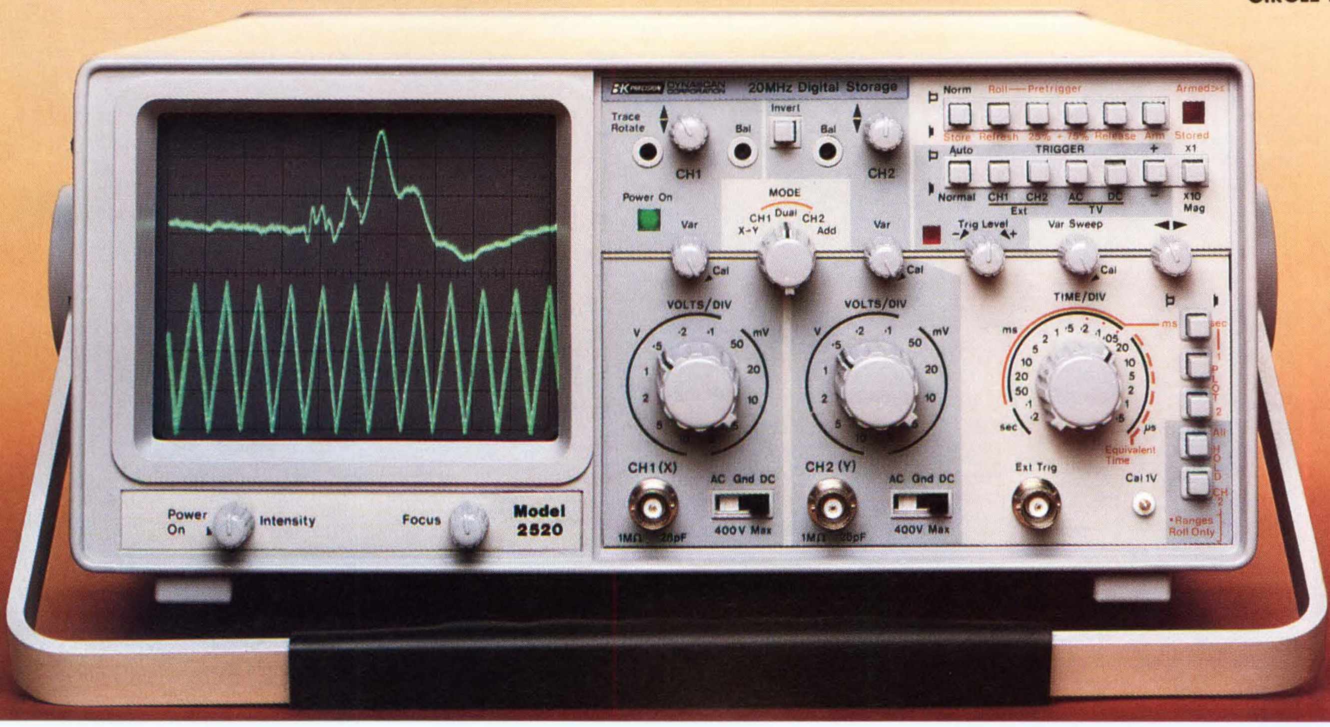
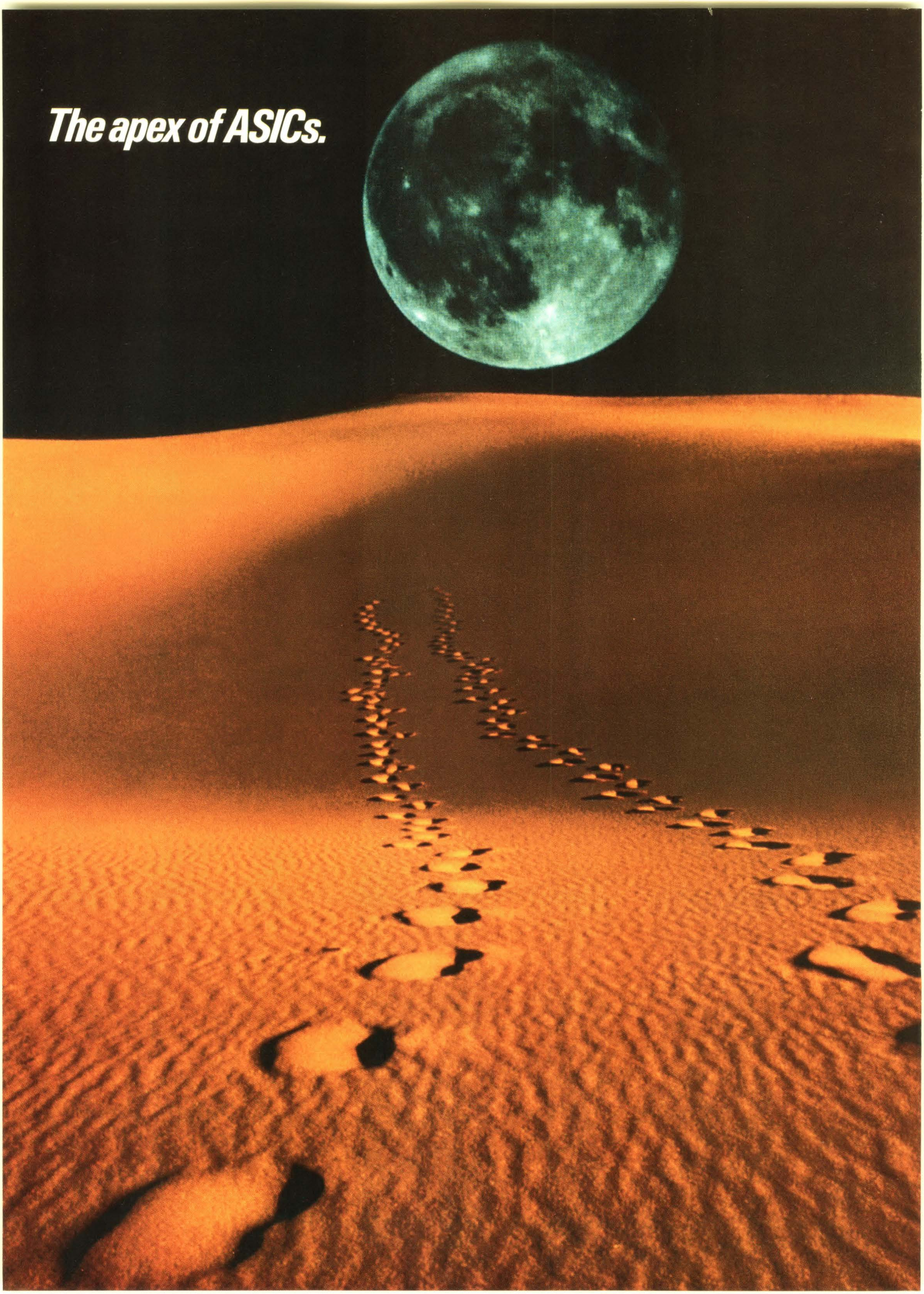
CIRCLE 78

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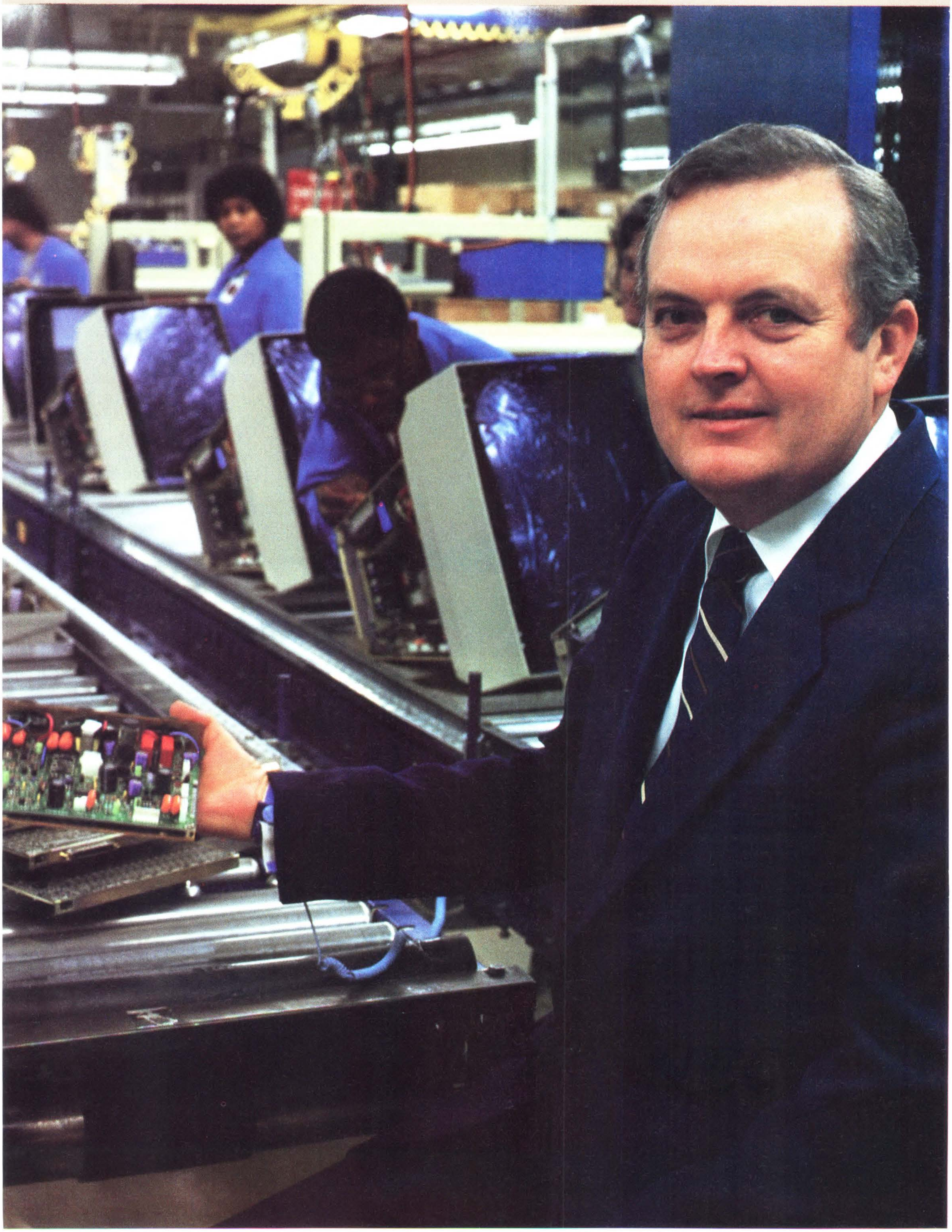

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CIRCLE 80

ELECTRONIC DESIGN EXCLUSIVE

With input bias current of 40 fA, op amp IC makes low-level measurements

In the past, only complex, costly hybrids could measure very small currents. Now, with the help of dielectric isolation, a monolithic op amp performs the task precisely.

Roy Kaller
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International Airport Industrial Park
P.O. Box 11400
Tucson, AZ 85734
(602) 746-1111

Circuits that measure low currents precisely demand special op amps, ones that pull less than 1 pA of input bias current. However, low bias levels and low input noise have always required hybrid multichip amplifiers, which are costly and complex. As a result, the cumulative cost of the amplifiers becomes prohibitive in tasks that use many of them. A computer-aided tomography (CAT) scanner, for example, needs one amplifier for each of its hundreds of measurement channels.

Breaking the barrier to low input bias in one-chip op amps is the OPA128. Its nominal 40-fA bias current (75 fA maximum) promises a solution to many design problems. In addition, the op amp's maximum offset voltage is 500 μV and its drift no more than 5 μV/°C. The open-loop gain is 128 dB and noise specifications are equally impressive for the electrometer op amp: 92 nV/(Hz)$^{\frac{1}{2}}$ at 10 Hz and 27 nV/(Hz)$^{\frac{1}{2}}$ at 1 kHz (ELECTRONIC DESIGN, Jan. 23, p. 44, and March 6, p. 157).

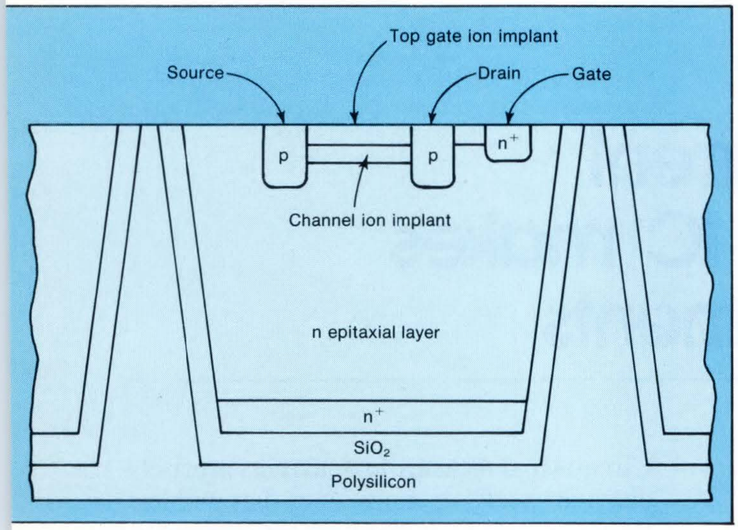
On top of its low cost, the chip can tolerate high temperatures, making it desirable to designers of industrial and military systems. Even at 125°C, the input bias current is less than 100 pA, better than any other monolithic amplifier with FET inputs. The chip's impressive figures result, in part, from the use of dielectric rather than junction isolation. While dielectric isolation remains stable at high temperatures, junction isolation degrades, producing high input bias currents and possible circuit latch up.

Dielectric isolation also gives the chip radiation hardness. The amplifier maintains its integrity in high neutron and gamma fields, although input-voltage noise and bias current may increase.

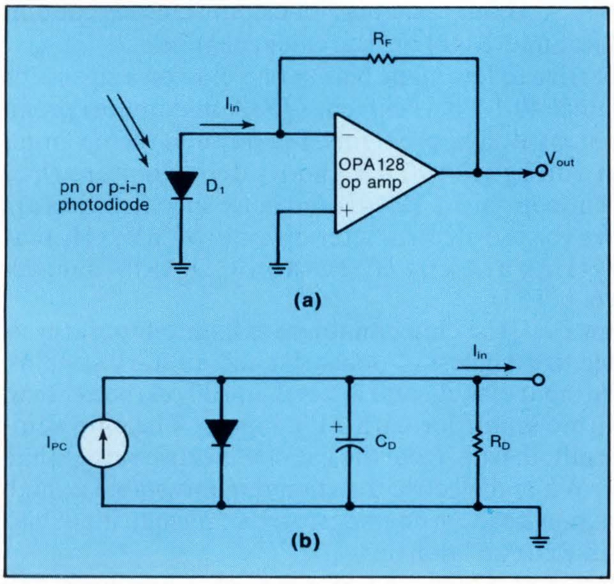
In contrast, junction-isolation devices fail dramatically, often by latching their outputs to a power rail. When neutron or gamma radiation strikes a pn junction, not only are silicon atoms physically displaced in the lattice, many chemical changes occur that degrade the isolation. Damage can be severe enough to destroy the isolation altogether.

To achieve the monolithic device's low bias, offset, and noise, its

Ultralow bias op amp



1. The chip owes its superior specifications partly to DIFET process technology, which uses dielectric isolation. A silcon dioxide layer, which insulates each ion-implanted JFET, completely eliminates reverse bias isolation leakage current. The layer also helps the chip to withstand high temperatures and radiation.



2. The OPA128 op amp's ultralow input bias current enables it to act as a voltage-to-current converter—a common configuration in CAT scanners, for example. The op amp is driven directly by a pn or p-i-n photodiode (a). The equivalent circuit of the diode plays a key role in calculating the voltage-to-current conversion factor (b).

designer, aided by a custom version of Spice, applied DIFET technology and extensive on-chip guarding. The process completely eliminates the reverse-bias isolation leakage current that flows in junction-isolated ICs (see "Detailing the Process Technology", opposite). The process constructs a very high performance ion-implanted JFET in a dielectrically isolated device tub (Fig. 1). Surrounded by an insulating layer of silicon dioxide, the tub prevents electrical interaction with neighboring devices or the wafer substrate. In addition, the geometry of the FETs strikes an optimal balance that reduces input bias without adversely increasing noise. (As an FET's size is reduced, its transconductance decreases and stage noise increases.)

ON GUARD

Guarding is crucial. Even a path resistance as high as $10^{14}\ \Omega$ will divert 75 fA if 7.5 V appears across it. Consequently, a low-impedance point in the amplifier drives the guard lines and tracks the common-mode input voltage, minimizing leakage current (and, therefore, bias current), as well as reducing the chip's input capacitance. In addition, the chip's guarding scheme stops parasitic leakage paths on top of and just below the passivation glass by separating sensitive FET gate runs from their neighbors.

Other circuit design measures also focus on reducing input bias current. One technique defeats the effect of impact ionization. The ionization in the FET channel can significantly increase bias current as the drain-to-source voltage (V_{DS}) or drain current increase. To counter that effect, an FET cascode configuration formed by two transistors clamps the V_{DS} of the input transistors to a low and constant value. Thus, common-mode voltages at the input transistors neither change V_{DS} nor increase the bias current. Instead, the voltages drop across the cascode transistors. Each input FET draws only 54 μA of drain current, which is supplied by a zero-drift source.

PULLING IN POWER

Keeping the chip's power consumption low was another important design goal. Reduced internal power dissipation helps cap bias current, which about doubles for every 10°C rise in temperature. To keep down power dissipation, the design budget called for a quiescent current drain of only 900 μA, or 27 mW. The designer not only met that goal, but also achieved a 3-V/μs slew rate and a 1-MHz bandwidth. The low power consumption also benefits portable, battery-powered designs, as well as instruments that use many amplifiers.

Finally, careful layout of devices on the chip minimizes offset voltage and drift. With the help of CAD tools, active devices that critically affect drift are cross-coupled on the chip's thermal center line. In addition, a correction algorithm is used to laser trim any offset voltage and drift at the wafer level.

A precision op amp such as the OPA128 can connect directly to the output of a current-generating analytical sensor. For example, it can perform as a transimpedance amplifier —a voltage-to-current converter for a pn or a p-i-n photodiode (Fig. 2a). In that configuration, the converter's accuracy depends on an input bias current that is nearly zero.

In a CAT scanner, X rays passing through a patient's body strike a scintillation crystal, which in turn emits light that is detected by the photodiode. The overall converter's dc transfer function is estimated by:

$$\frac{-V_{out}}{I_{PC}} = \frac{1}{1/A\,(1/R_F + 1/R_D) + 1/R_F}$$

where V_{out} is the output voltage; I_{PC}, the photodiode current; A, the open-loop gain; R_F, the feedback resistance; and R_D, the diode resistance (Fig. 2b).

Detailing the processing technology

The development of the OPA128, with its ultralow input bias current, requires an FET process whose performance matches or exceeds that of discrete FETs in hybrid circuits. At the same time, the chip must mesh with bipolar technology. Research and experimentation combined with statistical analyses reveal the need for several critical steps to the standard process.

First, the silicon wafers have very low intrinsic oxygen, reducing the possibility of defects that could increase gate current and noise. Next, the passivation layer includes silicon nitride (Si_3N_4), which blocks ionic transport. In addition, annealing corrects damage caused by ion implantation, and special cleaning techniques remove any traces of heavy metal contamination.

Though an electrometer op amp could employ junction isolation, the FETs would have to be so small that their noise performance would render them useless for most tasks. Their small size would also make it impossible to cross-couple the input FETs, an important technique for minimizing offset and offset drift. However, enlarging the FETs for cross-coupling would increase the gate current.

The amplifier's low input bias and high-frequency response also suit it for ion-selective electrodes, such as pH probes; photo and electron multipliers; Faraday cups, which collect electrons in scanning electron microscopes; low-droop, sample-and-hold circuits; and precision integrators.

SERVING AS A SOURCE

Though the op amp most commonly measures very low current levels, it can also serve as a source for precision low-level current. As a secondary or tertiary current standard, it can supply 10 pA to ±3% accuracy and be trimmed to 0%. One design uses a precision bandgap reference circuit, an LM113-1 reference diode, in a feedback loop (Fig. 3). The diode sets the voltage in the loop to 1.22 V ±1%. That voltage, plus the amplifier's offset, appears across R_2, a 12.2×10^{10}-Ω, 1% resistor.

The amplifier's input bias current introduces a maximum error of 75 fA, which is less than 1% of the 10-pA output. The equivalent output impedance of the current source is the parallel combination:

$$R_{out} = \frac{R_1 R_2}{R_{bandgap}} \parallel \frac{R_2}{CMRR}$$

and is dominated by the amplifier's common-mode rejection ratio (CMRR) and R_2. Setting R_2 to 12.0×10^{10} and trimming the output current by sensing the bandgap voltage with a precision attenuator produces less than ±1% error.

The op amp also goes to work as an electrometer instrumentation amplifier, which precisely measures differential voltages. The input bias current of an ordinary instrumentation amplifier would introduce an error in high-impedance sources. In characterizing a gallium arsenide semiconductor process, for example, the designer must probe samples by measuring bulk resistivity and Hall mobility to determine the concentration and mobility of carriers. In both measurements, the electrometer instrumentation amplifier requires less injected current for a given accuracy. It measures precise differential voltages, where the input bias current of a typical instrumentation amplifier might adversely change the measured value. Among other benefits, the smaller current reduces IR drops from probe resistances to almost zero.

Determining the bulk resistivity takes a common four-point probe technique, and solving the expression:

$$\rho = \frac{hV_R\pi}{I\ln_2}$$

Ultralow bias op amp

where ρ is the resistivity of the sample, h is the thickness of the sample, V_R the measured voltage, and I is the current injected into the sample.

The mobility is determined from:

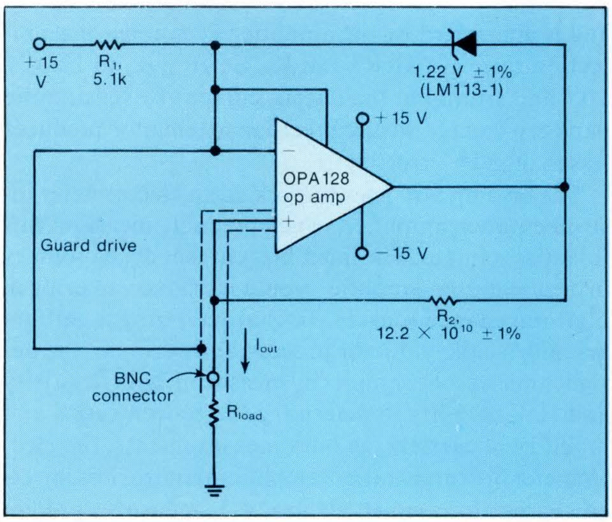
$$\mu_H = \frac{hV_H}{IB\rho}$$

where V_H is the Hall voltage generated across the sample and B is the magnetic field strength.

DESIGN WITH CARE

Whatever the application, a poorly designed board and faulty interconnections can cause troublesome low-level current and voltage errors. An error current of only a few nanoamperes exceeds the signal levels of many op-amp tasks.

Specifically, errors can result from piezoelectric, triboelectric, and space-charge phenomena. Piezoelectric currents arise when insulating materials come under stress. Triboelectric currents, which occur when two dissimilar materials rub together, might flow when a coaxial cable bends. Space-charge currents are generated when an insulator changes in size. For a given set of dimensions, an insulator with capacitance C and voltage V across it has a value for its stored charge of Q = CV. In a measurement circuit, any change in that charge constitutes an error current.



3. An unusual task for the op amp is in a precision low-level current reference. Paired with an LM113-1 reference diode, the amplifier supplies 10 pA to an accuracy of ±3%. The output voltage is pressed across a 12.2 × 10^{10}-Ω resistor. Moreover, using a 12.0 × 10^{10}-Ω resistor and trimming the output current can produce accuracies better than ±1%.

Price and availability

The OPA128 monolithic op amp comes in four grades. Three are specified for the commercial temperature range: The LM, at ±75 fA of input bias current, sells for $20; the KM, at ±150 fA, for $15.50; and the JM, at ±300 fA, for $10.95. The SM version, specified for military temperatures, draws ±150 fA of input bias current and sells for $38.50. Prices are for quantities of 100, and all grades are available off the shelf.

CIRCLE 504

Current leakage paths can also create measurement errors. Leakage paths result from solder flux, photoresist, or even fingerprints. The same contaminants can react electrochemically to generate current and voltage noise, making low-level measurements impossible. As a preventive measure, the op amp's input pins must be carefully insulated. They should also be guarded on both sides of the pc board by a low impedance source that tracks the input voltage.

An even better approach is to solder the critical pins to Teflon or to sapphire standoffs, rather than directly to the printed circuit. In addition, the standoffs should be kept clean and free of contact with substances that would degrade performance.

Cleaning the connections with electronic- or IC-grade solvents maintains measurement integrity over time. Equally important is the manner in which the parts are dried. Best results are achieved at high temperature in an atmosphere of electronic-grade nitrogen or argon treated by a desiccant. Circuit insulating materials should also be chosen for their resistance to moisture. Teflon and sapphire absorb very little moisture compared with ceramic and glass epoxy materials.□

Roy Kaller is an analog design engineer and a former member of Burr-Brown's analog product engineering staff. He is currently a member of the precision op amp design group. He joined the company in 1983, after receiving a BSEE from the University of Arizona.

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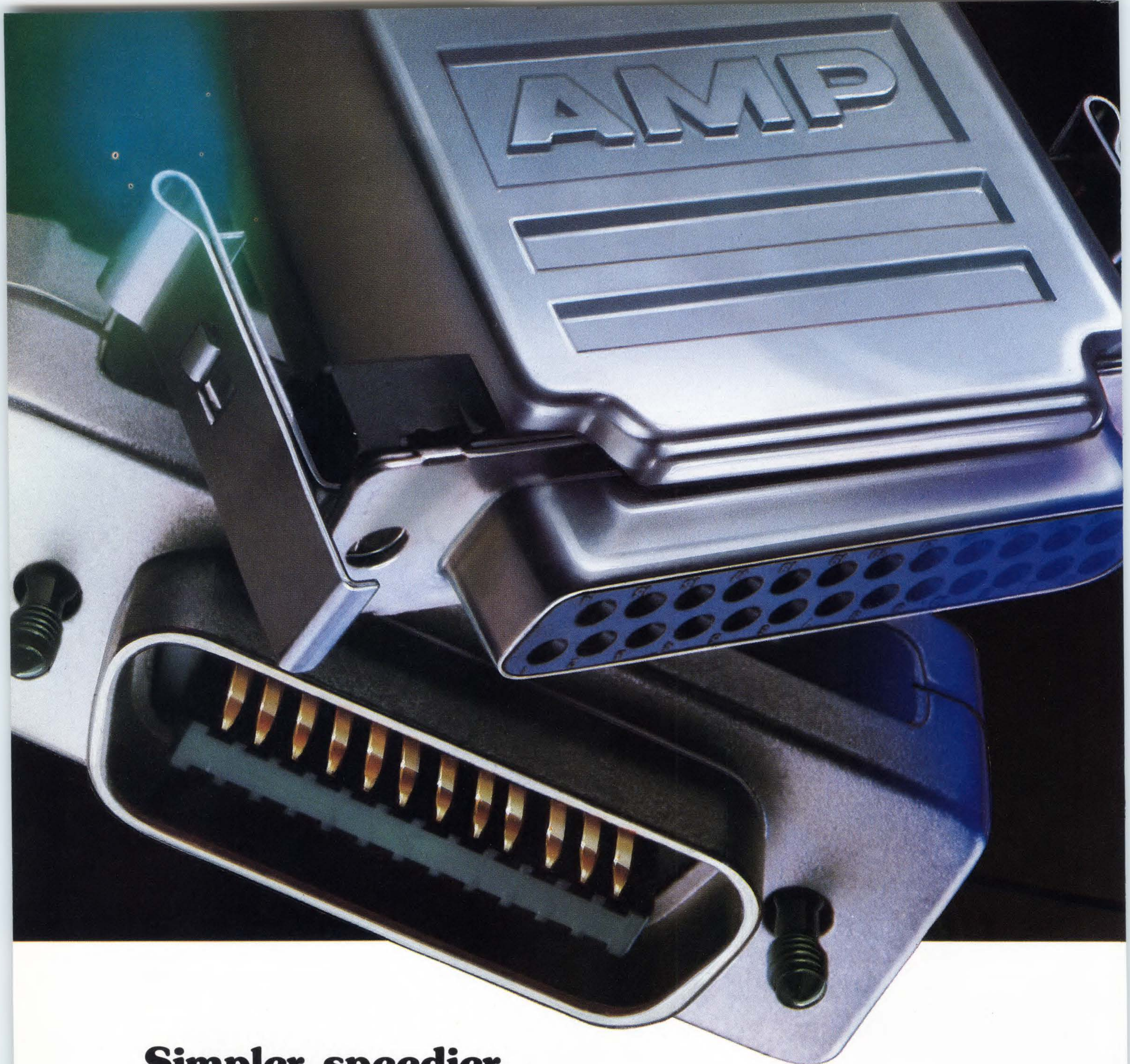

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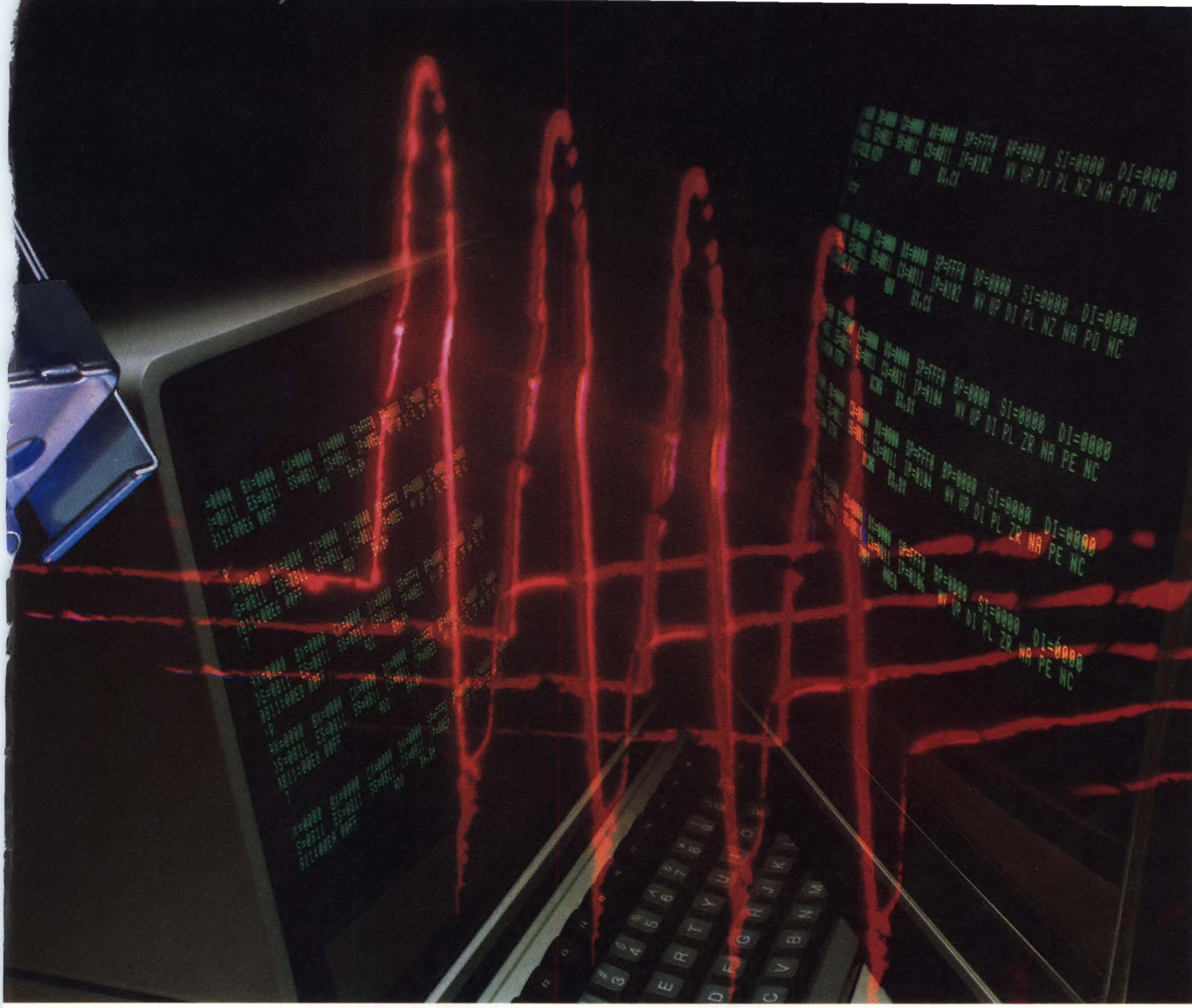

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CIRCLE 82

ELECTRONIC DESIGN EXCLUSIVE

Memory management chip for 68020 translates addresses in less than a clock cycle

For 68020-based systems that need virtual memory, a demand-paged management chip offers a fast and flexible solution, and an alternative to discrete components.

Michael W. Cruess
Motorola Inc.
6501 William Cannon Dr. W
Austin, TX 78735
(512) 440-2232

Designers who must couple a virtual memory to the 32-bit 68020 microprocessor now have a single-chip solution. The MC68851 paged-memory management unit (PMMU) not only embodies the necessary management hardware in a single IC, its features promise to satisfy demanding system requirements.

The PMMU translates an address and function code—the logical address—issued by a microprocessor into a corresponding physical address in main memory. Within a system, it offers speed as its premier advantage. It's translation cache churns out a physical address from a logical one in just 45 ns—a delay below one clock cycle at 16-MHz. Future systems running at 20 MHz will require only one wait state to make the same translation.

Other features of the PMMU make it easy to drop the chip into a system. In addition to an eight-level memory protection scheme, for example, its flexible architecture accommodates varied virtual memory designs. Many of the PMMU's traits can be configured by software, and its internal instruction set facilitates connections to the 68020's coprocessor interface.

A set of translation tables (residing in main memory) describe the memory map for a task being executed. A field in the logical address indexes different levels of the tree-structured tables. Although five levels of tables are possible (Fig. 1a), fewer levels can be established (Fig. 1b).

Except for the last table in a branch, which is also called a page descriptor or leaf table, a field in each table entry specifies the physical address of the next table. In a leaf table, that field contains the physical address of the next page instead.

The translation tables also contain information for managing the chip's address translation cache (ATC) and any data caches, as well as for setting protection levels and recording accesses to the tables themselves. In addition, table descriptors (tables that point to other tables) maintain a "used" bit. That bit helps the operating system tell which areas of the logical space are in use without scanning all page-table entries. Page descriptors contain "used" and "modified" bit fields, indicating accesses and changes to a particular page. Finally, protection information is reflected by cache inhibit and lock bits, and by write protect, supervisor only, and read/write access-level fields.

A straightforward sequence of events follows a cache miss. In such an event, the PMMU signals the current bus master to terminate and retry the bus cycle. In a 68020 system, the chip specifically asserts the Bus Error (BERR) and Halt signals. At the same time, the PMMU enters bus arbitration by setting its Bus Request signal. (By taking the bus-arbitration route, the chip avoids the need for external buffers on its control signals. When the CPU relinquishes control, it puts its bus lines into a high-impedance state.) The PMMU then takes over the physical bus to find the information it needs from main memory.

ADDRESS TRANSLATION CACHE

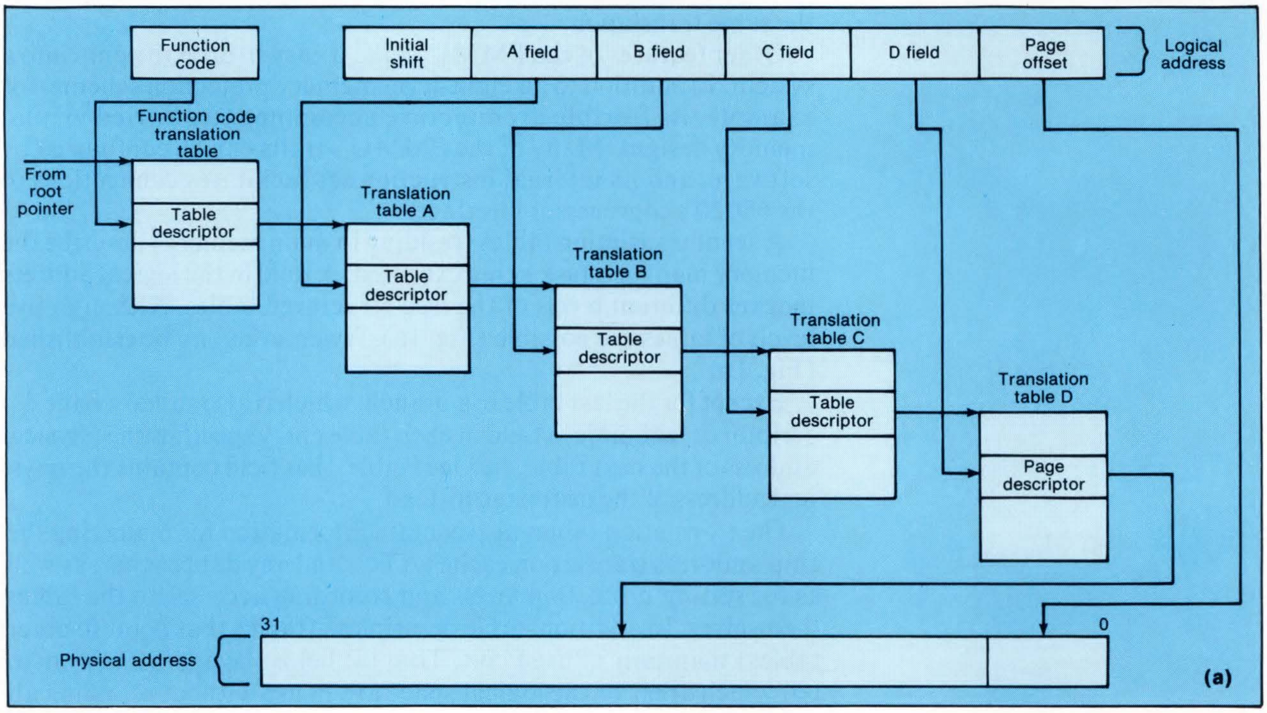
When the information is found, the chip either enters the translation into the ATC or indicates an error. An error occurs if the translation data is not immediately available (i.e., the page sought is on disk, not in main memory) or if the task requesting the page does not have the correct access level. In any case, the microprocessor takes control and retries the suspended bus cycle. On that attempt, the address will be translated or, if the error prevails, the PMMU asserts BERR to start the CPU on an error-handling route.

Since the 64-entry ATC translates logic addresses to physical ones in only 45 ns, the process adds less than one clock cycle of delay at 16-MHz operation. Moreover, bus cycles for the 68020 microprocessor can be kept to three clock periods, while still checking access levels.

The ATC, which automatically loads from the tables in main memory, contains the 64 most recently used logical-to-physical translations. Since most programs use memory locations in relative proximity, the ATC can frequently supply the necessary translation information, and avoids time-consuming searches of the tables on every microprocessor bus cycle.

The ATC can also automatically maintain simultaneous entries for eight user tasks, one supervisory task, and 8 DMA devices. As a result, multiprocessor systems need not swap ATC entries before starting each new task. At the same time, only a single entry is needed for objects like operating systems, which are accessed system wide. Moreover, setting a single bit will lock any entry into the ATC.

Another aspect of the chip facilitiates multiprocessing by recognizing instructions that use interlocking bus cycles. In fact, the PMMU itself executes interlocked bus cycles to allow multiple PMMUs to share the translation tables. Specifically, the cycles are executed when the chip updates the modified-bit field in the tables. Moreover, the chip avoids a potiential problem by reporting protection



errors on the read portion of an interlocking instruction. Otherwise the instruction might partially modify a data structure, but then be aborted because it attempted an illegal access.

MULTILEVEL PROTECTION

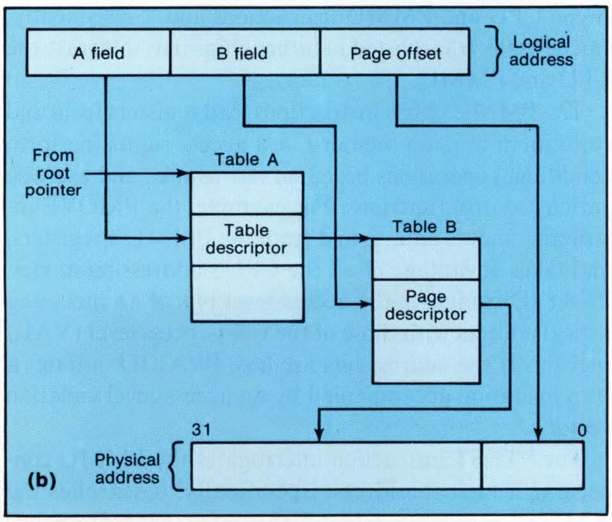
The PMMU has several ways to protect code and data. The most basic of these protects either entire segments or individual pages of memory from being overwritten. Alternatively, it can put code into the supervisory address space. Both methods are invoked by setting bits in the translation tables; the bits, in turn, control the ATC.

The PMMU also features a hierarchical protection scheme, which divides the user address space into two, four, or eight distinct levels. The access level of a given task, as specified in the PMMU's Current Access Level (CAL) register, must meet or exceed the level of a page that the task wants. The address translation tables hold the access level required to read from or write to a page.

SHARING SPACE

Prior to the capabilities offered by the PMMU, many operating system functions could only occupy the supervisory address space to make its tables and peripheral-device registers unavailable to user code.

The hierarchical protection mechanism allows an operating system to share the same address space as the user tasks and, therefore, use all addressing modes to access



1. In converting logical addresses to physical ones, the MC68851 paged memory management unit relies on translation tables stored in main memory. Separate fields in the logical address reference as many as five tables (a), but having fewer tables speeds the translation process (b).

the tasks without cumbersome interface subroutines.

The PMMU's access mechanism protects the operating system, including its restricted tables and device registers, at a high-privilege access level, while application code runs at a lower level. Rather than hold the operating system, the microprocessor's supervisory memory space can be reserved for the small amount of code that executes the most privileged instructions and for the front ends of exception handlers.

The upper bits of a logical address determine its privilege level. If access checking is enabled, a user task's address is issued only if its upper bits are equal to or greater than a value stored in the CAL register. Otherwise, the termination of the bus cycle will prohibit the task from accessing the higher-level address.

If the check against the CAL register passes, the address is compared with the contents of the ATC. If an exact match is found, the chip translates the address. Otherwise the chip searches the translation tables. When the correct description is found, and if the read and write access levels permit, the address translation is written to the ATC.

Because the translation tables store access-level information, protection is available at any level of the tables. Individual pages or entire segments can be protected, letting routines that store portions of memory have different degrees of access.

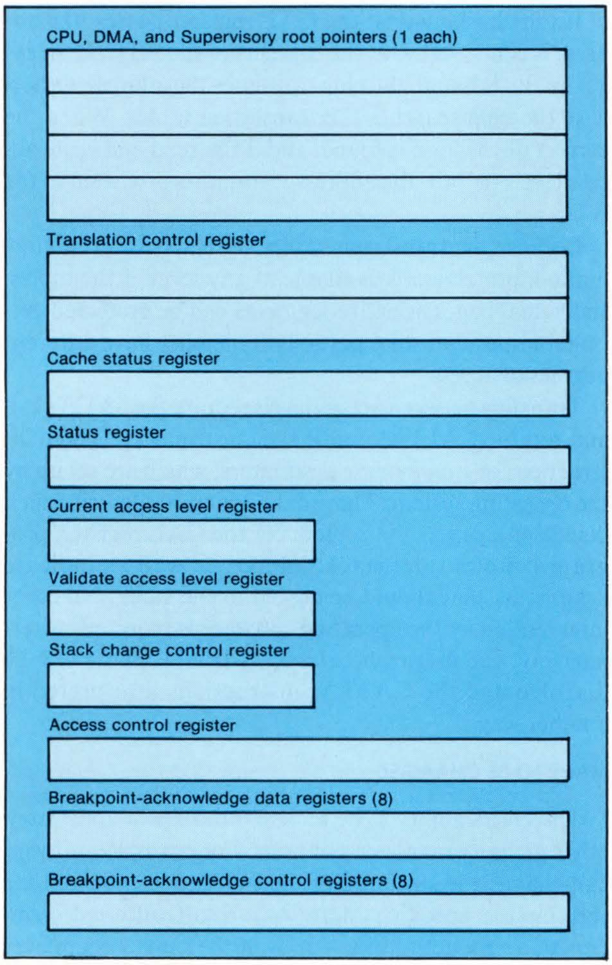
Transfers between access levels require the 68020's call and return (CALLM and RTM) instructions. Those instructions rely on module descriptors, which are set up by the operating system. Those data structures describe such details of a call as the contents of the CAL register, program-counter, and stack pointer, as well as indicate arguments that should be copied to the stack. No other intervention by the operating software is required. Alternatively, the hierarchical access-level scheme can be disabled and the CALLM instructions interpreted in another way.

MADE TO BE CHANGED

The chip's ability to be reconfigured sets it apart from other memory management units. For example, software can change the structure of the translation table to tune the chip to a specific system. As a result, different members of a product family—or even the same system over time—can be changed to make the most of improvements in the disk drives, software, and the size of main memory.

In addition, the chip accommodates date caches connected to the logical or physical buses, and checks access levels in either case. The chip allows software to manage external cache devices—containing instructions and data—through its Cache Status register in the same way that it manages multiple user tasks. Thus a separate cache can be maintained for as many as eight tasks. In addition, information that must not be stored in a cache, like data from a memory-mapped I/O device, is kept out when the chip asserts a Cache Load Inhibit signal. Setting the Cache Inhibit bit in a translation-table entry causes that signal to become active.

Individual cache entries can be shared by several separate tasks. Sharing saves time that would otherwise be spent loading translation descriptors for frequently used code, like language run-time libraries. It also frees descriptors in the cache for other uses. The chip shares cache data automatically in response to the shared globally



2. The programmer's model of the memory management chip reflects its translation and protection features. One of three root pointers pick a set of tables, and a translation control register spells out the details of the translation process. Other registers implement the chip's hierarchical access mechanism and reflect the operational status.

(SG) bit of translation-table entries. The SG bit indicates that a page appears at the same logical address in all tasks and that its descriptor need only appear once in the ATC.

Software also controls page size, and the size and number of the translation trees. With no extra hardware, an operating system can set the page size from 512 kbytes to 32 kbytes, in increments that are powers of two.

Standard bus request protocols and cycles establish communication between the PMMU and other devices on the coprocessor interface. As a result, the PMMU and any user-designed coprocessors that access it can be installed readily. Designers can use the microprocessor's function code signals since coprocessors using direct memory access can share the CPU's address space or have their own. I/O devices that use DMA can also be accommodated, because the PMMU allows DMA operations directly over the logical bus. In effect, the same translation tables accessed by the CPU are available for DMA.

DMA devices can also appear on the logical or physical sides. The PMMU contains a physical bus arbiter, as well as logical-bus arbitration signals that allow daisy chain connections.

A NEW SET OF INSTRUCTIONS

The 68000-family coprocessor interface controls the PMMU's registers and functions. The chip has its own set of instructions, carried over the interface, that augment those of the CPU. The software makes no distinction between CPU and PMMU instructions and, consequently, can be easily transported to future chips that integrate the CPU and PMMU.

The PMMU chip's instructions load registers from and store them to main memory, test access rights, perform conditional operations based on test results, and exercise various control functions. For example, the PMOVE instruction moves data to and from the PMMU's registers, and takes advantage of all the CPU's addressing modes. PVALID compares the access-level bits of an incoming logical address with those of the valid-access level (VAL) register. If the address bits are less, PVALID initiates a trap operation accompanied by an access-level violation vector.

The PTEST instruction interrogates the PMMU concerning a logical address. Specifically, it searches the ATC and translation tables for an entry that corresponds to a particular address and function code. The results of the search are placed in the status register and can be tested by various conditional branch and set instructions. Optionally, the PTEST instruction can return the address of the page descriptor. A companion instruction,

PLOAD, takes an address and function code, searches the translation table, and loads the ATC with an entry to translate the address. PLOAD can speed up a DMA operation by preloading the ATC before starting the memory transfer.

The PFLUSH instruction and its variations clear the ATC of either all entries, entries with a specified function code, or those limited to a specified function code and logical address. Those instructions can rid the cache of entire data areas or of particular pages that no longer exist in main memory. One variation, PFLUSHR, eliminates the entries associated with one of the three root pointers.

PSAVE stores the contents of any registers that reflect the current task's state, as well as the internal state of the PMMU that deals with coprocessor and module call operations. Conversely, the PRESTORE instruction restores the information saved by PSAVE. Together, they allow the context of the PMMU to be switched by two instructions, should an error otherwise hangup the PMMU.

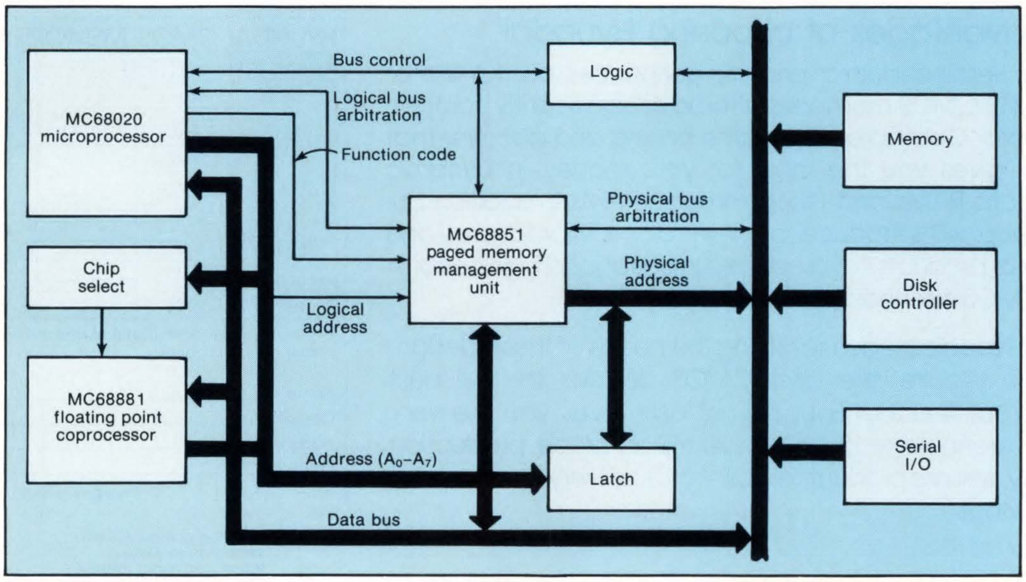
REGISTERING CONTROL

Registers within the PMMU control its translation and protection features (Fig. 2). Three root pointers (CPU, supervisory, and DMA mode root pointer registers, or the CRP, DRP, and SRP, respectively) identify the translation trees currently being used. The CRP points to trees accessed by the CPU when it operates in the user and supervisory modes; alternatively, the SRP can be applied to the supervisory mode operations, leaving the CRP dedicated to user code. The DRP is reserved for logical DMA devices.

A translation control register sets the specific details of how logical address fields will index the translation tables and set the page size. It also invokes the SRP and allows an optional table lookup capability by function code. A status register returns information in response to a PTEST instruction, and a cache-status register stores the information that allows the ATC to handle eight different tasks.

Other registers include the access, stack-change, current-access, and validate-access control registers which play a role in module call and return, and access checking operations. Finally, two sets of registers—the breakpoint-acknowledge data and control registers—control the chip's breakpoint function.

An example of a system that employs the PMMU has demand paged virtual memory with 2-kbyte pages, dynamically allocated page tables, and shares its address space between the user task and operating system (Fig. 3). The overall memory structure gives a translation table with a three-level structure. Starting at the least signifi-



3. A 68020 microprocessor-based system takes advantage of the PMMU chip, which sits between the logical and physical address buses. Both the memory management chip and a floating-point processor connect easily to the microprocessor's coprocessor interface. The PMMU's bus arbitration logic lets it serve other masters.

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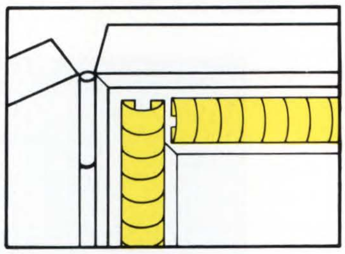

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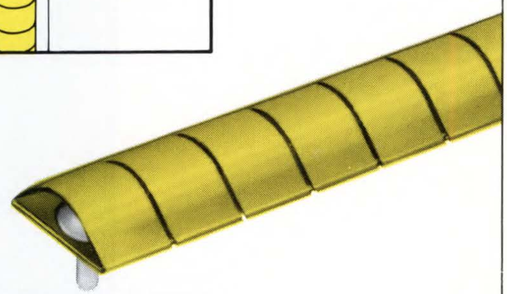

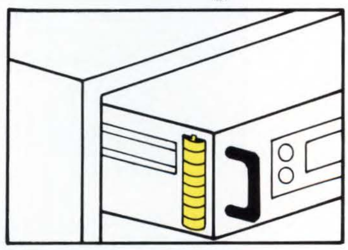

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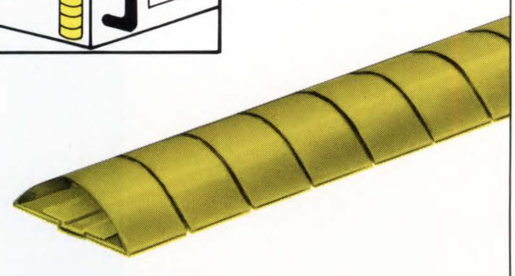

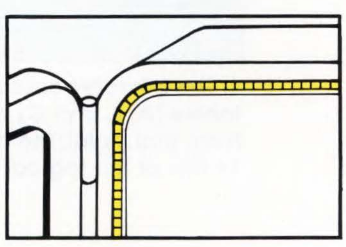

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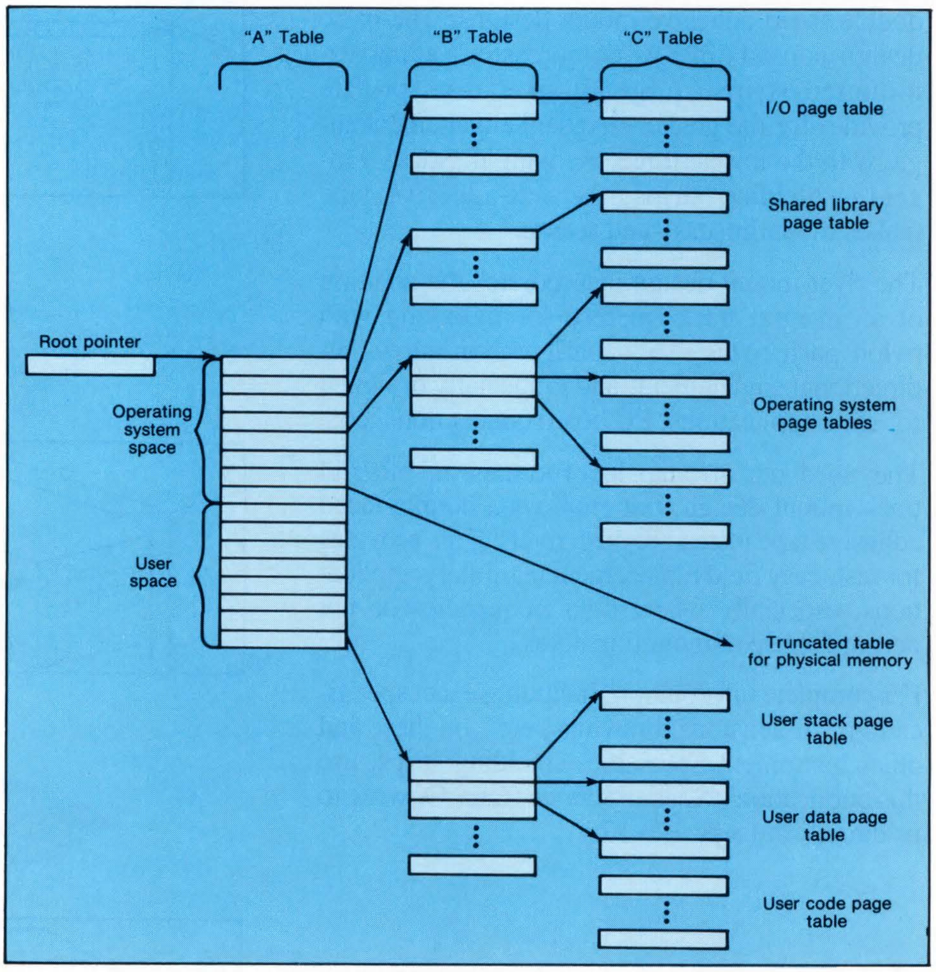
cant bit of the logical address, eleven bits—the PS field—are used as an offset into a 2-kbyte page. The next field, C, indexes the lowest level in the translation table (Fig. 4).

Short format descriptors reduce the overhead. Since 512 short format page descriptors fit in a 2-kbyte page, the C field is 9 bits wide. Together, the 11-bit page offset and the 9-bit table index represent a 1-Mbyte unit of the logical address space. Although not specified in the requirements, 1 Mbyte makes a convenient segment size, so the next field, B, serves as a segment table index. (The hardware does not actually interpret segments, but the term is used here for convenience.)

Long descriptors contain information that specify segments. Since 256 long format descriptors fit into a 2-kbyte page, the next field in the address is 8 bits wide. The remaining 4 bits of the logical address serve as an index to a table of long format descriptors.

User programs begin at logical address 0. The lower half of the address space is dedicated to the user task; the upper half is reserved for the operating system (Fig. 5). Each task sees a similar map, with its code and data in the lower half of the map and the operating system in the upper half. Conversely, the operating system sees its code and data in the upper half of the address map, and the current user task in the lower half. Write- and supervisor-protection bits in the translation tables keep the user task from accessing protected areas in the operating system.

The separation of the operating system and user tasks is accomplished by creating a translation table for each task. The top level, A, contains 16 entries, 8 of which ap-

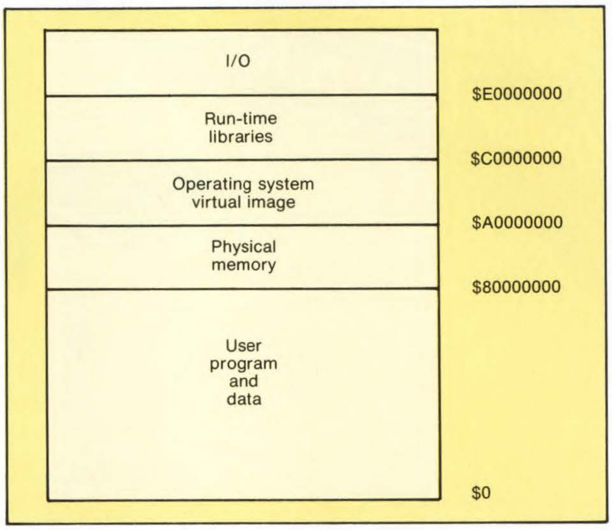


4. The microprocessor's logical address follows a path through three levels of tables (A, B, and C) which ultimately points to a 2-kbyte page in main memory. From that point, the actual physical address is specified by the least significant 11 bits of the logical address, which serve as an offset into the page.

ply to the user task. Three separate page descriptor (leaf) tables are allocated to the code, data, and stack of the user task. Using the limit field of the long format descriptors in the B-level table keeps the C-level tables to less than 512 entries. Similarly, using the limit field of the long descriptors in the A-level tables keeps the B-level tables small.

The rest of the tables serve the operating system. Only one set of the tables is required throughout the system, and they are shared by all the tasks. When the A-level table for a new task is created, the upper eight entries are set to point to the existing system tables. Assuming the system has less than 2^{28} bytes of physical memory, a single descriptor in the A table is all that is needed to map physical address into logical ones. The lone descriptor is marked as a page descriptor.

Operating system code and data, shared libraries, and the I/O page are mapped in the same fashion as the user code and data. As with the user task, the tables could be deleted and the operating system run through the physical memory descriptor. As mentioned, the mapping of physical memory is done using only one descriptor. It is marked as a page descriptor even though it is not in a page



5. The chip's access protection mechanism lets the operating system and task software share the user memory space. User programs start at address 0 and execute in the first half of the memory. The second half is reserved for the operating system and shared run-time libraries. Translation-table bits keep the user code out.

table. The PMMU hardware uses that form of descriptor to map large areas of logic address space into a contiguous physical memory.

Task switching is done by loading the address of the A-level table for the new task into the CRP register. The PMMU hardware flushes the ATC as needed. In fact, whenever a task is destroyed, the operating system need only execute a flush instruction to remove any inactive ATC entries.

Some common operating system functions become very easy when the memory is shared. Fetching and setting a byte in the user address space of the current task is the same as reading or writing any byte. A byte in physical memory is addressed as the physical memory address ORed with the hex value 80000000.

Many operating systems prefer to test the legality of an access before trying it to avoid causing a fault. A typical test of this kind consists of a two-instruction sequence of PTEST (operating on the address in question), followed by PBIS, or branch on the state of the invalid bit in status register PSR.

Copying a block of data from the current task to a target task is also easy, especially if less than half of the supervisory address space is otherwise used. The appropriate segment table from the target task is installed in an unused area of the supervisory address map and the transformation is made from the target task address to one in the supervisory map. Data can then be moved directly from the current task to the target task, without intermediate buffering or switching of address maps.□

Michael W. Cruess is a project manager at Motorola's microprocessor products group, where he headed the system design team for the MC68851 paged-memory management unit. He is currently involved in defining system software and new products. Cruess has a BSEE from Rice University in Houston and an MSEE from the University of Texas at Austin.

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Designing a precision op-amp circuit dictates a tight rein on every error source. Most potential sources, among them finite gain and gain nonlinearity, are not immediately obvious, and the imprecision they introduce will often eat up a system's error budget. Though errors cannot be corrected very easily, simply being aware that error sources exist can help designers fend off, if not completely eliminate, potential troublespots.

A temperature-measuring system illustrates one application in which the precision of an op amp can be a major issue. A typical circuit might be found in a semiconductor wafer-processing furnace (Fig. 1), where temperatures must be tightly controlled within ±1°C. Since process set points vary, the system must be equipped to monitor temperatures accurately and over a broad range.

As in most applications, the accuracy of the op amp depends on many things, including offset voltage, noise, nonlinearity, common-mode rejection, and external resistor value. Some factors are more critical than others, but all contribute some degree of error to the circuit. For example, if an op amp with an open-loop gain of 500,000 resides in a circuit with a closed-loop gain of 1000, analysis shows that the circuit exhibits a 0.2% gain error. The open-loop gain can vary as much as 100% from device to device and also vary considerably with temperature. No simple and reliable way exists to compensate for the error because an op amp's open-loop gain cannot be controlled tightly.

If a designer were reading the gain value from an op amp's data sheet, he might get the impression that the gain is constant over the output range of −10 V to +10 V. In fact, constant gain is far from the true performance for many amplifiers, since the specification is usually a value derived from a two-point measurement. Actually, gain fluctuates significantly with temperature and with output voltage and load.

For example, the incremental gain of the industry-standard OP-07 with a 2-kΩ load varies as much as 50% from the typical value quoted on a data sheet. The open-loop gain is the inverse of the slope of the curve, and ideally, the gain curve should be a straight line through the origin. However, thermal feedback in the chip yields a nonlinear curve that reflects both the gain drift and the drift induced by input offset voltage.

Within an op amp, open-loop gain is determined by the transconductance and the complex load resistance (including a beta-reflected resistance of the output stage) seen by the gain-stage transistor. Both parameters change significantly over temperature; hence, so does the open-loop gain. The slope of every point on the gain curve changes constantly throughout the output voltage range.

Since the accuracy of the circuit is a function of open-loop gain, overall linearity also suffers if the amplifier behaves nonlinearly. The linearity error of a high-gain stage used in a 12-bit measurement system can be analyzed quantitatively. Reconsider the example of an amplifier having a gain of 500,000 and exhibiting a 0.2% error in a closed-loop circuit of gain 1000. A 10% change in gain results in an overall gain error of 0.18% or a nonlinearity figure of 0.02%. Taking the example to a gain-change extreme of 50%, the circuit experiences an overall gain error of 0.133%, or nonlinearity of 0.067%—only about 10 bits linear. A full-scale adjustment potentiometer can eliminate the overall gain error only at one point. As soon as the open-loop gain of the amplifier changes, linearity error reappears.

AVOID THE TRAP

Designers should not be trapped into assuming that a precision op amp has sufficient gain to behave like an ideal op amp, especially in highly demanding designs. A review of the classic feedback control mechanism, which is analogous to an op amp in a closed-loop circuit, reveals the problem (Fig. 2). At the negative summing junction, the signal is merely the product of the output and of the feedback factor, F. Consequently, the signal at the amplifier's input is the original input less the product. The difference is subsequently multiplied by the gain, A, of the amplifier, yielding an expression:

$$\text{Output} = A(\text{input} - F \times \text{output})$$

Rearranging and dividing the numerator and denominator by A produces:

$$\frac{\text{Output}}{\text{Input}} = \frac{1}{\frac{1}{A} + F}$$

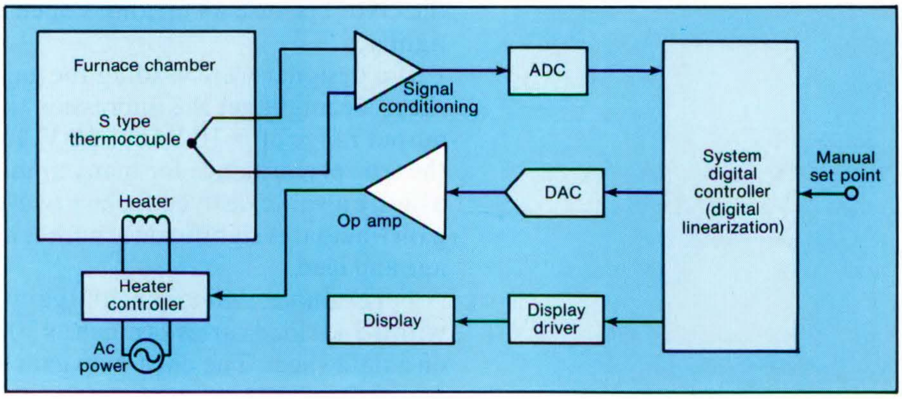
As gain increases toward infinity:

$$\frac{\text{Output}}{\text{Input}} = \frac{1}{F}$$

The final expression implies that the transfer function of the closed-loop system is purely a function of the feedback factor.

In practice, however, op amps are far from perfect. If an industry-standard precision op amp like the OP-07, which has a typical voltage gain of 500,000, appears in a closed-loop circuit with a gain of 1, feedback factor F will be unity, making the net transfer function 0.999998. That value translates into a very tolerable error of 2 ppm. However, if the desired closed-loop gain is 1000, F will equal 0.001 and the closed-loop transfer function is 998. The equivalent 0.2% net gain error exceeds the total error budget allowed in most cases. The higher the closed-loop gain, the more sensitive the circuit to open-loop gain.

To deliver the high performance required in such applications as the temperature-measuring system, the high-gain OP-77 has been developed (see "A Perfect Fit," p. 171). Its dc performance improves the most critical part of the system—the front end of the thermocouple amplifier along with its necessary signal-conditioning circuitry (Fig. 3). The thermocouple's extremely low-level signal demands more than mere gain from the amplifier, even though in this case the OP-77's gain is a minimum of 5 million. The low offset (below25 μV), low drift (0.3 μV/°C), and low noise (less than 0.6 μV pk-pk) of the device play equally important roles.



1. In a semiconductor wafer-processing furnace, the temperature must be controlled extremely accurately, usually to within 1°C. That accuracy can be obtained only if an op amp retains its precision within tight limits. With its extraordinarily high open-loop gain and very low input offset voltage, an op amp like the OP-77 helps the control system meet that temperature tolerance.

With the exception of the cold-junction compensation circuit, the front end requires no elaborate error correction circuits. The amplifier's high degree of accuracy simplifies the design, which suits three popular types of thermocouples: the J and K types for temperatures up to about 700°C and the S type for up to 1500°C.

Because the Seebeck coefficient of the S-type thermocouple is a mere 10.3 μV/°C, the component presents the accompanying circuit with a very difficult signal amplification requirement. The design focuses on this particularly useful application.

Piecewise linearization techniques can compensate for the continuously nonlinear nature of thermocouples. One very simple and easily implemented method uses a power series polynomial:

$$T = a_0 + a_1X + a_2X^2 + a_3X^3 + \cdots + a_nX^n$$

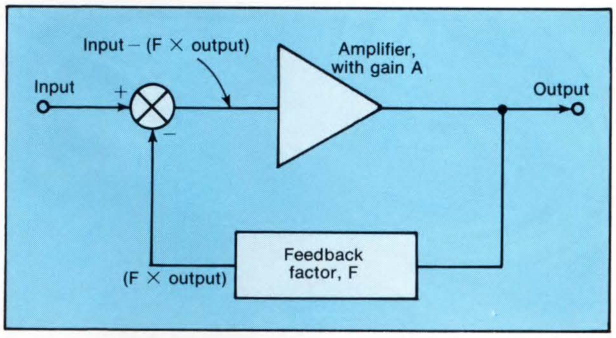
where T is the temperature, X is the thermoelectric voltage, a is the polynomial coefficient unique to each type of thermocouple, and n is the maximum order of the polynomial. The higher n goes, the more accurately the power series can be estimated.

Computers or microprocessors can implement the algorithm far more efficiently than can analog linearization circuits. Consequently, the design does not attempt to linearize the thermocouple.

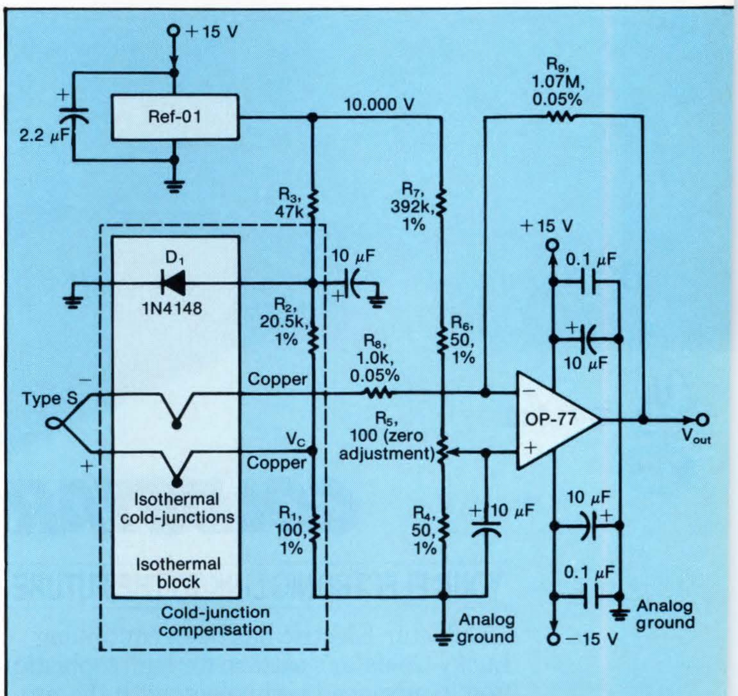
DESIGN CONCERNS

In completing the circuit, designers must carefully consider several details. For example, any thermoelectric voltage generated at the measuring junction can also be generated at any other junction of two dissimilar materials. The most critical of these contacts lie in the gain path. Fortunately, parasitic junctions of this type usually come in opposing pairs, creating a self-canceling effect if the opposing junctions are at the same temperature. Therefore, the layout itself must not give rise to a large temperature gradient across the circuit.

In addition, resistors R_1 and R_2 and sensing diode D_1 form a compensation circuit that cancels the error generated by the terminating junctions. The circuit makes use of the highly predictable −2.1-mV/°C temperature coefficient of a semiconductor pn junction. The resistor divider effect of R_1 and R_2 generates −10.3 μV at V_C for every degree Celsius the temperature of D_1 rises. That temperature coefficient is equal, but opposite, to the error voltage generated by the terminating junctions. The compensation network works well, provided the body of D_1 is in thermal proximity to the point at which the two junctions join with copper wires. Thus the cold-junction error can be canceled over a reasonable range of change in am-



2. In a standard feedback circuit, the signal at the negative summing junction represents the output times the feedback factor, F. For an amplifier with a very high open-loop gain, the transfer function of the circuit, output/input = 1/F, makes the transfer function depend only on the feedback.



Thermocouple type	Seebeck coefficient	R_1	R_2	R_7	R_9
K	39.2 µV/°C	110 Ω	5.76 kΩ	102 kΩ	269 kΩ
J	50.2 µV/°C	100 Ω	4.02 kΩ	80.6 kΩ	200 kΩ
S	10.3 µV/°C	100 Ω	20.5 kΩ	392 kΩ	1.07 MΩ

3. The OP-77 does its job in the critical part of the temperature-measuring system. To amplify the thermocouple's low voltage output and still maintain stability, the amplifier uses its extraordinarily high gain of 5 million and its low 0.3-µV/°C drift.

Measuring temperature with op amps

bient temperature.

Potentiometer R_5 compensates for the composite offset voltage, which is created by both the cold-junction compensation circuit and the amplifier's inherent input offset. The measuring junction generates the remaining net thermoelectric voltage in the circuit. The gain factor amplifies the signal so that the amplifier develops a 10.0-V full-scale voltage for 1000°C. At a Seebeck coefficient of 10.3 μV/°C, a type-S thermocouple generates 10.3 mV of thermoelectric voltage at 1000°C. Therefore the gain of the circuit is 10 V/10.3 mV, or 970.9. Scaling like that allows temperature either to be converted into digital form using standard analog-to-digital converters or to be read directly off a 4½- or 5½-digit precision digital voltmeter.

Resistor R_8 is purposely chosen to be 1 kΩ, a value that reduces the amplifier's input noise current and the thermal noise of the resistors. The value of R_9 is derived by multiplying the gain, 970.9, by the sum of R_8 and the parallel resistance of R_1 and R_2. The value calculated for R_9 is 1.0675 MΩ; thus a standard resistance of 1.07 MΩ can be used. Alternatively, if more accurate gain is required, a 100-kΩ potentiometer can be placed in series with a 1.02-MΩ fixed resistor and both inserted in the feedback path as a fine-gain adjustment.

Circuit grounding, another important consideration, is frequently overlooked. Since every 10 μV of signal represents 1°C, noise in the ground circuit can swamp the sig-

A perfect fit

The new OP-77 is tailor-made to fit many applications, from strain-gauge bridge amplifiers to resistance temperature detectors. Like thermocouples, those transducers produce low-level signals that demand outstanding performance from an op amp. Because the OP-77's operating current runs less than 2 mA, the device blends nicely into 4-to-20-mA current-loop applications.

In CMOS d-a converters requiring a resolution of better than 12 bits, offset voltage is a significant error source. For converters built with an R-2R ladder, it degrades the differential linearity of the converter's output. With a worst-case initial offset voltage of 25 μV, the op amp contributes an error of less than 0.2 LSB for a 16-bit system, an error that usually can be nulled if necessary. More problematic is the offset voltage drift over temperature that plagues many op amps. The OP-77 drift confines the worst-case error to 55 μV over a 100°C change in ambient temperature. At 10 V full scale, that drift produces an error of less than 0.01 LSB for a 12-bit system, 0.05 LSB for a 14-bit system, and 0.20 LSB for a 16-bit system.

Measuring temperature with op amps

nal. A single-point analog "star" ground should be used throughout the circuit layout and should also be the reference ground for the digital converter or the voltmeter. Any digital signal ground reference should be terminated only at the power-supply ground return.

SOURCES OF ERROR

Thanks to the op amp's high open-loop gain and gain stability, the thermocouple itself contributes the only linearity error. With the OP-07, the finite gain of the op amp might cause an additional error of about 0.2%. In contrast, the high open-loop gain of the OP-77 contributes less than 0.02% measurement error, or 0.2°C.

The layout of the amplifier's input stage warrants special attention, as it affects virtually all dc parameters. For instance, the zener-zapping resistors in each differential leg of the input stage must be carefully matched and symmetrically laid out. Doing so yields several distinct benefits. First, it produces an exceptionally low initial input offset voltage of 25 μV, but even more important, it makes the offset voltage drift come in at less than 0.1 μV/°C typically. Second, the setup raises common-mode rejection and power-supply rejection to about 120 dB. A common-mode rejection of 120 dB translates into an error of only ± 10 μV over a full-scale common-mode range of ± 10 V.

Finally, the circuit should keep input noise level equal to if not better than the industry-standard OP-07 while reducing the operating supply current. A dilemma arises, of course: Cutting the input-stage operating current reduces input current noise level but causes the voltage noise to rise unacceptably. Trimming the input-stage bias current brings noise to an acceptably low level while reducing the subsequent stage currents. The resulting amplifier has the characteristic low noise of the OP-07 but operates at half the current of its predecessor. □

At Precision Monolithics James Wong acts as an application engineering manager, working on data acquisition and control systems. Previously he cofounded Finell Systems, a motion control systems company, and held positions with National Semiconductor, Singer Business Machines, and Texas Instruments. He holds a BSEE and an MBA from San Jose State and Santa Clara University, respectively.

How valuable?	Circle
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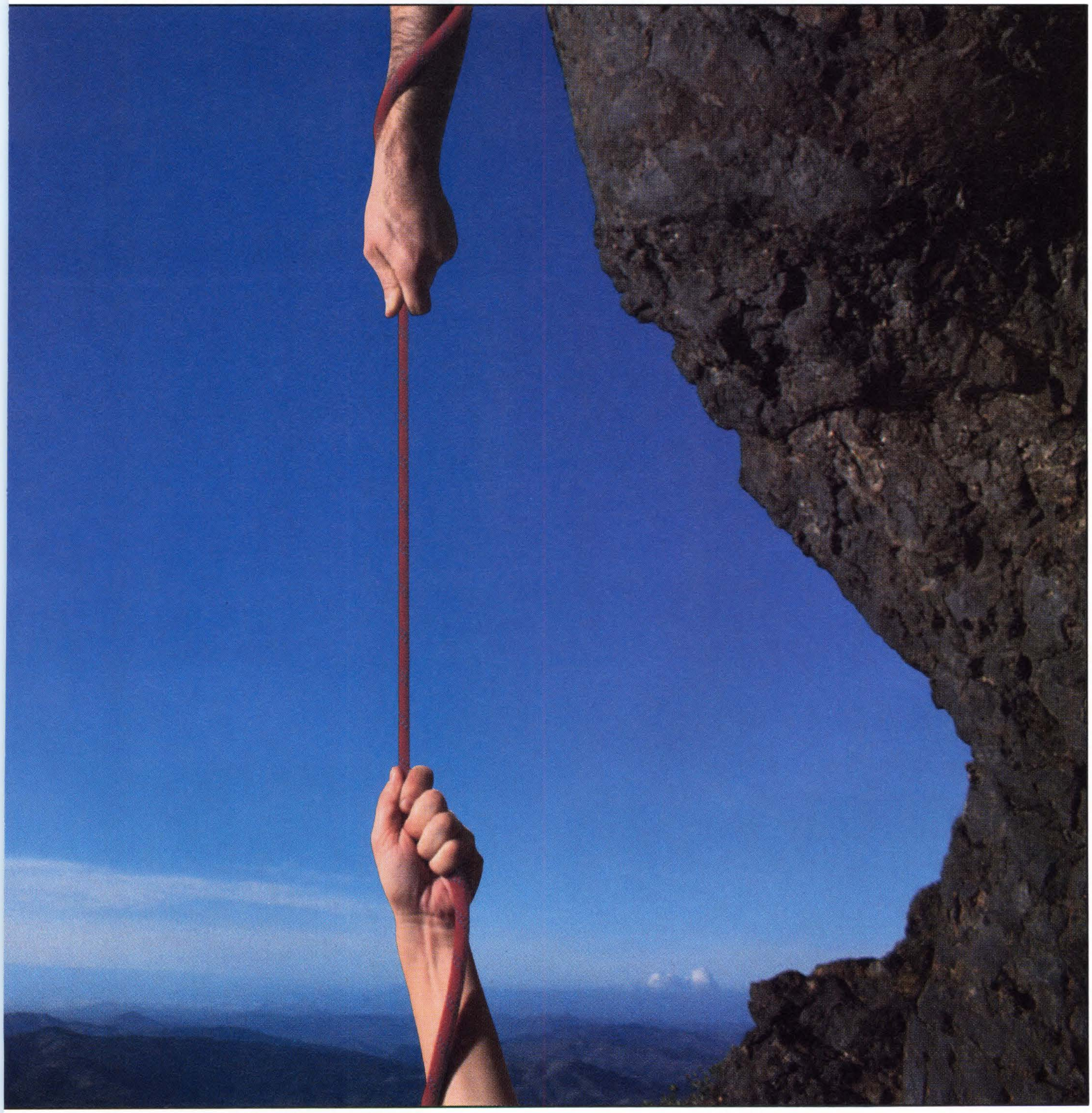

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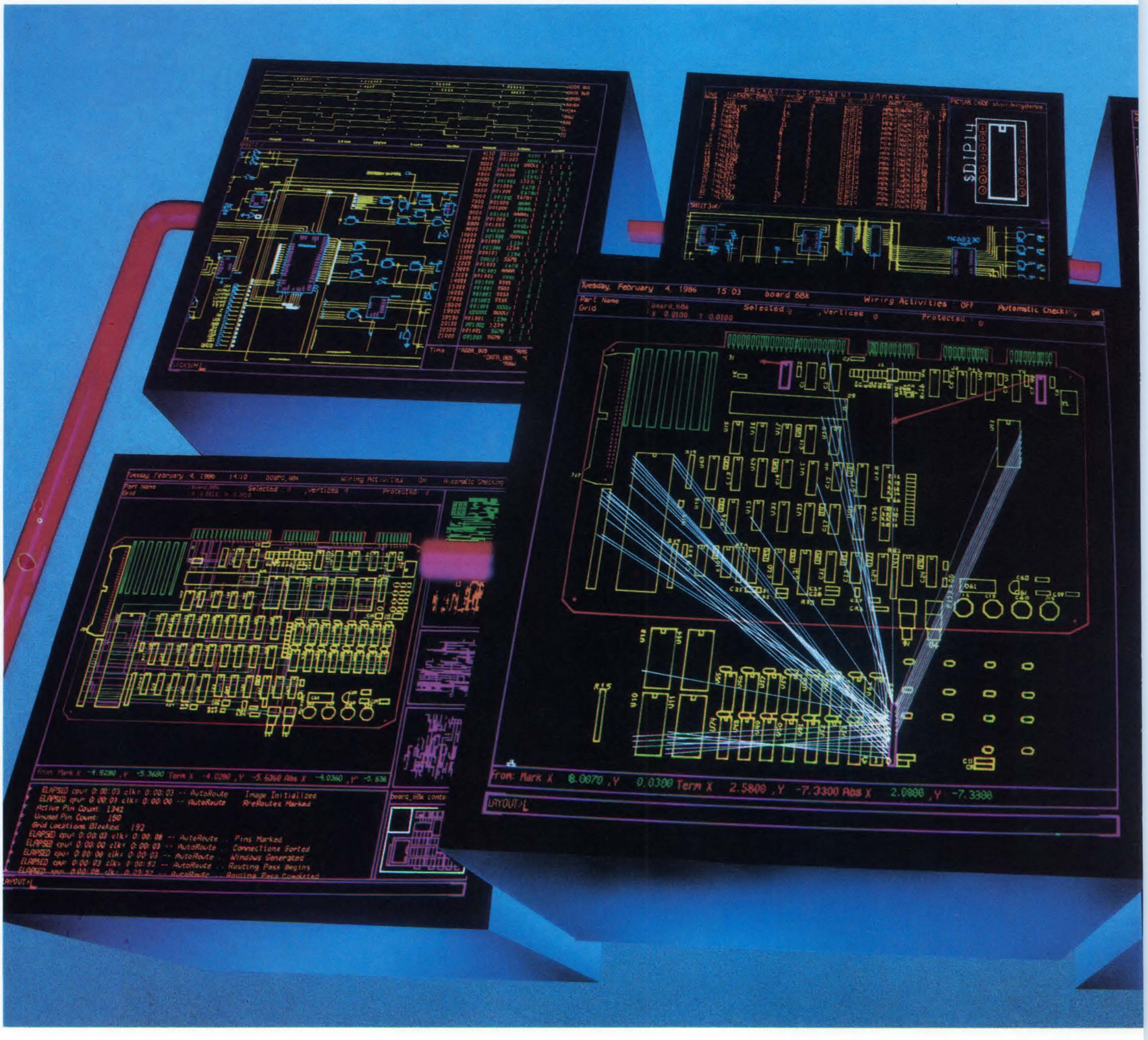

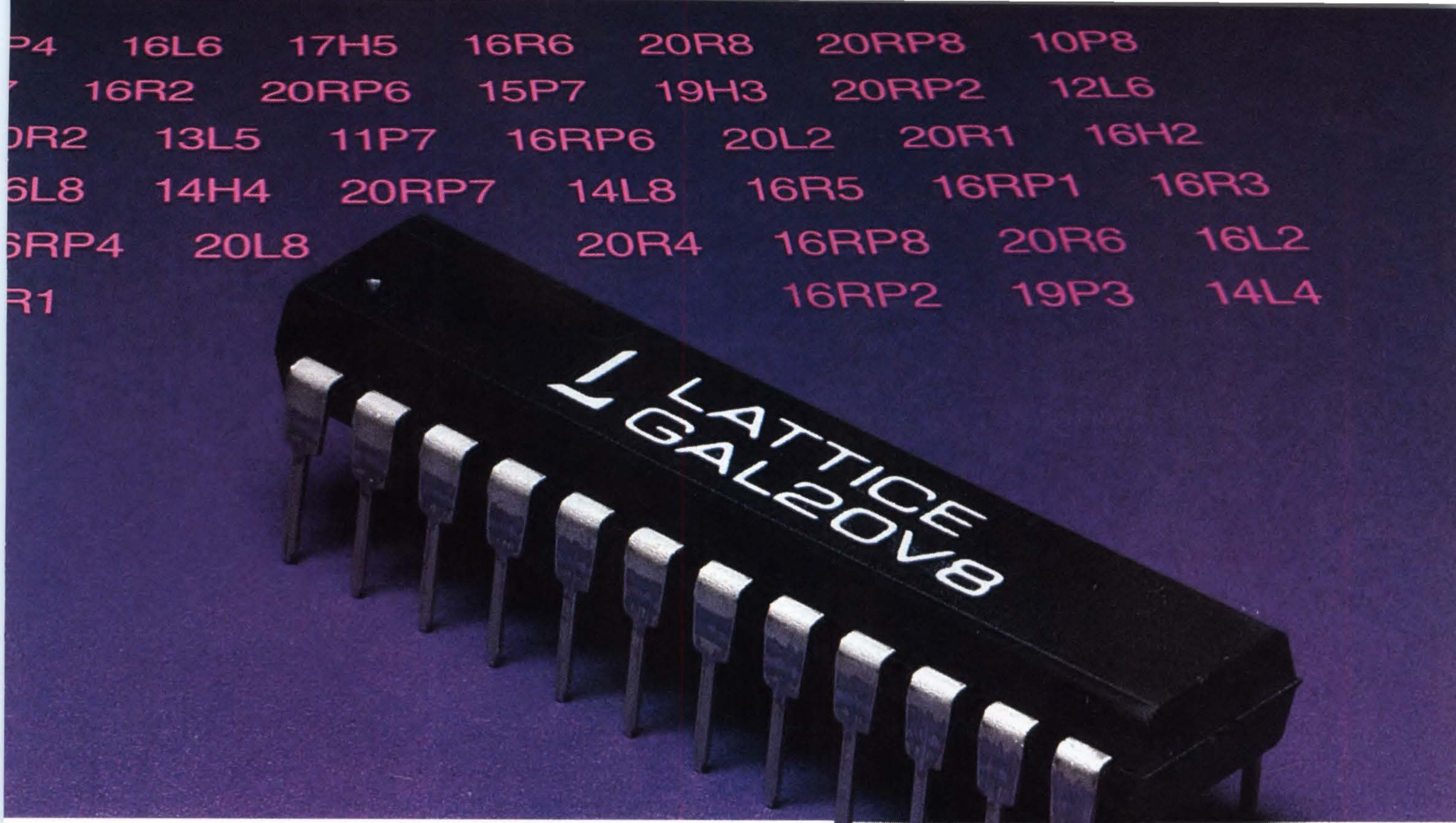

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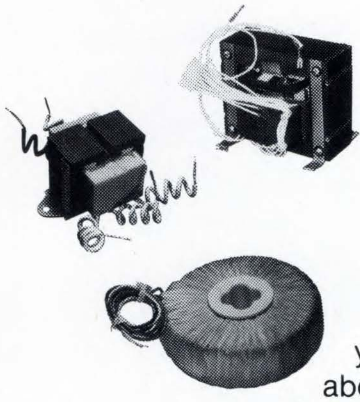

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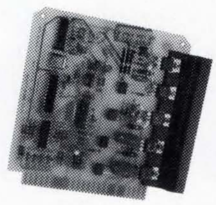

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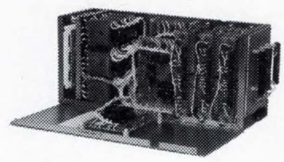

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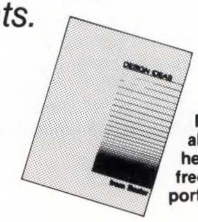

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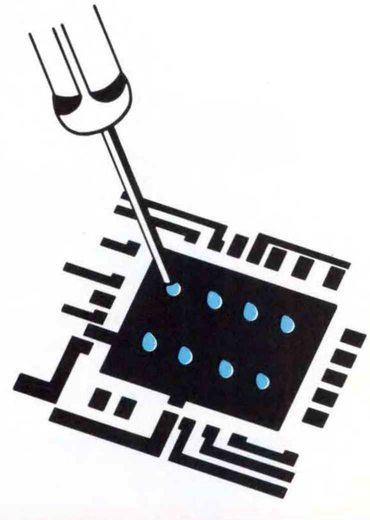
PRODUCT REPORT

FOCUS ON CONDUCTIVE EPOXIES



Stronger and cleaner than their predecessors, conductive epoxies compete with solder and polymides to carve out a niche in surface mounting.

Conductive epoxies have long been used to attach chips to substrates in standard DIPs and hybrid ICs. Now they are finding their niche in the emerging world of surface mounting. Here their relatively low curing temperatures (compared with the melting point of solders) can reduce the stress placed on extremely sensitive devices. Coincidentally, epoxies are undergoing such key improvements as greater shear strength and lower levels of ionic contamination.

Even though the formulations of epoxies for different applications vary radically, they show similar benefits over solders and polyimides, the alternative attachment materials. The low temperature needed for their curing gives epoxies an edge over solders, and the shorter curing time, an edge over polyimides. And for hybrids, epoxies eliminate a costly and time-consuming step, since solders require metallization of the ceramic substrate. The bonding strength of epoxies, superior to that of solders, is roughly equivalent to polyimide adhesives, which cost far more.

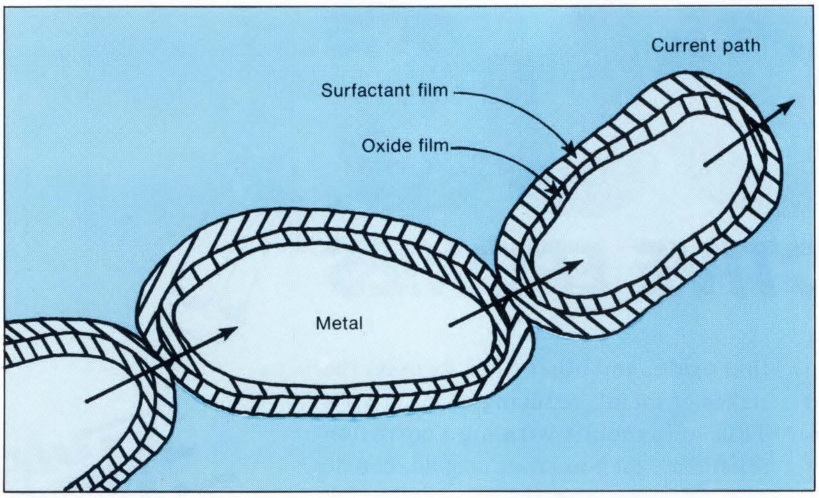
Epoxies achieve their combination of bonding strength and good electrical conductivity through the addition of silver particles. These particles, typically making up at least half an epoxy's volume, align themselves to form enough conductivity paths to ensure good contact (Fig. 1).

Some researchers have explored the use of copper or other low-cost materials instead of silver, but their results have largely proved unsatisfactory. One problem is that oxides and other films form on the flakes of metal, reducing conductivity. Thus only metals with high corrosion resistance, such as silver or gold, can be used. Of course, after the price of silver fell from its highs of the late 1970s, there was little economic reason to use other metals. (Because of its cost, gold is used only when an extremely high degree of reliability is called for.)

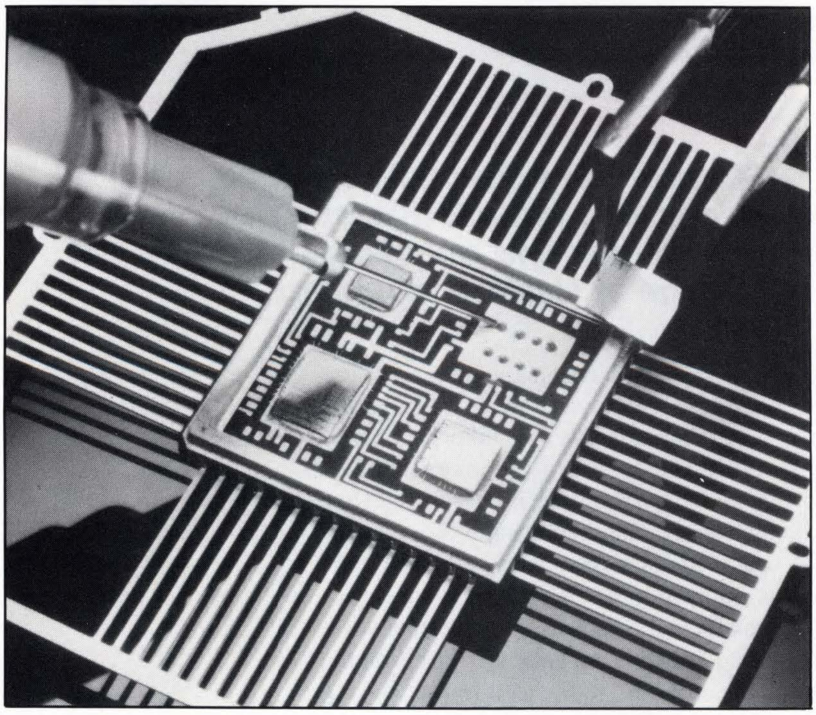
The drop in silver prices has also encouraged many DIP manufacturers to use conductive epoxies even where nonconductive adhesives would do, simply to avoid the cost and inconvenience of switching from one kind to the other during the manufacturing process. In the past, conductive epoxies had often been employed in chips requiring back-face conductivity, as well as the normal wire-bond attachments linking the pads on the face of the IC to the lead frame. During the 70s, when the price of silver soared, many users turned to nonconductive epoxies for chips that needed no back-face conductivity.

Improvements in polyimides, which have far fewer of the impurities that can cause failures than do epoxies, are pressing epoxy makers to improve the performance of their materials too. A recently devel-

Terry Costlow



1. Metal flakes suspended in epoxies render them conductive. But because these metals tend to oxidize and otherwise film over, they lose their conductivity. As a result, silver and other highly corrosion-resistant metals must be used—despite their cost.



2. Such companies as Ablestik are improving their adhesives' viscosity so that automated equipment can deposit small spots of epoxy on substrates at very high speeds. The adhesive flows quickly and leaves no "stringing" as the deposition head moves on.

oped military specification, MIL-A-87172, sets new criteria for epoxies destined for hybrids in military use. The specification, which sets guidelines for outgassing (emission of corrosive vapors), thermal expansion, pot life, resistivity, and many other parameters, is also making its appearance in some industrial requirements.

The standard demands for ionic contamination and shear strength are commanding the most attention from epoxy makers. Developed by the Rome (N.Y.) Air Development Center, the specification aims at limiting ionic contamination, which leads to corrosion that can weaken or even destroy the bonds. Polyimide adhesives are cleaner and do not emit corrosive vapors, so epoxy makers have had to respond swiftly to hold on to their market position.

FAST RESPONSE

Such companies as Amicon and Ablestik, the two largest in the conductive epoxy industry, have been quick to come up with adhesives meeting the new standard. Like most makers, these two offer special formulas to meet their customers' demands.

MIL-A-87172 calls for no more than 300 ppm in total of chloride, sodium, and potassium, the ionic impurities that cause the most problems. While epoxies of the previous generation sometimes met that level —some specially monitored and selected batches even having no more than 100 ppm of these impurities —it was not uncommon to find impurities up to 400 ppm. But many epoxies that have been released over the past six months have impurity levels consistently as low as 20 ppm from batch to batch. Credit for that high degree of purity goes to adhesive resins that are specially formulated and processed to eliminate salts and other impurities.

While most problems posed by the new standard have been easily overcome, shear strength—the force needed to break the adhesive bond and remove the die from the substrate—has proved one of the more difficult parameters to upgrade. Although epoxies generally meet the MIL-A-87172 adhesion demands at room temperature, some do not yet meet the required standard at 150°C.

The specification requires epoxies to withstand a stress of 6.0 meganewtons/m^2. Epoxy Technology, which developed the first conductive epoxy 20 years ago, has already exceeded the specification. While other epoxies go to only 2 MN/m^2 before letting go, its H35-175M can withstand 7.2 MN/m^2. The material will hold fast under a pressure of more than 4500 lb/in.^{2} at 200°C.

While attempting to meet MIL-A-87172's purity standards, epoxy makers have also concerned themselves with the demands, in military and industrial markets, of smaller dice and fast production equipment. Both these aspects of a manufacturing process call for an epoxy that can be deposited in small spots onto substrates without causing "stringing" as the equipment's insertion head moves from point to point (Fig. 2).

GO WITH THE FLOW

To enhance the epoxy's flow, makers have added solvents that not only cut down its viscosity but, by evaporating quickly around the edge of an application, actually reduce the flow, or bleeding, that takes place before curing. The new makeup halts undesired flow, leaving more adhesive for the bond and reducing the chance of short circuits between tightly spaced interconnections.

This benefit did not come without drawbacks at first. Solvents lead to outgassing. Though the emissions cause no damage during the curing process, if they continue after a package has been sealed, they can damage or destroy interconnections. But this problem, too, was overcome as soon as it was spotted during tests for certification under the new military specification. Recently introduced epoxies use either nongassing solvents or none at all.

Cutting out the solvents also cuts the number of voids left after the solvent bubbles out of the adhesive (Fig. 3, left). Epoxy Technology's H20E has no solvents and so presents a smooth surface (Fig. 3, right). Curing time is not greatly altered—it hardens in 5 minutes at 150°C, standard parameters for many high-end epoxies. Amicon

Directory of conductive epoxy makers

Company	Conductive epoxies for surface mounting	Under 100-ppm ionic purity	Viscosity meets automation demands	Circle
Ablestik Laboratories, National Starch and Chemical Corp. 833 W. 182 St. Gardena, CA 90248 (213) 532-9341		★	★	464
Acme Chemicals and Insulation Co. P.O. Box 1404 New Haven, CT 06505 (203) 562-2171	★			465
AI Technology Inc. P.O. Box 3081 Princeton, NJ 08540 (609) 799-5550		★	★	466
Amicon Corp. 25 Hartwell Ave. Lexington, MA 02173 (617) 861-9600	★	★	★	467
Bacon Industries Inc. 192 Pleasant St. Watertown, MA 02172 (617) 926-2550			★	468
Chomerics Inc. 77 Dragon Ct. Woburn, MA 01888 (617) 935-4850		★	★	469
Dynaloy Inc. 7 Great Meadow La. Hanover, NJ 07936 (201) 887-9270	★	★	★	470
Emerson & Cuming Inc. 869 Washington St. Canton, MA 02021 (617) 828-3300	★	★	★	471

uses solvents that cause only small voids. Its epoxy thus provides adequate bonding strength and actually generates less stress when bonding a large die, since the voids absorb some thermal compression and therefore act as a sort of built-in shock absorber.

Also among new products from Amicon, as well as other makers, are the so-called B-stage epoxies, which can be attached to a die when it comes off the production line. The epoxy is then cured to a B stage, in which state it is not tacky to the touch but will nevertheless reflow when the part is applied to a heated substrate. The epoxy is then cured in the normal way (at about 150°C for the Amicon products) to form a solid bond. These epoxies can remain in their B stage for months without losing the ability to set permanently when heat is applied.

Directory of conductive epoxy makers (cont.)

Company	Conductive epoxies for surface mounting	Under 100-ppm ionic purity	Viscosity meets automation demands	Circle
Epoxy Technology Inc. 14 Fortune Dr. Billerica, MA 01821 (617) 667-3805		★	★	472
Formulated Resins Inc. P.O. Box 508 Greenville, RI 02828 (401) 949-2060	★	★	★	473
Hysol 15051 E. Don Julian Rd. Industry, CA 91749 (818) 968-6511	★		★	474
Micro-Circuits Co. Inc. Box 518, RR1 New Buffalo, MI 49117 (616) 469-2727			★	475
Tecknit 129 Dermody St. Cranford, NJ 07016 (201) 272-5500		★		476
Thermoset Plastics Inc. 5101 E. 65 St. Indianapolis, IN 46220 (317) 259-4161	★		★	477
Tra-Con Inc. 55 North St. Medford, MA 02155 (617) 391-5550			★	478
Transene Co. Inc. Rte. 1 Rowley, MA 01969 (617) 948-2501	★		★	479

Note: This is a representative sampling of manufacturers; it is not meant to be a definitive list.

ON THE SURFACE

Nonconductive epoxy is no stranger to surface mounting, but only recently has conductive epoxy started to make inroads in this emerging technology. Nonconductive epoxies have been in use for years, holding components on the pc board as it moves through the production line. They then evaporate when the board goes through the soldering process.

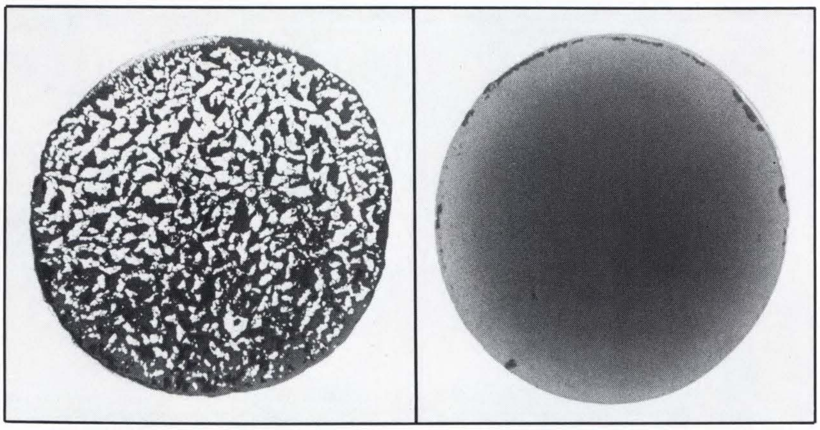
Conductive epoxies, however, make the electrical bond between the device and the traces on the board. Though little likelihood exists that a circuit board would be processed entirely with conductive epoxies, the adhesives are well suited to components that cannot withstand the extreme heat of surface-mounting soldering.

AFTER THE SOLDER

For these supersensitive devices, conductive epoxies can be placed on the board after it has gone through the solder cycle and the parts have been mounted and cured at under 150°C—a far less strenuous cycle than infrared or other solder-reflow processes. Although most estimates give such special epoxies less than 10% of the total surface-mounting market, that segment is enough to attract such companies as Transene and Amicon. The task of revising the adhesive for use on circuit boards instead of on DIP or hybrid substrates presents few problems; even so, few epoxy manufacturers at present plan to develop such adhesives. The key change involves optimizing the material for bonding to glass-epoxy boards instead of to ceramic or other kinds of substrates

used in DIPs and hybrids.

Flexible circuit boards are also likely candidates for conductive adhesives, since the epoxies can be formulated to flex. Acme Chemicals' 3026 adhesive can, in applications up to $^1/_{32}$ in. thick, be bent over a $^1/_{16}$ in. circular bar without cracking, and even when flexed, it can withstand up to 1400 lb/in.^{2}.



3. Voids typically occur when solvents bubble out during curing (left). To avoid the problem, Epoxy Technology eliminates solvents from its epoxy, which thus affords a smoother bonding surface (right).

Yet another small niche application is in emi/rfi shielding. Tecknit, among others, aims its silver-filled epoxies at sealing gaskets and joints in shielding packages. For instance, a waveguide attached to a flanged section might be sealed with conductive epoxy to prevent signals from leaking out through what would otherwise be an unshielded junction.

Although this might appear a less demanding application, high-quality epoxies must be used for these bonds as well, since the connection must perform well over time and pass Federal Communications Commission tests. Tecknit's two-component material maintains its strength at temperatures ranging from $-80°$ to $+300°F$. Shear strength is 100 lb/in.^{2}.□

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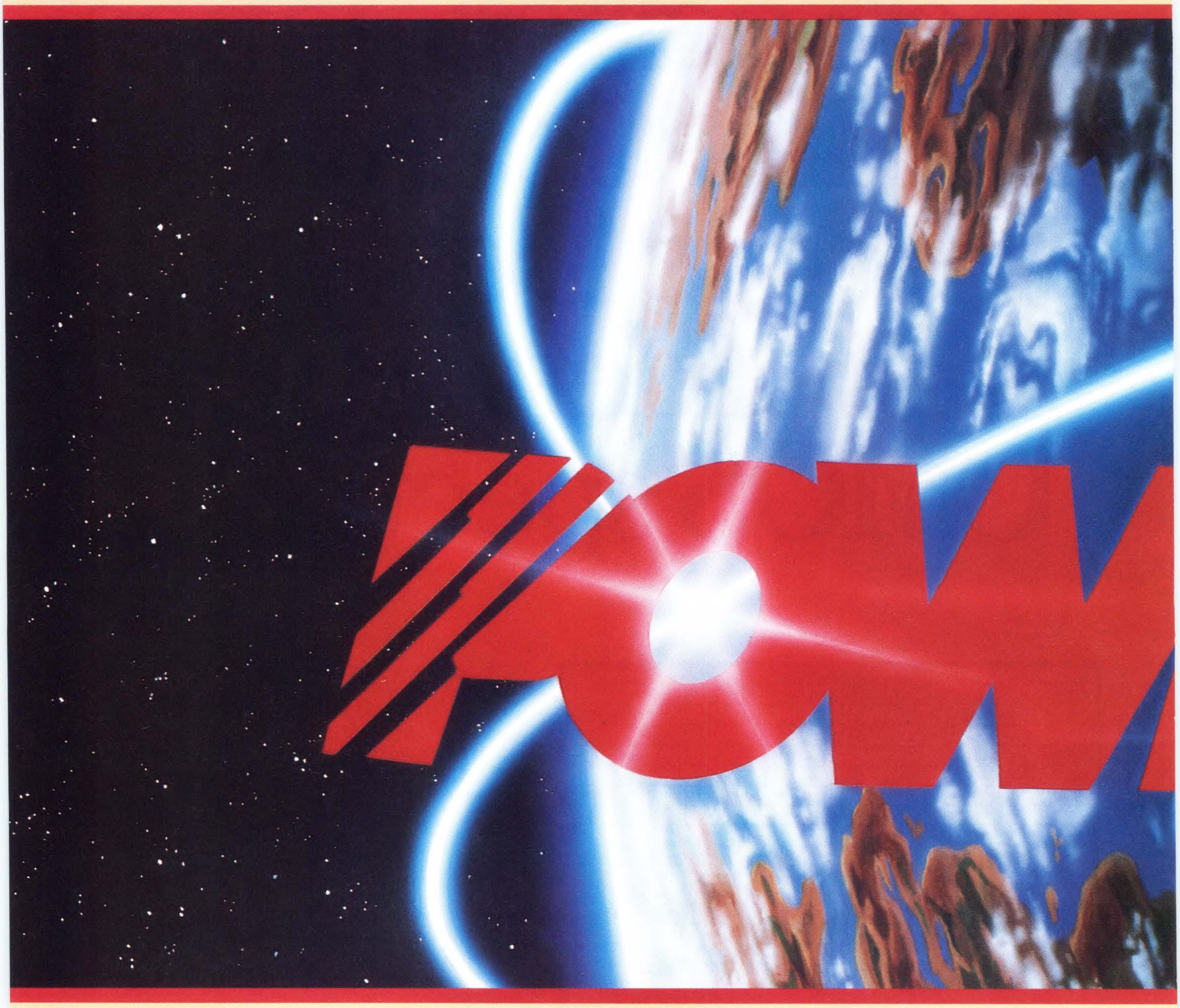

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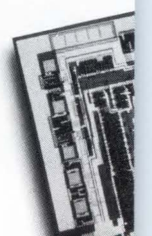

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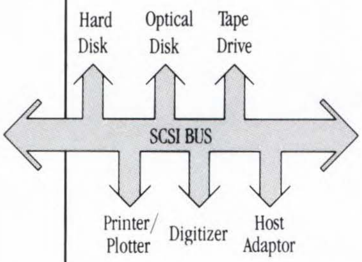
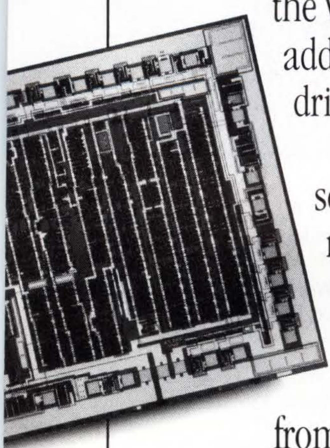


Make the WD33C92/3 controller the backbone of your SCSI system.

Now, whether you're designing hard disk systems, printers or plotters, optical or tape drives, digitizers, even host adaptors — or adding a SCSI bus in a host system — SCSI has never been more practical or easier to design in.

REAL ESTATE SAVINGS

We've taken a board full of devices and shrunk them into a single-chip solution. The WD33C93 has on-chip high current drivers, and supports both synchronous and asynchronous transfers. Or choose the WD33C92 if you prefer to add your own differential drivers.



Either way, four MB per second transfer rates, combination commands that minimize host intervention, and a *Translate Address* command that switches from logical to physical address make our SCSI controller the highest performance, space-saving single-chip solution you've been looking for.

REAL COMPATIBILITY

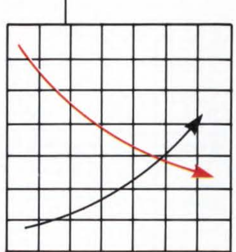
The WD33C92/3 is completely SCSI/ANSI X3T9.2 compatible. So you can standardize on it as either SCSI initiator or target, and be sure of total compatibility with any SCSI implementation on the market today including other SCSI devices, controllers and host adaptors.

100% ANSI X3T9.2 SCSI COMPATIBLE

REAL ECONOMY

We've got a proven history of putting complex standards into silicon, then driving those devices down the experience curve as fast as the market demands.

As complex as the WD33C92/3 is, it's a down-to-earth implementation that makes SCSI that much more attractive. Matter of fact, you can just about afford to design a WD33C92/3 into every system you build, as an extra competitive feature.



Our VLSI capabilities drive down cost as we drive up functionality.

REALLY HERE.

Count on Western Digital to support your SCSI system requirements at both host and peripheral ends of the cable. The WD33C92/3 is here today, ready to sample, with high volume production right around the corner. For details, contact the Western Digital sales office in your area.

Includes all necessary SCSI logic in a CMOS + 5V 44 pin chip carrier or 40 pin DIP.

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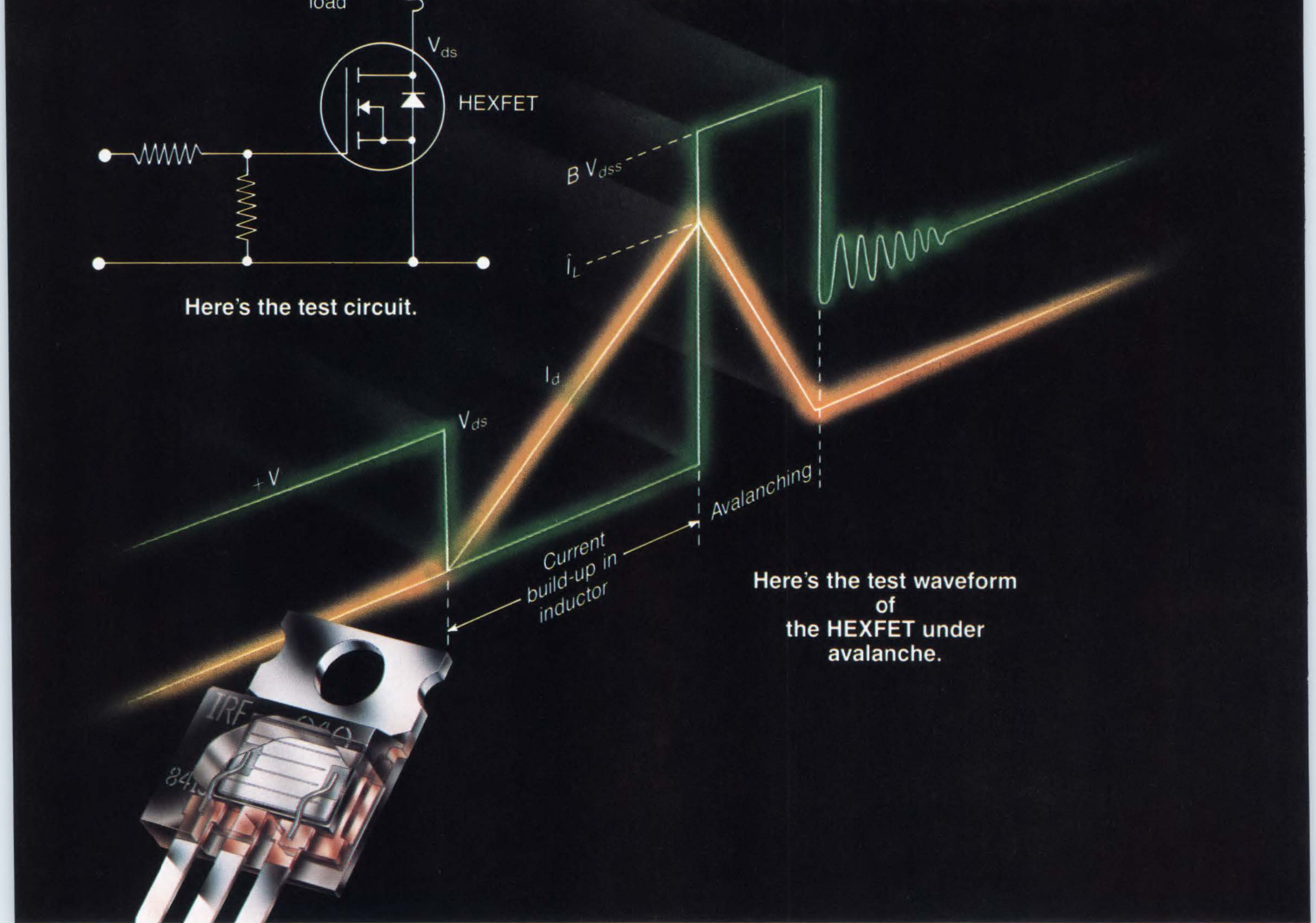
CIRCLE 87

HEXFET® secret unveiled!



You're looking at the avalanche withstand capability of a HEXFET – something few designers know and appreciate about the inherent ruggedness of IR's power MOSFET.

Fact is, we put *every* HEXFET we make through its own avalanche test before shipment. It's just another little secret why HEXFETs survive where others fail.

And with that extra margin of safety, HEXFETs add more value to your system. What's more, we're the only major power MOSFET manufacturer to specify avalanche capability *in writing*. And because we test every device, we can guarantee it.

It's one more reason why HEXFETs are today's quality choice. Call or write us for data.

NUMBER 1 IN POWER MOSFETs!

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WORLD HEADQUARTERS: 233 KANSAS ST., EL SEGUNDO, CA 90245, U.S.A. (213) 772-2000. TWX 910-348-6291, TELEX 472-0403

EUROPEAN HEADQUARTERS: HURST GREEN, OXTED, SURREY RH8 9BB, ENGLAND TELEPHONE (088 33) 3215/4231. TELEX 95219

CIRCLE 101

ELECTRONIC DESIGN EXCLUSIVE

32-bit color workstations drop almost 50% in price without losing performance

Thirty-two bit workstations with color graphics traditionally cost over $10,000. A beefed-up version of the Commodore Amiga microcomputer cuts that price almost in half, yet still delivers full 32-bit processing and floating-point functions. Developed by Computer Systems Associates, the Turbo Amiga is outfitted with a plug-in board carrying a 68020, a 68881 floating-point coprocessor, and an extra 512 kbytes of high-speed RAM. The card drops into the socket usually filled by the standard 68000. A 20-Mbyte hard disk is optional.

These additions complement the Amiga's multitasking operating system, AmigaDOS, and take advantage of the existing software base. All of the 68000 software runs on the 68020, which contains a superset of the 68000's instruction set. However, the 68020 brings performance advantages to the Amiga, like full 32-bit addressing and processing and a 256-word instruction cache.

Performance is further upgraded because the 68020 is running at 14.1 MHz, as compared to the 7.1 MHz of the Amiga 68000. The enhanced microcomputer uses 120-ns high-speed static RAM to match the higher processor speed. Further, the card's PAL-based interface handles the differences in the processor bus cycles. Since the 68020 can execute the 68000's code, it can interface with the Amiga's memory. Also, the 32-bit processor has dynamic bus sizing, enabling it to access the Amiga 16-bit bus.

Overall performance of the Turbo Amiga is at least an order of magnitude greater than that of a PC AT for computationally intensive processing. The Turbo speedups and the full 32-bit processor help. Additionally, the Amiga's special VLSI coprocessors relieve the CPU of graphics and peripheral control.

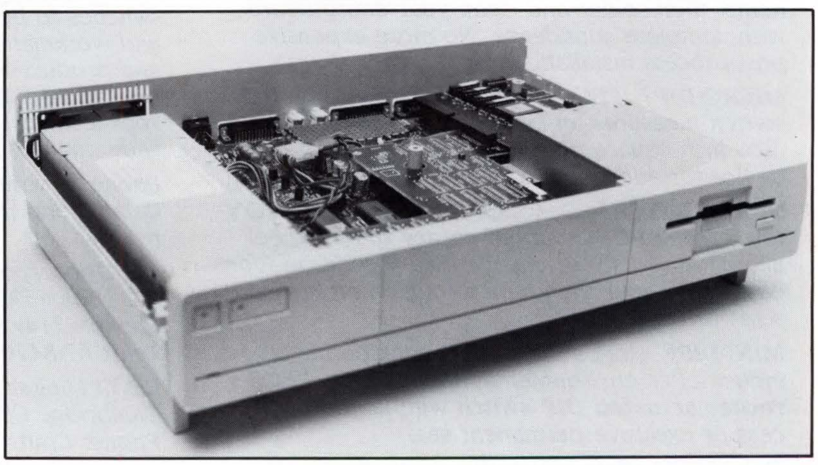
Some of the software running on the Amiga already supports the floating-point processor, including an optimizing macroassembler, a Fortran 77 compiler, and a C compiler. More speed is gained by configuring portions of the operating system to use the coprocessor board's high-speed memory space.

In addition, CSA is developing an expansion box to hold up to eight extra cards. A card version of the 68020 processor and memory set will also be built. It will reside in the expansion box with a cable connection to the 68000 socket.

A Turbo Amiga, with a 68020, a 68881 floating-point processor, 1 Mbyte of memory, a color monitor, and an 800-kbyte floppy costs $5,500. An optional 20-Mbyte hard disk costs $1500. The expansion box will be priced at $495. The Turbo Amiga has been placed on the GSA purchasing schedule, which means that government or government-related projects can directly purchase the workstation without competitive bidding.

Computer Systems Associates Inc., 7564 Trade St., San Diego, CA 92121; Patricia Chouinard, (714) 566-3911.

CIRCLE 313



Ray Weiss

NEW PRODUCTS

COMPUTERS & PERIPHERALS

Backup drive boasts reliability

A simpler, more reliable design distinguishes the I480 high-performance cartridge tape drive from its more established counterpart, the IBM 3480. Indeed, the I480 is the first plug-compatible unit to match the defacto standard of the 3480 for 0.5-in. magnetic tape drives. The recording format and tape cartridge are also compatible with those employed by IBM.

In all, the I480 contains 15% fewer mechanical parts than the 3480. Its mean time between failures (MTBF) is greater than 10,000 hours and mean time to repair (MTTR) is less than 0.5 hours. Unlike its predecessor, the unit has separate power and air supplies for each of its two drive mechanisms. Consequently, the failure of one pump only disables a single drive. In contrast, the 3480 has one air pump and power system for both mechanisms.

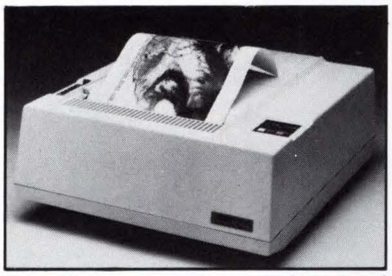
Although the frame of the I480 matches the size of the 3480, the actual drive mechanism is 75% smaller. In fact, it all but fits the form factor of an 8-in. floppy disk drive, being slightly longer. In addition, the new unit features a display that is about 25% larger than that on the 3480. Further, the unit has a keypad that lets a user take the drive offline to isolate and repair problems without interrupting the rest of the system.

With fewer parts and comparable reliability, the I480 lets OEM and plug compatible manufacturers maintain the usual 15% to 20% price advantage over their major competitor. Evaluation units will be available in July, to be followed by volume production. Once production begins, the I480 will cost from about $26,000 to $28,000 in single unit quantities. Delivery time is expected to be 12 weeks.

Aspen Peripherals Corp., 1860 Lefthand Cir., Longmont, CO 80501; (303) 678-0808.

CIRCLE 312

Thermal printer produces 64 shades



Combining economy and ease of use, the TP-115 thermal video printer provides high-quality hard copy from both interlaced and non-interlaced monochrome monitors. It prints a minimum of 32 shades of gray with standard paper and up to 64 shades with synthetic paper. The cost per copy is far lower than instant film or dry silver processes. A 6.5-by-8.5-in. print is produced in 40 seconds.

Test & Measurement Systems Inc., 349 Cobalt Way, Suite 301, Sunnyvale, CA 94086; (408) 720-8877. $5350; 30 days.

CIRCLE 314

CIRCLE 103

"SWITCH DC TO HUNDREDS OF MHz IN 8x8 to 64x8 CONFIGURATIONS"

It's easy to switch eight DC to 500Mhz inputs to any of eight outputs with our Model 4108 wide-band coaxial relay matrix shown at the left. This miniaturized matrix is completely self-contained, requiring only TTL control signals and DC power.

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These miniaturized extremely wide-band matrices are perfect for Automatic Test Equipment (ATE) where fast rise time, wide bandwidth data from the unit under test must be connected to any array of test equipment, or in telecommunications where wideband data rates must be connected between modems, transceivers or satellite uplink/downlink terminals.

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No matter what kind of high frequency switching system you're buying, it pays to deal with a company who really understands the business. Matrix does. We've been designing state-of-the-art reed relay and semiconductor switching matrices for over 17 years—to the toughest electrical and packaging specs imaginable. Our customers include government agencies, defense contractors, the TV industry, ATE and telecommunications companies and more. So deal with the leader and be sure.

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CIRCLE 104

COMPUTERS & PERIPHERALS

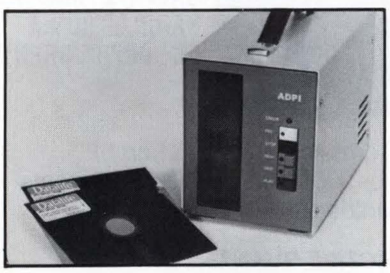
Terminals provide text and graphics

Two color graphic terminals, the MX6000 and MX8000, offer users a choice of either 640-by-480- or 1024-by-780-pixel resolution, respectively, on their 19-in. screens. Both are software-compatible with Tektronix 4107, 4010, and 4014 terminals in the graphics mode, as well as with DEC VT220 and VT100 systems in the alphanumeric mode. Other features include a 132-column text mode, 256,000 color palette, horizontal and vertical pan, and hardware zoom.

Pericom Inc., 51 Digital Dr., Novato, CA 94947; (415) 382-8800. $6995 (MX6000) and $8995 (MS8000).

CIRCLE 315

Data-transfer unit links to IBM PC



The Easi-Disk 5¼-in. floppy-disk drive system provides a means of transferring data between an IBM PC and a noncompatible computer. Suitable for such applications as field data acquisition, the portable unit formats data from the RS-232-C port of a noncompatible system into PC-compatible disk format. It has a storage capacity of 360 kbytes.

Analog & Digital Peripherals Inc., 815 Diana Dr., Troy, OH 45373; (513) 339-2241. $1095.

CIRCLE 316

Page scanner snares written information

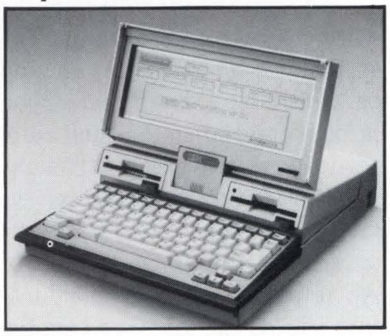
A compact page scanner automatically transfers information from paper into an IBM PC or compatible personal computer. The PC Scan unit comes with Text Pac, a character-recognition software package that allows users to quickly enter text into popular word-processing programs. The system is 4 by 11.5 by 16 in. and can fit under a small disk drive, printer, or terminal. The unit automatically scans one sheet at a time. Pages placed right-side up emerge face down to maintain the correct sequence for multipage documents. An automatic video threshold feature adjusts the scanning contrast to accommodate varying paper colors. The scanner accepts paper weights from 16 to 30 lbs and sizes from 6 by 6 in. to 8½ by 14 in.

DEST Corp. 1201 Cadillac Ct., Milpitas, CA 95035; (408) 946-7100. $1995 (PC Scan); $595 (Text Pac); 30 days.

CIRCLE 317

COMPUTERS & PERIPHERALS

Fledgling PC is portable

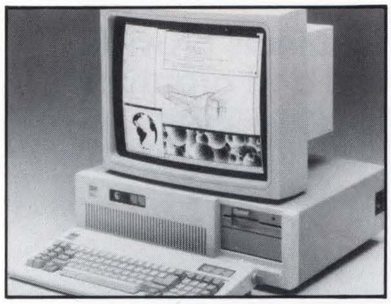


The newest member of the IBM family of personal computers, the portable PC Convertible offers a host of functions for less than $2000. Based on an 80C88 microprocessor, the computer has 256 kbytes of internal memory and dual 3½-in. disk drives, each with a capacity of 720 kbytes. Data is displayed on an 80-column-by-25-line detachable LCD, which may be replaced with a monochrome monitor for desktop use. Also included are a battery pack and an ac adapter, which can run the system while simultaneously recharging the battery pack.

IBM Corp., Entry Systems Division, P.O. Box 1328, Boca Raton, FL 33432; (305) 982-3474. $1995.

CIRCLE 318

Graphic subsystem works with PC



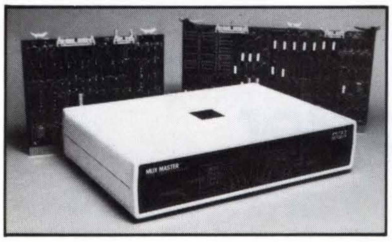
Designed for the IBM family of personal computers, the Viking 1 graphic subsystem enables users to run both high-resolution 1280-by-960-pixel graphics and 128-character-by-60-row text. The system comprises a 19-in. monochrome monitor and controller card that resides in a single expansion slot in the computer. Based on the Hitachi HD63484 advanced CRT controller, the Viking 1 provides high-speed data exchange with the PC bus.

Moniterm Corp., 5740 Green Circle Dr., Minnetonka, MN 55343; (612) 935-4151. $2195.

CIRCLE 319

COMMUNICATIONS

Multiplexer handles up to 128 lines

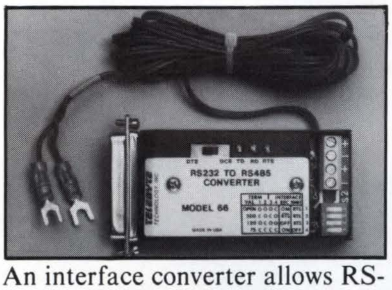


A distributed multiplexer system connects up to 128 users to MicroVAX II, VAX, and PDP-11 computers via a single composite link. Each Muxmaster desktop cluster controller can be configured for 8 or 16 users. Controllers are then connected to the Muxmaster host interface board, which supports up to 128 lines, via a twisted-pair cable. This single cable can extend up to 2000 ft from the host and permits communication at speeds of 1 Mbit/s and terminal data rates to 38.4 kbaud.

Able Computer, 3080 Airway Ave., Costa Mesa, CA 92626; (714) 979-7030. $3000 for the first 16-line cluster system.

CIRCLE 320

Device links RS-232, RS-485

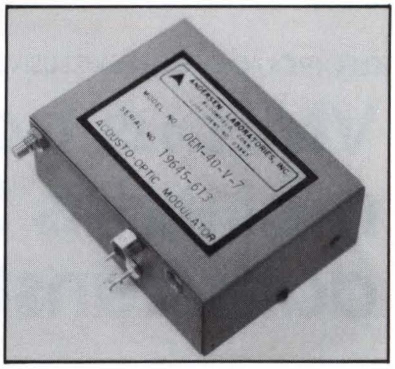


An interface converter allows RS-232-C computers to access a local area network based on the RS-485 interface standard. The Model 66 transfers data at rates of up to 38,400 bits/s over a single twisted-pair wire. Transmission and reception of data to and from the network is programmable using DIP switches and the RS-232 control signals RTS (Request to Send) and CTS (Clear to Send). The unit is supplied with a wall-mounted transformer and 8 ft line cord.

Telebyte Technology Inc., 270 E. Pulaski Rd., Greenlawn, NY 11740; (800) 835-3298 or (516) 423-3232. $91 (100 units); stock.

CIRCLE 321

Laser modulator has 7-MHz bandwidth



A light modulator driver, designated the OEM-40-V-7, combines the features of an acousto-optic modulator cell and its associated rf drive electronics into a single compact package. The unit is 2.7 by 2 by 1 in. and is designed primarily for compact laser systems where space is limited. It has a modulation bandwidth of 7 MHz and can be used to modulate 400-to-700-nm lasers with light power densities of up to 5000 W/cm^2 continuous wave.

Andersen Laboratories Inc., 1280 Blue Hills Ave., Bloomfield, CT 06002; (203) 242-0761.

CIRCLE 322

ELECTRONIC DESIGN EXCLUSIVE

VMEbus board for SCSI maintains 20% to 30% faster data transfer rates

Processing commands at the same time that it transfers data between VMEbus hosts and an SCSI interface, a processor board sustains data throughput rates that are some 20% to 30% higher than those of other intelligent SCSI boards. Plessey's PME SCSI-1 is a double-height Eurocard that deals with up to 16 concurrent tasks and connects to Winchester, floppy, and optical disks, as well as to streaming-tape drives.

The board accepts 32-bit data and addresses. It is controlled by a 68008 processor with 8 kbytes of EPROM for programs and an additional 2 kbytes of scratchpad memory. The 68008 manages the board's 68430 DMA controller, an NCR 5380 SCSI interface chip, and a 2-kbyte 32-bit-wide FIFO that holds data traveling between the VMEbus and SCSI interface. In parallel with the FIFO is a 128-byte dual-port RAM that holds commands from processors on the VMEbus for up to 16 I/O tasks.

A local bus allows the board's processor to get the SCSI chip ready for the next data transfer at the same time that the current data is being shipped out. That means that the board maintains a transfer rate of 1.5 Mbytes/s—the maximum that the SCSI interface will allow. Other cards can only reach this rate briefly; as soon as their on-board memory is exhausted, they must take time out to set up the next data transfer.

To transmit information across Plessey's board, a host simply places a command parameter block (CPB) in the VMEbus' global memory and notifies the processor board. The CPB includes the standard SCSI command block, the base address and length of the data block to be transferred, and the address modifier code. The parameter block also contains one of seven optional interrupt levels and is transferred to the processor board's RAM by the DMA controller.

The same controller serves another purpose, reading the data into the FIFO and transferring it across to the SCSI IC and then on to the mass storage device. When the command is completed, status and SCSI sense information are returned to the CPB in the board's RAM, and the board either generates a software-selectable VMEbus interrupt or is polled by the host.

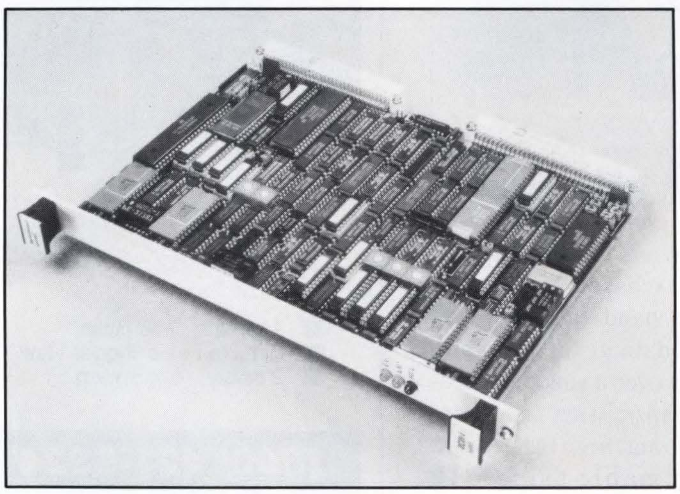
The board consumes roughly 5 A from its 5-V supply. It costs $1660, and full production is expected by June. A lower-cost version, with a 16-bit-wide FIFO, is also planned for later in the year. Unix and Versados drivers are available.

Plessey Microsystems, One Blue Hill Plaza, Pearl River, NY 10965; (914) 735-4661; Twx: (710) 541-1512.

CIRCLE 306

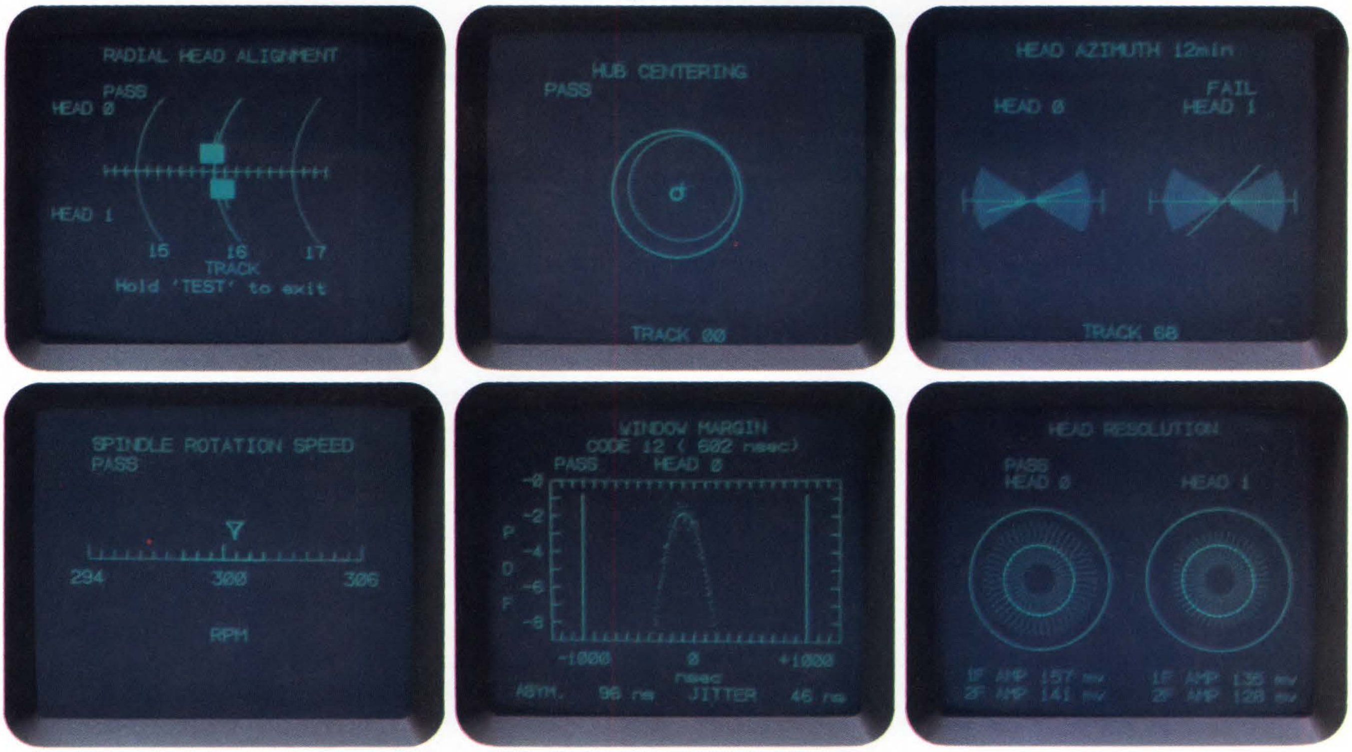
Plessey Microsystems, Wood Burcote Way, Towcester, Northants. NN12 7JN, England; (+44) 327 50312.

CIRCLE 307



Mitch Beedie

THE DJ FLOPPY DISK DRIVE ANALYZER



THE TOUGHEST TEST DRIVE A DISK DRIVE CAN TAKE.

Finally, a disk drive analyzer anyone can use. The new Disk Jockey Floppy Disk Analyzer illustrates a wide range of test results through easy-to-understand, real-time graphics.

Simple enough for novices.

With only three front panel controls to worry about, even relatively untrained operators can run a host of delicate tests: radial head alignment, index pulse timing, rotation speed, and many more. All graphically displayed. All easily set up and quickly implemented.

Versatile enough for demanding engineers.

Though easy-to-use and understand, the Disk Jockey is also highly sophisticated. With the convenient plug-in EEPROM cartridge feature, you can program test sequences and specifications. Engineering displays show amplitudes, timing, lobe ratios, and read/write errors. And with the unique window margin analysis, you can receive invaluable insight into a drive's long term reliability. Finally, punch out a hard copy reference and store your drive parameters and test specifications in memory for fast retrieval. Anytime you need them.

Get the whole picture today.

The tough, innovative new Disk Jockey from Nicolet. Your picture-perfect solution to complex disk drive testing and adjustment. For more information, write Nicolet Oscilloscope Division, 5225 Verona Rd., Madison, WI 53711. Or call 608/273-5008.

Nicolet

FOR MORE INFORMATION CIRCLE 109

Microcontroller cuts design time

An 8051-based microcontroller comes preprogrammed for use as a general-purpose terminal controller. The first device of its kind, MIW's MIW-F-x51 incorporates subroutines for managing a printer, a display, serial I/O, and a keyboard. The chip can cut design time by a factor of five over conventional microcontrollers: A user merely adds his parameters in EPROM or RAM to customize the device to an application. The controller is suited to instrumentation and laboratory equipment, as well as to any setup that does not justify generating a complete, customized program.

The user programs the chip with the standard 8051 instruction set; other software routines are held in 4 kbytes of internal ROM. A table holds the default initialization values that are given to the keyboard, display, and other peripherals. The table can be modified by placing it in user-added RAM. Temporary values (for example the current screen line and column number) are held in registers. A series of flags show the internal state of the controller.

The IC controls a variety of displays, including CRTs (showing a maximum of sixteen 40-character lines), as well as LEDs and LCDs and works with 128-key keyboards. Serial communications (which can be 8 or 9 bits) are passed through two FIFO buffers. An internal printer controller drives a printer with a 7- or 8-dot head, which writes in both directions and creates up to 255 columns per line. The chip also carries an internal 7-by-5 character generator.

In quantities of 1000 or more, the device costs FF.198. An evaluation kit costs FF.1500. The controller comes in HMOS (MIW-F-H5F1) and CHMOS (MIW-F-C51).

MIW SA, 34 rue du General Brunet, 75019 Paris, France; (+33) 1 420 09975.

CIRCLE 308

Analyzer sports 115 state channels

Software switching gives Philips' PM 3570 logic analyzer a total of 115 state channels—a number surpassed only by instruments costing twice as much. The instrument features 83 state analysis channels and 32 timing analysis channels. The latter 100-MHz channels can be reconfigured as state channels. Further, the number of channels can be traded off against speed, allowing the instrument to catch glitches right down to 5 ns (using 8 channels at 400 MHz).

The analyzer works with 16- and 32-bit processors. Its so-called Combi mode allows the state and timing sections to trigger each other, and a time-correlated mode enables the timing analyzer to run synchronously with the state section, simultaneously displaying state and timing data. Also, transitional timing stores changing data; thus the instrument can catch glitches that arrive seconds apart.

The analyzer accepts a maximum input of ± 50 V and has a minimum sensitivity of 250 mV. The data input has a 12-ns setup time, and a 0-ns hold time. To simplify the user's task, settings and data from the last working session are stored in nonvolatile memory.

Another version of the logic analyzer, the PM 3565, is geared to 8-bit microprocessor systems. This version features up to 59 state channels, sixteen of which can serve as 50-MHz timing channels. The timing channels also can be configured as four 300-MHz channels. The 8-bit instrument can be upgraded into the PM 3570. Performance analysis comes as standard on both models. Prices start at roughly Hfl. 25,000.

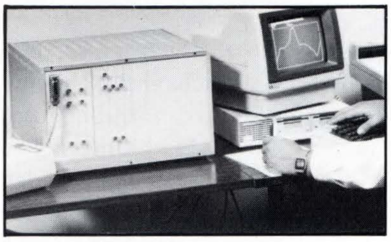
Philips Test and Measurement Department Inc., 85 McKee Dr., Mahwah, NJ 07430; (201) 529-3800.

CIRCLE 309

Philips I&E, P.O. Box 523, 5600 AM Eindhoven, The Netherlands; (+31) 40 757005; Telex: 51573.

CIRCLE 310

Modular DA system has 16,000 inputs



A transient recording and data acquisition system provides up to 16,000 analog or digital input channels. The BE256-400 links to an IBM PC or HP-200-series computer and has channels with 8-, 12-, and 16-bit resolution. Each channel has maximum sampling frequencies between 20 kHz and 1 MHz and a memory size between 8 and 64 kbytes. There is an IEEE-488 link; optional are a 16-bit parallel (TTL-level) port, and a 9.6 kbits/s RS-232 interface. Software for the computers allows both the waveform and mathematical functions to be shown graphically. A variety of triggering options suit transient recording. The system comes rack-mounted or stands alone. A 4-channel system costs between £4000 and £12,000, depending on configuration.

Thorn EMI Datatech Ltd., Spur Rd., Feltham, Mddx. TW14 0TD, England; (+44) 1-890 1477; Telex: 23995.

CIRCLE 323

Resistors have 15-n pull forces

A family of tough surface-mounted 1206-size chip resistors trebles the conventional pull-force from 5 to 15. The DC2 thick-film resistors are rated at 0.2 W at 40°C, derating linearly to 0 W at 125°C. The devices come in a variety of standard resistance ranges: E12, E24, and E48, covering values from 1 Ω to 10 MΩ and with tolerances of ±10%, 5%, 2% and 1% (depending on the range). The resistors work between −55° and 125°C; the resistance element is protected beneath a thick glass coating.

Steatite Group, Hagley House, Hagley Rd., Birmingham B16 8QW, England; (+44) 21-454 6961.

CIRCLE 324

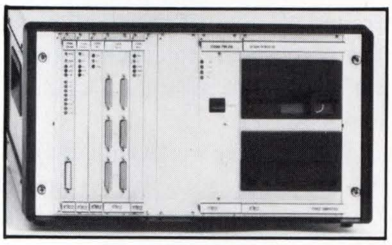
System heeds 500 voice orders

A voice-recognition system for the IBM PC or AT accepts complete sentences and does not need long pauses between words or commands. The system recognizes some 500 commands; it consists of an IBM card, menu-driven software, and a microphone. Combined with a voice response system, it allows an operator to work the computer remotely, neither needing to touch the keyboard nor look at the screen. The voice recognition processing is done using the PC's microprocessor in a time-share architecture. The microprocessor converts the recognized words into keystrokes, as if they were entered through the keyboard. To train the system to a particular voice, the user speaks words and commands and enters the corresponding series of keystrokes. Each series may represent 10 or more keystrokes. The system costs between $1000 and $3000, depending largely on the application software that is needed.

Comsys International BV., Winthontlaan 4, 3526 KV Utrecht, The Netherlands; (+31) 30-89 19 81; Telex: 70461.

CIRCLE 325

Development system runs under P-DOS



A multiuser VMEbus development system uses the P-DOS real-time operating system with a flexible real-time kernel. Besides software development, the miniFORCE 2 system suits real-time process control, signal processing, and factory automation. The system has a processor board with a 68000 processor running at 10, 12.5, or 16.7 MHz and has between two and seven multi-protocol RS-232 lines with speeds of up to 19.2 kbits/s. Main memory stretches from 512 kbytes to 2 Mbytes. A Winchester provides 25 or 51 Mbytes and a 5.25-in. floppy disk provides 1 Mbyte. The card cages have up to six free slots. Depending on the configuration, prices range from DM 25,000 to DM 30,000.

Force Computers Inc., 727 University Ave., Los Gatos CA 95030; (408) 354-3410; Telex: 172465.

CIRCLE 326

Force Computers GmbH, Daimlerstrasse 9, D-8012 Ottobrunn, West Germany; (+49) 89 600910; Telex: 524 190 FORC-D.

CIRCLE 327

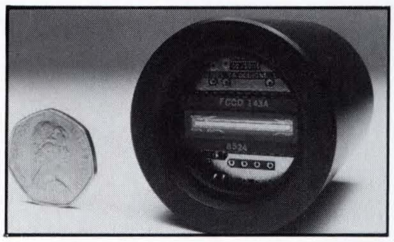
2.5-V reference works at 60 μA

Working with currents right down to 60 μA, a voltage-reference IC's nominal 2.5-V output is accurate to within ±2%. The internally compensated REF25Z requires a single resistor for operation from a dc supply. The temperature coefficient is typically 35 ppm/°C for temperatures between 0° and 70°C. The device comes in a TO-92 plastic or TO-18 metal can. The low operating current suits the IC for battery-operated equipment.

Ferranti Electronics Ltd., Fields New Rd., Chadderton, Oldham, Lancs. OL9 8NP, England; (+44) 61 624 0515.

CIRCLE 328

CCD camera works at up to 20 MHz

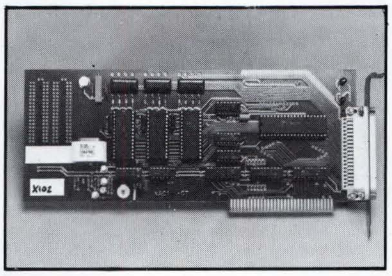


Resolutions of 512, 1024 and 2048 elements per line can be achieved with a range of line-scan CCD cameras. The Ca-1 camera is compatible with the Fairchild CCD1000 series and suits process control and robotics systems. Balanced differential clock and scan signals allow individually screened twisted pair cores to be used at distances of up to 150 m. Internal regulators and filters provide noise immunity for the bias-voltage inputs, while separate force and sense lines allow the supply voltages and ground potentials to be controlled at the end of long cables. Two TDM analog video outputs, together with the supply, timing, and control signals are available from a 25-way Canon 'D' connector. The camera operates from +5 and +15-V dc supplies. Together with a Series-800 processor, a 24-line 80-column display, and a miniature printer, the camera forms a complete computer imaging system for under £3,000.

T.A. Designs Ltd., Station Rd., Industrial Estate, Maiden Newton, Dorset DT2 0AE, England; (+44) 300-20719,

CIRCLE 329

I/O card handles a-d conversions



A multifunction IBM PC card offers twelve, 12-bit analog-input and 24 digital I/O channels. The three 8-bit digital I/O ports are programmable as either inputs or outputs, with one of them generating strobe and handshaking. The 12 analog-to-digital channels work between 0 and 5 V and can all be driven simultaneously. A clock and calendar can count tenths of seconds and also track leap years; the battery-backed clock can generate interrupts, thus performing real-time control. Industrial signals can be interfaced and buffered by using a patch area on the card. A 37-way "D" interface socket is standard.

Xcalibur Computers Ltd., Spencer House, 3 Spencer Parade, Northampton NN1 5AB, England; (+44) 604-21051/4; Telex: 31612.

CIRCLE 330

8-bit ADC has flexible interfacing

An 8-bit analog-to-digital converter reads and puts out data in either serial or parallel form for easy interfacing to 8-bit buses. The U 3009 M successive-approximation converter has a typical clock frequency of 100 kHz. It has a 4-channel input multiplexer, sample-and-hold circuits, and an 8-bit output register. The converter accepts analog voltages up to 5 V, and gives outputs with one of three accuracies: ±0.4%, ±0.8%, and ±1.6%. The differential linearity is ±0.2%, and the integral linearity is below 0.3%. The IC comes in a 28-pin plastic DIP.

Telefunken Electronic GmbH, Obere Kanalstr. 24, D-8500 Nurnberg 80, West Germany; (+49) 7131 88 22 30.

CIRCLE 331

FET probe covers 100 kHz to 1.25 GHz

The 2388 FET active probe eliminates the voltage dividers that normally clip onto spectrum analyzers to vary attenuation. The probe works between frequencies of 100 kHz and 1.25 GHz and incorporates a rotating barrel attenuator with a micrometer-type scale that can vary attenuation levels over 40 dB. In addition to spectrum analyzers, the probe connects to rf test equipment such as modulation and frequency meters and radio test sets. The unit's power can be supplied from the front panel of the host instrument or from an optional power supply.

Marconi Instruments Ltd., Longacres, St. Albans, Herts. AL4 0JN, England; (+44) 727 59292; Telex: 297221.

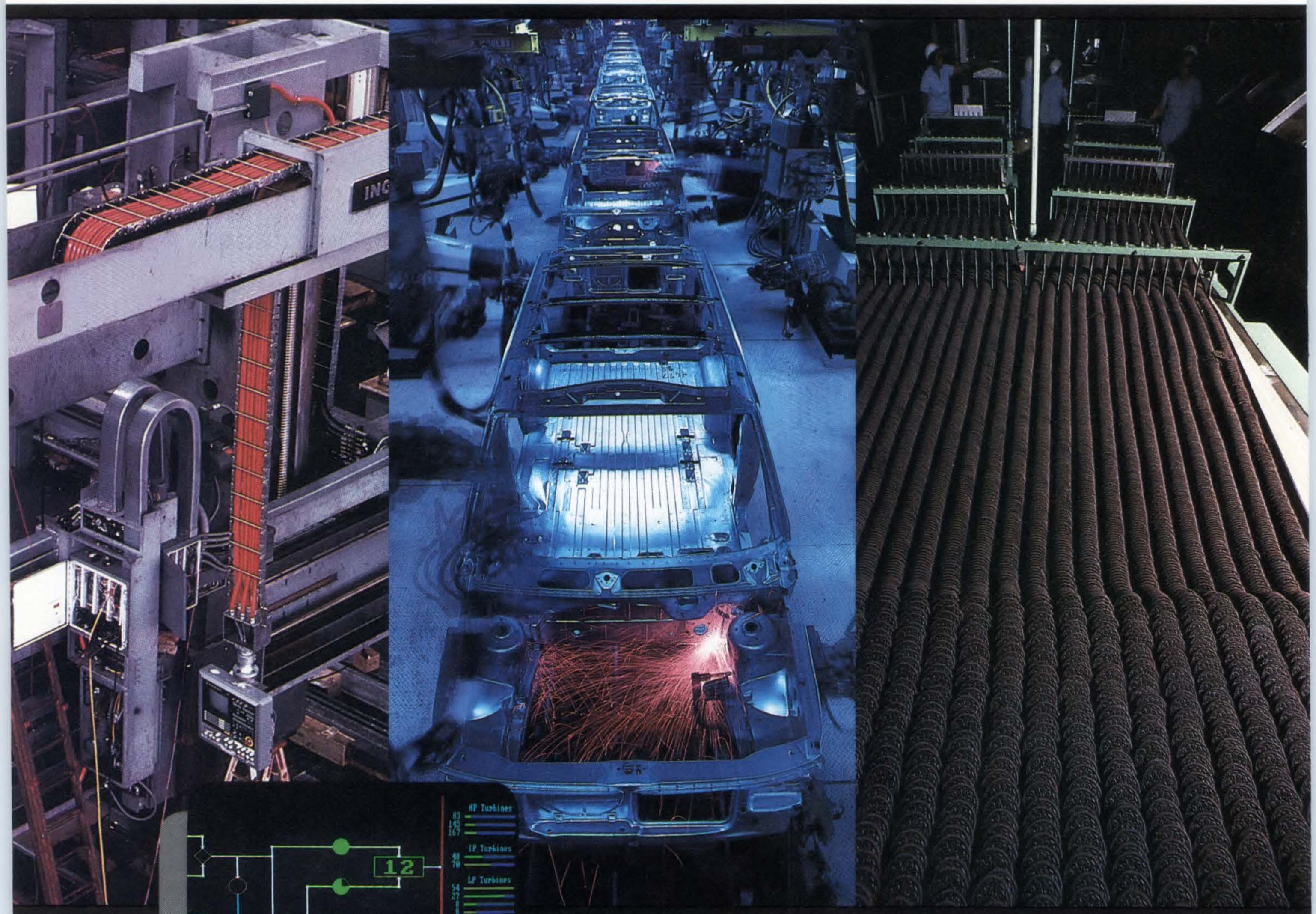
CIRCLE 332

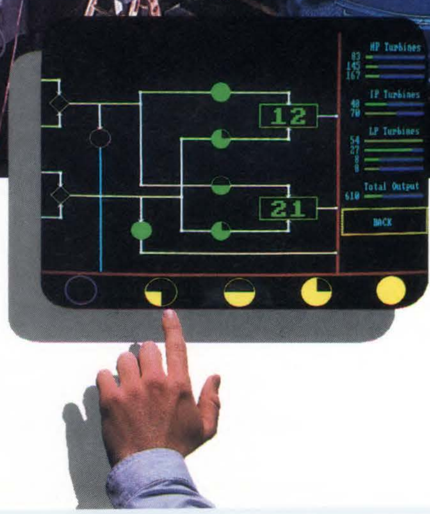
Solutions you can touch

When Foxboro, Taylor Instrument, Honeywell, and Abbott Laboratories had special requirements for their instrumentation products, they came to Carroll Touch for a solution.

Carroll Touch offers a line of low-cost infrared touch systems that makes user interaction easier, faster, and more accurate than ever. Providing exceptional functionality, these rugged and reliable add-in units are highly suitable for a variety of environments, from factory floors to sterile laboratories.

Join the growing number of companies that have discovered the advantages of Carroll Touch's Smart-Frame™ line and special custom units. You'll see why Carroll Touch is the company with the solutions you can touch.





CIRCLE 112

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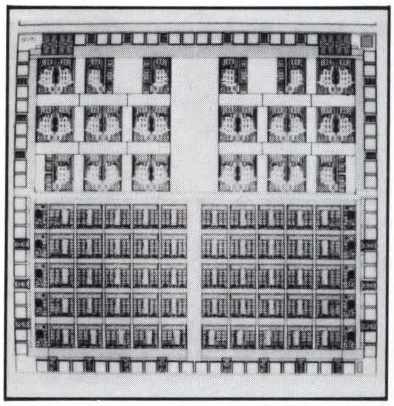
NEW PRODUCTS

ANALOG

ELECTRONIC DESIGN EXCLUSIVE

6-GHz analog transistors team up with ECL on array



A blisteringly fast bipolar array, about equally divided between 6-GHz analog transistors and ECL components, simplifies the design, boosts the speed, and cuts the size of wide-bandwidth, mixed analog-digital systems. QuickChip 4, built by Tektronix, is an extension of the arrays originally developed to build most of the circuitry for the company's 1-GHz real-time oscilloscopes (ELECTRONIC DESIGN, June 13, 1985, p. 86 and p. 180).

The analog (upper) portion of the array contains 30 cells arranged in the tile configuration that now dominates among bipolar analog arrays. The digital (lower) portion of the device is an ECL gate array with 300 equivalent gates.

Each of the tiles located in the upper section of the chip are identical both to one another and to the cell's used on the earlier arrays. The latter means that they can use the same macrocircuits employed in earlier designs. Each cell contains nine npn-type transistors. The npn devices combine an f_t of 6 GHz with a current gain of 50. Moreover, their breakdown voltage, BV_{CBO}, is over 15 V, and collector-to-substrate breakdown is even higher: At 32 V it is as much as twice that of transistors found on most high-speed ICs. And to top it off, the transistors can handle 30 mA. Thus they can easily build amplifiers with a bandwidth of dc to 1 GHz that are capable of putting at least 10 V across a 500-Ω resistor.

The pnp transistors have an f_t of 50 MHz and a beta of 50, nicely complementing their npn counterparts. The upper half of the array also contains zener diodes and ion-implanted resistors, ratio-matched to within 0.05%.

The ECL gate array contains smaller but equally fast npn transistors. Propagation delays through the gates run about 350 ns and D-type flip-flops built with the array toggle at 500 MHz. The speed of both sections is enhanced by the use of gold rather than aluminum, dual metal interconnects.

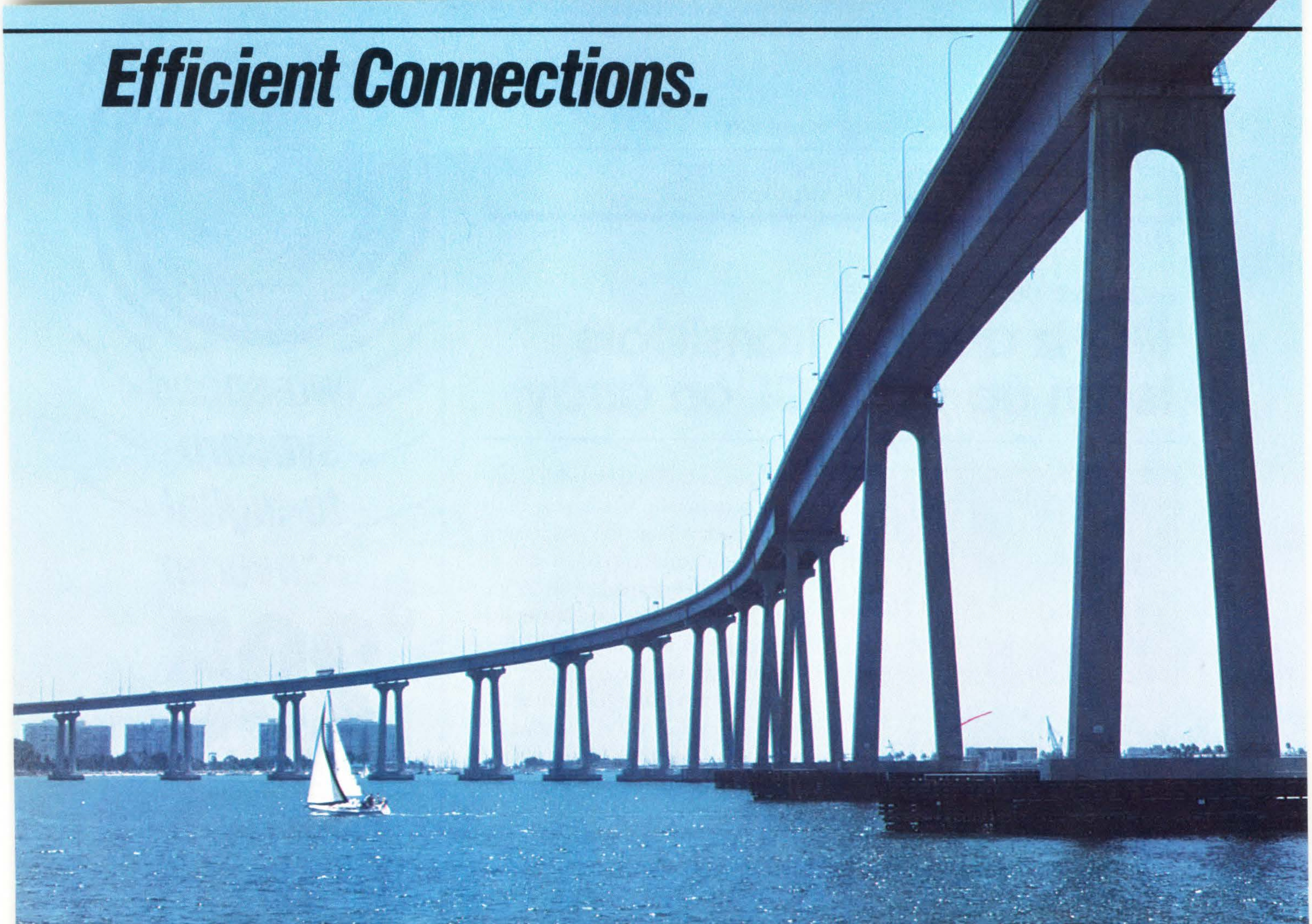
Turnaround time for the IC, once a design is approved by a customer, is as short as three weeks. Prototype wafers, or packaged parts, are priced at $26,000, plus a nonrecurring engineering charge of $25,000 to $30,000, including simulation software.

Tektronix Integrated Circuits Operation, Marketing Department, P.O. Box 500, Delivery Station 59-420, Beaverton, OR 97077; (503) 627-2515.

CIRCLE 302

Frank Goodenough

Efficient Connections.



Cost Driven Connectors. Low cost reliability.

Viking introduces the simple, complete answer to the problem of low cost reliability in card edge connectors: a combination cantilever beam contact and thermoplastic insulator. We've designed an entire line of card edge connectors around this concept and automated its production. Then named it *Cost-Driven*. For obvious reasons.

This simple design brings prices down, yet retains the uncompromising quality for which Viking is known. This kind of reliability has resulted in accreditation, ship-to-stock, and Just-In-Time programs with major companies.

These connectors are preloaded to provide a minimum of 100 grams of normal force per contact, assuring reliable connections in worst case conditions. The bifurcated contacts provide added assurance through redundancy. And the connectors are U.L. listed, not merely "material approved".

Standard dimensions make them interchangeable with most connectors on similar grid spacings. And they're available in a variety of mounting styles.

For the IBM PC AT™ motherboard and compatible products, here's the simple, complete way to eliminate the need for two end-to-end connectors: Viking's 18 plus 31 position dual card slot connector. It reduces installation costs. Reduces material costs. And it can be packaged for automatic assembly.

Get complete details on Viking's "CD" connectors, along with specifications and prices.

Call or write today.

Efficient Connections With Viking

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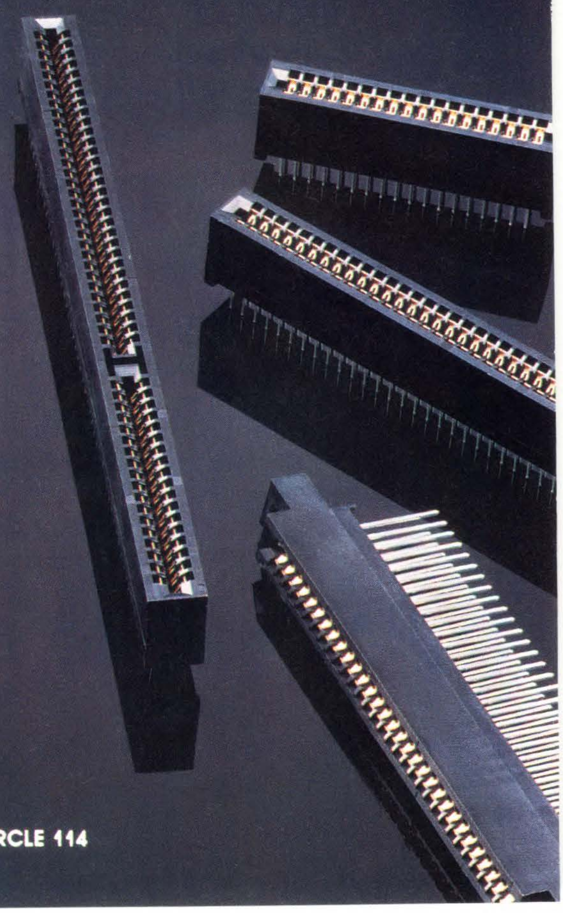
Electronics and
Defense Group
Viking Connectors Co.
21001 Nordhoff Street
P.O. Box 2379
Chatsworth, CA 91311
(818) 341-4330
TWX: 910-494-2094



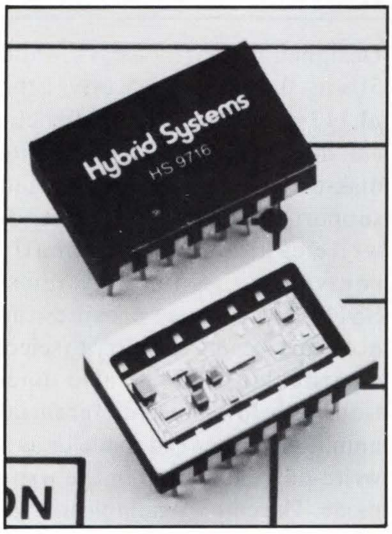
PC AT is a registered trademark of IBM.

CIRCLE 114

ANALOG

ELECTRONIC DESIGN EXCLUSIVE

16-bit sampling amplifier tucks into 14-pin DIP



For the first time, a small hybrid sample-and-hold amplifier is accurate to 16 bits. In fact, Hybrid Systems' HS9716 packs a number of firsts into a 14-pin ceramic DIP. The most impressive is its compensation for errors caused by the dielectric absorption of its internal NPO ceramic capacitor. For a 10-μs sampling time, the maximum error caused by dielectric absorption is just 0.00075%, or a maximum of 150 μV for a 20-V change in signal ($^1/_2$ LSB at 16 bits). The significance of that error level becomes apparent when it is realized that the best capacitors—bulky, expensive Teflon units—exhibit dielectric-absorption errors as great as 0.01% for 10-μs sampling times.

And the device is just as quick as it is accurate, grabbing a 20-V signal to an accuracy of within $\pm$0.0008% in a maximum of 10 μs (over temperature). Further, if the user only needs 14-bit accuracy, acquisition time is cut in half.

Droop rate, even with the hybrid's chip capacitor, is a maximum of 0.05 μV/μs at 25°C. At 125°C, it is only 10 μV/μs, permitting a military-grade device to operate with 16-bit accuracy at 125°C.

When the amplifier is sampling or tracking, the noise in the band between dc and 1 MHz is just 20 μV rms. In hold, feedthrough rejection is a minimum of 96 dB for a 20-V pk-pk signal at 20 kHz, and it only drops 6 dB at 200 kHz.

Aperture uncertainty is typically just 100 ps, better than many 12-bit sample-and-hold devices. The uncertainty allows 16-bit accurate snagging of signals slewing at 1 V/μs. The small-signal bandwidth when tracking is 1 MHz minimum, and the slew rate and its attendant full-power bandwidth are typically 10 V/μs and 200 kHz, respectively.

The commercial and military devices need only 500 mW maximum from a $\pm$15-V power supply. In quantities of 100, the unit price of the commercial and military HS9716 are $79 and $150, respectively. Small quantities are available from stock.

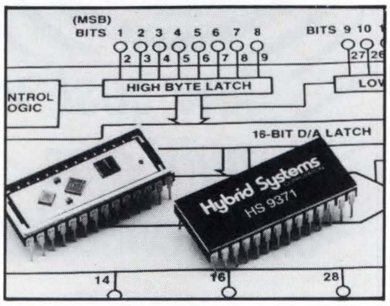
Hybrid Systems Corp., 22 Linnell Cir., Billerica, MA 01821; Dennis Buchenholz, (617) 667-8700.

CIRCLE 305

Frank Goodenough

ANALOG

D-a converter has 16-bit monotonicity

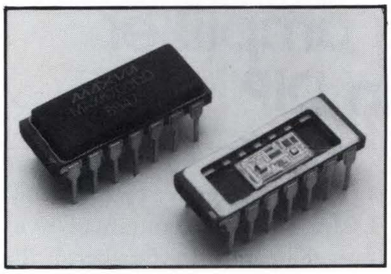


The HS9371, a current-output multiplying digital-to-analog converter, offers monotonicity to 16 bits over the commercial and military temperature ranges. What's more, it does so while dissipating only 45 mW when driven with CMOS input levels. Integral nonlinearity is ±0.003% maximum over temperature, while differential nonlinearity is ±0.0015%. The converter has dual 8-bit input registers for direct interface with 8- or 16-bit bus structures. It comes in a 28-pin double DIP.

Hybrid Systems Corp., 22 Linnell Cr., Billerica, MA 01821; (617) 667-8700. $65 (commercial) and $150 (military) in lots of 100.

CIRCLE 333

References have Kelvin connections



The use of Kelvin connections on both the output and ground give two 10-V reference sources excellent load and line regulation, independent of the line impedance between the voltage reference output and ground. Each part has a maximum line regulation of 50 μV/V, load regulation of better than 10 μV/mA, and a typical noise specification of 12 μV pk-pk over the 0.1-to-10-Hz bandwidth. Long-term stability is typically 50 ppm/1000 hours. The MAX671 has a guaranteed maximum output voltage drift of 1 ppm/°C with an initial output accuracy of 1 mV. The MAX670 guarantees 3 ppm/°C with 2.5 mV initial accuracy.

Maxim Integrated Products, 510 N. Pastoria Ave., Sunnyvale, CA 94086; (408) 737-7600. From $33.84 (MAX670) and $39.80 (MAX671) in lots of 100.

CIRCLE 334

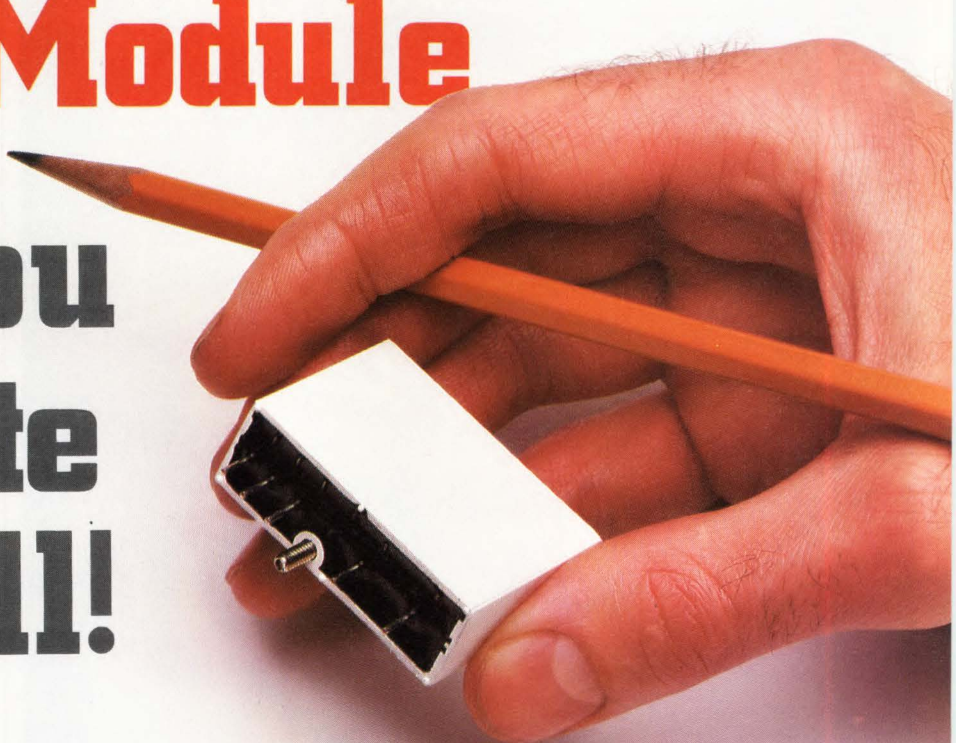
Read-write IC handles 6 channels

Designed primarily for 3½- and 5¼-in. Winchester disk drives, the μL117 read-write preamplifier circuit directly connects to the ferrite disk-drive heads of the drive and supports up to six separate read-write channels. Functionally equivalent to Silicon Systems' SSI117, the device provides the necessary analog circuitry to select a particular head and also functions as a low-noise differential amplifier in the read mode or as a write-current switch in the write mode. The chip is available in a variety of optional packages, including a 24-pin slim-outline configuration.

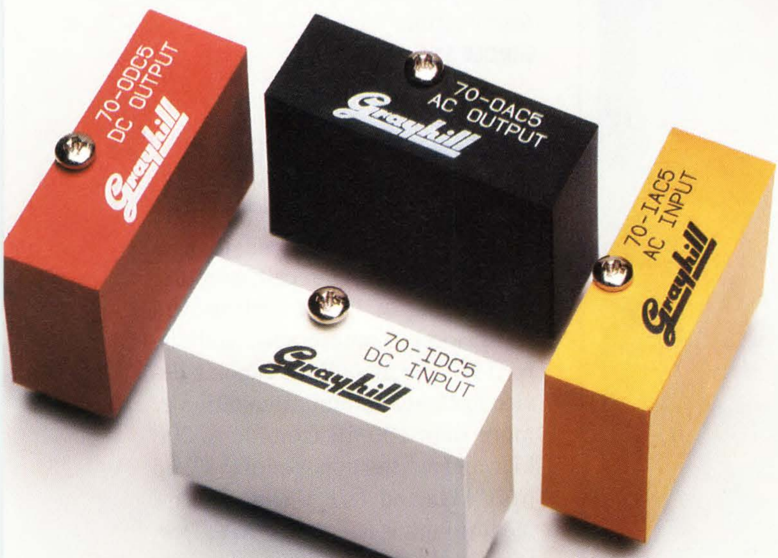
Micro Linear Corp., 2092 Concourse Dr., San Jose, CA 95131; (408) 262-5200. $5.65 (1000 units).

CIRCLE 335

Don't buy any I/O Module



until you evaluate Grayhill!



You'll find outstanding specs, performance, pricing and availability in these new I/O Modules . . . from Grayhill or your local Grayhill distributor, in all standard configurations. All are compatible with 5, 15 or 24V logic circuits.

AC output	120V or 240V	black case
DC output	3V to 60V	red case
AC input	120V or 240V	yellow case
DC input	3V to 32V	white case

Prove it to yourself . . . ask us for free literature with complete product specifications and prices.

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TWX: 910-683-1850 FAX: (312) 354-2820

CIRCLE 117

NEW PRODUCTS

ANALOG

Video DACs are TTL-compatible

Two hybrid d-a converters operate from a single 5-V power supply and feature TTL-compatibility for use in raster-scan graphics systems. The HDG-0407 and HDG-0807 feature update rates of 50 MHz and maximum settling times of 12 and 18 ns, respectively. The parts differ in gray-scale resolution. The HDG-0407 accepts 4 bits of digital input, while the HDG-0807 accepts 8 bits. Those inputs yield 16 and 256 levels of gray and a nonlinearity of 3.2% and 0.2% of gray scale, respectively. The devices have an analog output impedance of 75 Ω and a full-scale output current of 17 mA.

Analog Devices Inc., Computer Labs Division, 7910 Triad Center Dr., Greensboro, NC 27409; (919) 668-9511. In lots of 100, prices start at $35 (0407) and $43 (0807); small quantities are from stock to four weeks.

CIRCLE 336

Attenuator handles agc tasks

A voltage-controlled attenuator uses a supermatched gain cell structure (consisting of 144 interdigitated transistors) to reduce noise and distortion. The monolithic bipolar device has a maximum attenuation of more than 100 dB from dc to 200 kHz and a distortion spec of 0.1% up to 20 kHz and 7.75 V rms. Control feedthrough is less than 5 mV. Designated the MTA 1537A, it comes in a 14-pin DIP.

VCA Associates, 7131 Owensmouth St., Suite B-87, Canoga Park, CA 91303; (818) 704-9202. $4.50 (1000 units).

CIRCLE 337

Introducing the LH Research LM Series: a line of fully regulated, 250 to 600 watt, convection cooled switchers.

Simon says: *"Call my guardian angel Lillian for price quotations on larger quantity orders."*

21 models, 1 to 4 outputs, up to 28V, up to 100 amps.
LH is its own distributor—2 day shipment. 2 year guarantee.

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For price, delivery, and order placement call toll free: 1-800- LH SALES

UL recognized/CSA certified for easier system certification.

Little-MITE® Switching Regulated Power Supplies

MODEL NUMBER	WATTS OUT	OUTPUTS*				CASE SIZE	QUANTITY PRICING			
		MAIN	2	3	4		1-9	10-49	50-99	100
		VDC/AMPS	VDC/AMPS	VDC/AMPS	VDC/AMPS					
LM11-1	250	5 @ 50				1	**$420**	**$390**	**$370**	**$345**
LM11-2	250	12 @ 21				1	**420**	**390**	**370**	**345**
LM11-3	250	15 @ 17				1	**420**	**390**	**370**	**345**
LM11-5	250	24 @ 11				1	**420**	**390**	**370**	**345**
LM11-6	250	28 @ 9				1	**420**	**390**	**370**	**345**
LMX22-12	300	5 @ 50	12 @ 9			2	**520**	**480**	**455**	**430**
LM23-122	300	5 @ 50	12 @ 5	12 @ 5		2	**550**	**510**	**480**	**455**
LM24-1221	300	5 @ 50	12 @ 5	12 @ 5	5 @ 1.5	2	**580**	**535**	**510**	**480**
LM24-1122	300	5 @ 50	5 @ 5	12 @ 5	12 @ 1.5	2	**580**	**535**	**510**	**480**
LM24-1331	300	5 @ 50	15 @ 4	15 @ 4	5 @ 1.5	2	**580**	**535**	**510**	**480**
LMX33-122	350	5 @ 50	12 @ 10	12 @ 9		3	**620**	**575**	**540**	**510**
LM34-1221	350	5 @ 50	12 @ 10	12 @ 5	5 @ 5	3	**650**	**600**	**570**	**535**
LM34-1522	350	5 @ 50	24 @ 5	12 @ 5	12 @ 5	3	**650**	**600**	**570**	**535**
LM34-1331	350	5 @ 50	15 @ 8	15 @ 4	5 @ 5	3	**650**	**600**	**570**	**535**
LM41-1	500	5 @ 100				3	**625**	**580**	**550**	**515**
LM41-2	500	12 @ 42				3	**625**	**580**	**550**	**515**
LM41-3	500	15 @ 34				3	**625**	**580**	**550**	**515**
LM41-5	500	24 @ 22				3	**625**	**580**	**550**	**515**
LM41-6	500	28 @ 18				3	**625**	**580**	**550**	**515**
LM54-1221	600	5 @ 100	12 @ 10	12 @ 5	5 @ 10	4	**815**	**755**	**715**	**670**
LM54-1212	600	5 @ 100	12 @ 10	5 @ 5	12 @ 10	4	**815**	**755**	**715**	**670**

CAUTION: Total loading of all outputs not to exceed rated output power.

Prices subject to change without notice.

*Many additional standard voltage/current output combinations are available; refer to 1985 General Catalog or contact factory.

Ordering Information (Typical part number encoded)

LM 2 3 – 1 2Y2 / 1 1 5

Series — LM
Model* — 23
Output V1 (table 1) — 1
Output V2 (table 1) — 2
Output V3 (table 1) — Y2
Output V4 (table 1)
Input Voltage (115 or 230VAC) — 115

OPTIONS Dual input voltage: use 115-230.
OVP for auxiliary output: add letter Y after auxiliary output voltage code.

*Last Digit = number of outputs.

Table 1	
0 = 2VDC	4 = 18VDC
1 = 5VDC	5 = 24VDC
2 = 12VDC	6 = 28VDC
3 = 15VDC	8 = 48VDC

Options for LM Series

DELIVERY
Most LM Series switching power supplies with selected options are shipped within 48 hours after placement of your order. Units with optional dual 115/230VAC input require 3-4 weeks.

OPTIONS	QUANTITY 1*
Dual 115/230V input	$16.00
OVP (not available for outputs rated at 1.5A)	
1 auxiliary output	22.00
2 auxiliary outputs	44.00
3 auxiliary outputs	66.00

*For multiple unit pricing, contact factory.

Product Specifications

OUTPUT POWER
250 to 600 Watts maximum.

OUTPUT VOLTAGES
2, 5, 12, 15, 18, 24, 28VDC. 48VDC available on some models; contact factory.

OUTPUT CURRENT
See specific model.

NUMBER OF OUTPUTS
1 to 4.

COOLING
Convection.

INPUT VOLTAGE
92-130VAC or 184-260VAC, 47-440Hz.

HOLD-UP TIME
20msec in regulation minimum, after removal of nominal AC input.

LINE REGULATION
0.4% over entire input range for all outputs.

LOAD REGULATION
0.4% from no load to full load for all outputs, except 1.5A outputs are 1.5% or 70mV, whichever is greater.

INTERACTION (CROSS REGULATION)
0.1% maximum.

PARD (RIPPLE & NOISE)
1%p-p or 50mV, whichever is higher.

EFFICIENCY
Up to 80%; 70% typical.

POWER FAIL DETECTION
Upon removal of AC, the power fail signal drops to logic zero at least 2msec before loss of DC output. Upon AC turn-on, signal remains low until outputs are in regulation.

OVERVOLTAGE PROTECTION
Standard on V1. Factory set for 125% ± 5%. Optional on all auxiliary outputs except 1.5A.

CURRENT LIMIT
All outputs have current limiting.

REVERSE VOLTAGE PROTECTION
To 100% of rated current for main output.

OVERTEMPERATURE PROTECTION
Internal thermal switch turns off power supply if overheating occurs.

OVERSHOOT & UNDERSHOOT
2% maximum deviation with a load change of 25% at 5A/μsec. No overshoot or undershoot during AC turn-on or turn-off.

RESPONSE TIME
200μsec to within 1% after a 25% load change at 5A/μsec.

TEMPERATURE COEFFICIENT
±0.02%/°C from 0°C to 50°C after half hour warm-up.

OPERATING TEMPERATURE
0°C to 70°C, full power to 40°C. Derates linearly to 50% power at 70°C.

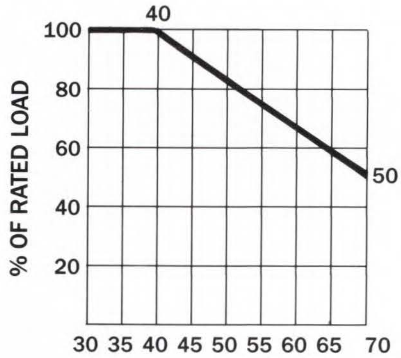
STORAGE TEMPERATURE
−55°C to 85°C.

VOLTAGE ADJUST RANGE
±5% minimum, all outputs.

MINIMUM LOAD
Zero for single ouput models. 10% required on V1 of multiple output models to insure regulation of auxiliary outputs. Contact factory for minimum load if main output is other than 5V. Lack of minimum load will not damage supply.

OUTPUT POLARITY
All outputs are floating and may be referenced to each other or chassis ground as required. Outputs may be isolated up to 100 volts from chassis ground.

POWER DERATING CURVE



T_A—AMBIENT TEMPERATURE—°C

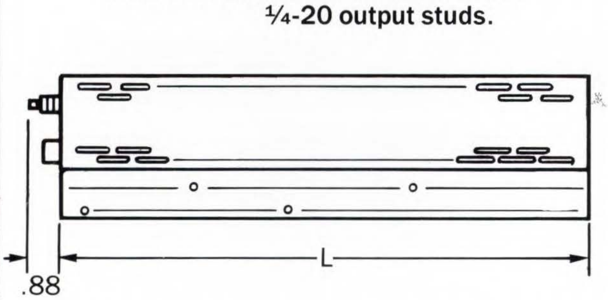
LIMITED INRUSH CURRENT
The AC input inrush current is limited to 42A rms when averaged over one cycle.

REMOTE SENSE
Standard on main outputs and auxiliary outputs having 5V current rating of 10A or greater. Compensates for up to 250mV of total lead cable loss. All outputs are internally sensed if the sense leads are opened.

REMOTE ON/OFF
The power supply is turned on with open circuit or TTL logic '1' and turned off by switch closure or TTL logic '0'.

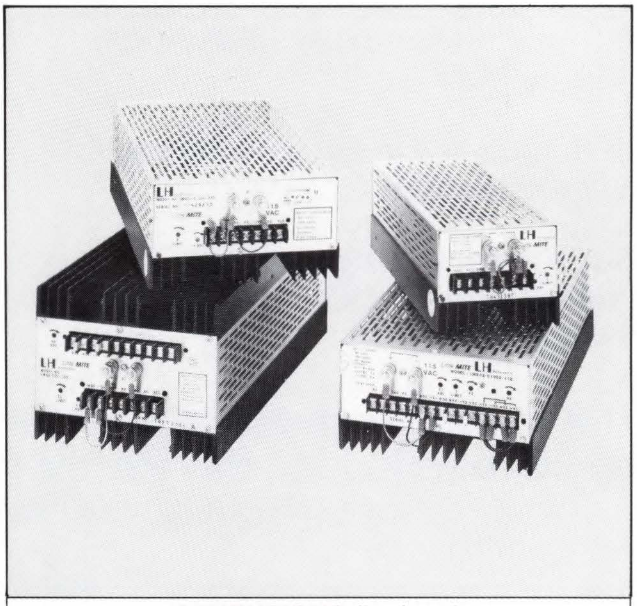
SAFETY
UL recognized. CSA certified.

OPTIONS
OVP on most auxiliary outputs.
Dual 115-230VAC inputs.



CONNECTOR: 6-32 terminal screws.
¼-20 output studs.

Note: Overall exterior dimensions may be increased by up to 0.194″ maximum on some models due to possible protrusion of hardware.



DIMENSIONS (in./cm.)

Case Size	L	W	H
1	11.25/28.58	5.00/12.70	4.00/10.16
2	11.25/28.58	5.00/12.70	6.45/16.38
3	15.03/38.18	7.50/19.05	4.12/10.46
4	15.00/38.10	7.50/19.05	6.00/15.24

LH Research is its own distributor. Simon says: *"My guardian angels will watch over your LM orders to make sure that we make 2 day shipment."*

Nine major product lines.

Standard models 10 to 1500 watts, 1 to 9 outputs.

Seven factories in three countries on two continents.

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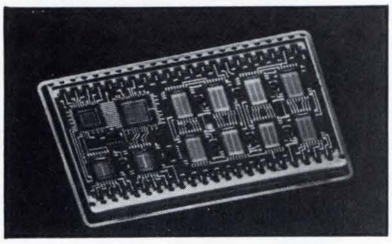
NEW PRODUCTS

DIGITAL ICs

Interface IC links to 1553B bus



Easily coupled to microprocessor-based systems, a CMOS hybrid IC creates an interface between a MIL-STD-1553B protocol hybrid and the host microprocessor. The CT1800 has a double-buffered register and internal memory to handle all read-write data without imposing critical timing constraints on the microprocessor subsystem. Designed for operation over the full military temperature range, the 5-V device typically draws only 100 mA when active and 50 mA on standby.

Circuit Technology Inc., 160 Smith St., Farmingdale, NY 11735; (516) 293-8686. $1250; RAMless versions cost $1150.

CIRCLE 338

CMOS DSP chip consumes 120 mW

A single-chip CMOS digital signal processor can replace complex pc boards in a variety of environments and applications where low power consumption is important. Designated the M77C20, the device was jointly developed by Oki and NEC. While functionally compatible with

NEC's μPD7720 NMOS processor, the CMOS device consumes 85% less power. Typical power consumption for the M77C20 is only 120 mW when running at an 8-MHz clock rate. The part is available in a 28-pin plastic DIP and 44-pin plastic leaded chip carrier.

Oki Semiconductor, 650 N. Mary Ave., Sunnyvale, CA 94086; (408) 720-1900. $25 (100 units); minimum order is 2500 units.

CIRCLE 339

Get a calculator that has no equal.

Get an HP-41.

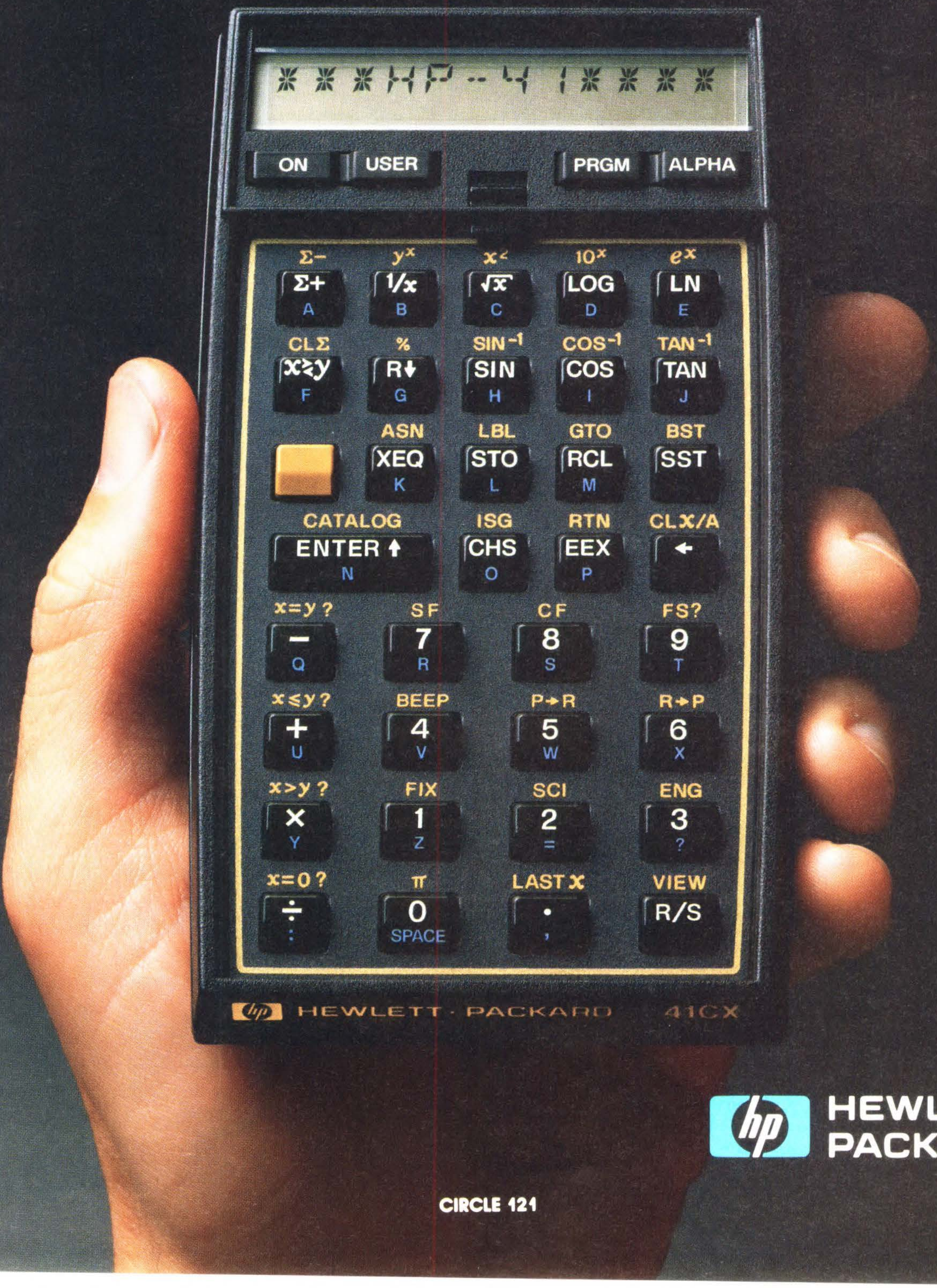
So advanced, it doesn't need an "equals" key. So extremely simple to use, you'll be quickly solving the most difficult electronic design and analysis problems.

The HP-41 has over 2,500 software programs to choose from. More than any other calculator. Also available are plug-in application pacs. They allow you to easily handle things like complex number operations, network analysis and fourier series. And four ports give you the ability to add a variety of enhancements and peripherals like additional memory, printers and mass storage devices.

The HP-41's quality also has no equal. That's something you can see. Even feel. Right down to the touch of the keys. They're designed to prevent double entry. So you won't enter more than one number at a time.

And there are two HP-41s to choose from. The HP-41CV or the extended capabilities of the HP-41CX.

So call (800) FOR-HPPC toll-free. Ask for Dept. 232K. We'll instantly give you the name of a calculator dealer who has no equal.



HEWLETT PACKARD

PG 12508

CIRCLE 121

DIGITAL ICs

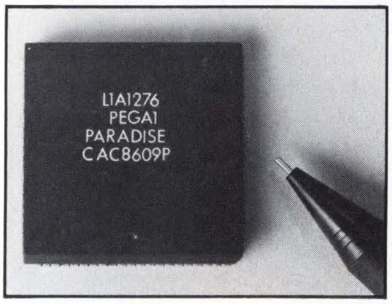
Dual-port RAMs hold 64k, 128k

Two dual-port static RAM modules offer densities of 64 and 128 kbits, among the highest of any dual-port memory device currently available. The IDT7M134 (8k by 8 bits) and the IDT7M135 (16k by 8 bits) incorporate four or eight 2k-by-8-bit monolithic RAMs in leadless chip carriers, assembled on a 600-mil–wide, 58-pin dual-inline ceramic substrate. The CMOS devices are available with commercial and military access times of 100, 120, and 140 ns. Power consumption for the IDT7M134 is 2.1 W, while the IDT7M135 requires 3.5 W. Standby power is 650 mW and 1300 mW, respectively.

Integrated Device Technology In., 3236 Scott Blvd., Santa Clara, CA 95054; (408) 727-6116. From $234 (7M134) and $468 (7M135); stock.

CIRCLE 340

Video chip supports IBM EGA

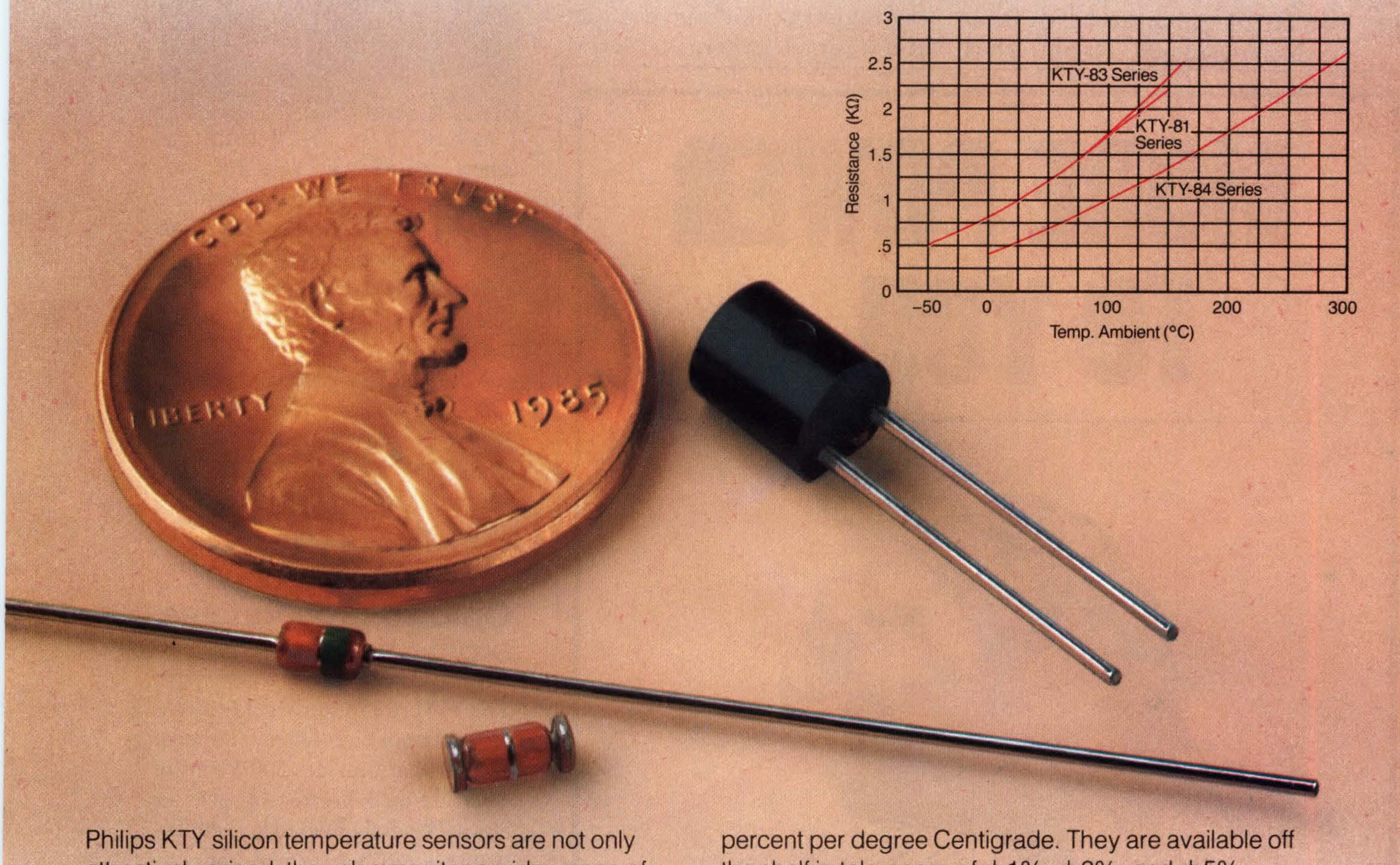


A single-chip implementation of the IBM Enhanced Graphics Adapter (EGA) allows OEMs to cost effectively provide a full range of video display options. In addition to the EGA standard, the PEGA-1 video controller supports software written for the earlier IBM monochrome and color graphics standards, MDA and CGA, respectively. It is also compatible with other non-IBM display standards such as Hercules monochrome graphics, Plantronics ColorPlus, and Paradise color simulation on monochrome.

Paradise Systems Inc., 217 E. Grand Ave., South San Francisco, CA 94080; (415) 588-6000. Samples with the chip on a board cost $900.

CIRCLE 341

Philips KTY sensors. For sensing a wider range of temperatures, for pennies.



Philips KTY silicon temperature sensors are not only attractively priced, they also monitor a wider range of temperatures than any other sensor.

Three models monitor temperature ranges from –55°C to +150°C; –55°C to +175°C; and 0°C to 300°C.

Wide operating range and excellent reproduceability are direct results of proven silicon planar technology.

By utilizing the nearly linear temperature-dependent resistivity of silicon, Philips KTY sensors can detect and respond to temperature changes in the broad ranges mentioned, with response times as fast as one second.

Exceptional accuracy of Philips KTY sensors results from a positive temperature coefficient (PTC) of 0.7 percent per degree Centigrade. They are available off the shelf in tolerances of ±1%, ±2%, and ±5%.

Because KTY sensors are small, are not polarity dependent, and need no special interfacing, they are ideal for applications involving solid-state circuitry. Configurations: plastic-encapsulated, axial lead glass bead, and surface-mounted device.

And remember, whatever the model, whatever the package, we're talking pennies.

To find out how Philips KTY sensors can fit into your measurement and control designs, call or write Amperex Electronic Corporation, A North American Philips Company, George Washington Highway, Smithfield, RI 02917. Phone (401) 232-0500; TWX 710-381-8808. In Canada contact Philips Electronics Ltd, ELCOMA Division.

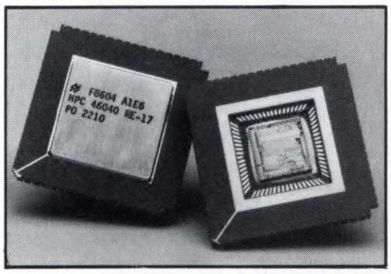
CIRCLE 122

Amperex®

DIGITAL ICs

Microcontroller has 240-ns cycle time

The first member of the HPC family of high-performance CMOS microcontrollers offers an instruction cycle time of only 240 ns. The core processor, which is rated at 17 MHz and is the same for all HPC members, is a 16-bit CPU with six working registers, microinstruction ROM, clock generator, serial



I/O bus, three 16-bit counter-timers, control logic, watchdog and reset circuitry, and National's Microwire/Plus interface. The HPC16040 additionally contains 4 kbytes of ROM, 256 bytes of RAM, 52 I/O lines, 8 16-bit timers, and a UART.

National Semiconductor Corp., 2900 Semiconductor Dr., P.O. Box 58090, Santa Clara, CA 95052; (408) 721-5926. $29.90 (ROMless version) in sample quantities.

CIRCLE 342

Optoisolator handles eight channels

The NM1608 Octo-Isolator is a bidirectional eight-channel optical isolator that provides 500 V rms of isolation on 8-bit microprocessor buses. For design flexibility, the Direction and Enable Input lines can be driven from either side of the device. It operates from a single 5-V supply, and its encapsulated 1.3-by-0.8-by- 0.38-in. package is compatible with standard 24-pin dual-in-line outlines.

International Power Sources Inc., 10 Cochituate St., Suite 6, Natick, MA 01760; (617) 651-1818. $39; stock.

CIRCLE 431

Newport Components Ltd., Tanners Dr., Blakelands N., Milton Keynes MK14 5NA, England; (0908) 615232; Telex: 825621.

CIRCLE 343

At last! Quality plots with the convenience of the

KOH-I-NOOR® Liquid-Ink Disposable Plotter Pen™

Koh-I-Noor's Disposable Plotter Pen™ (DPP) gives you the same convenience with over 3 times the write-out of fiber-tip pens • DPP provides greater line density and consistency without width or color variations • Provides waterproof, fade-resistant black and opaque colored inks • Provides check plots with final-plot quality • If you're now plotting with refillable, liquid-ink pens, Koh-I-Noor DPP can save you the downtime of refilling and cleaning pens.

Its true! The Koh-I-Noor Disposable Plotter Pen upgrades your plots while providing the easy features of disposable fiber-tip and roller-ball pens. Don't put off the benefits of liquid-ink plotting because you think they are available only with messy refilling and down time for pen cleaning; Koh-I-Noor DPP will lead you into a new era of operational efficiency with high-density, waterproof, fade-resistant black, red, blue and green inks. Other colors are available on special order.

Koh-I-Noor DPP styles accommodate most major makes and models of engineering and business-graphics plotters. See your dealer, or send for Koh-I-Noor DPP brochure for a complete rundown on plotters and compatible Koh-I-Noor Disposable Plotter Pens.

Koh-I-Noor Rapidograph, Inc., 100 North Street, Bloomsbury, NJ 08804 (201) 479-4124. In Canada: 1815 Meyerside Drive, Mississauga, Ont. L5T 1G3 (416) 671-0696.

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CIRCLE 124

SOFTWARE

Unix lookalike runs on IBM PC

A multiuser, multitasking operating system puts the powerful features of AT&T's Unix on the IBM PC and true compatibles for under $100. Called PCUnix, it offers more than 70 commands, representing the most commonly used features of Unix. It includes complete source code and is fully compatible with the MS-DOS file system. The entire system is packaged on four diskettes and can be installed and run on a 5-Mbyte hard-disk drive.

Wendin Inc., P.O. Box 266, Cheney, WA 99004; (509) 235-8088.

CIRCLE 344

Languages for PC support 8051 family

In an effort to lower the cost of developing software for the 8051 family of microcontrollers, Intel has introduced languages that run on the IBM PC AT and XT, as well as compatible computers. PL/M 51, a high-level alternative to assembly language programming, and ASM 51, a symbolic macro assembler, operate on PCs running DOS 3.0 or higher, as well as on Intel's Series II, III, and IV development systems.

Intel Corp., Literature Department W288, 3065 Bowers Ave., Santa Clara, CA 95051; (503) 681-2279. $750 each.

CIRCLE 345

Program eases rf filter design

The third in a series of low-cost programs to aid rf design, RF Notes No. 3 covers the design of low-pass, high-pass, band-pass, and band-reject Butterworth response filters to the seventh order. Outputs are in schematic diagram form with circuit values included. Supplied on disk, the program runs on the IBM family of personal computers and requires 128 kbytes of memory.

Etron RF Enterprises, P.O. Box 4042, Diamond Bar, CA 91765; (714) 594-8741. $85.

CIRCLE 346

SOFTWARE

PC-to-VAX link supports Kermit

A PC-to-VAX communications package combines VT100 terminal emulation, multi-protocol file transfer, and asynchronous communications up to 19.2 kbaud in a single software package. In addition to ASCII text-file transfers, VTERM III supports Columbia University's Kermit, the micro-mainframe communications standard. It supports the XMODEM error-correction protocol and Coefficient Systems' VTRANS7 and VTRANS8 protocols.

Coefficient Systems Corp., 611 Broadway, New York, NY 10012; (212) 777-6707. $195.

CIRCLE 347

Prolog tools ease development

With Turbo Prolog, even newcomers to programming can quickly build applications on their personal computers. The system's advanced incremental compiler generates native code, linkable object modules, and a linking format compatible with the PC-DOS linker. Interactive full-screen text editing is provided, as well as windowing support for both text and graphics. There are no limitations on the size of compiled modules or a module's source code.

Borland International Inc., 4585 Scotts Valley Dr., Scotts Valley, CA 95066; (408) 438-8400. $99.95.

CIRCLE 348

Program automates hard-disk backup

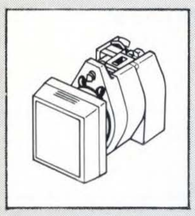
A software program automatically backs up hard-disk files to tape, to another disk, or to a floppy diskette. Called BackTrack, the program eliminates the time-consuming and repetitive aspects of floppy backup procedures. It operates in a background mode, searching for any new or revised files on the hard disk. Users may elect to have BackTrack scan the disk at regular intervals or at specified times during the day.

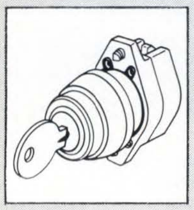
Tallgrass Technologies Corp., 11100 W. 82nd St., Overland Park, KS 66214; (913) 492-6002. $179; free with the purchase of a Tallgrass storage subsystem.

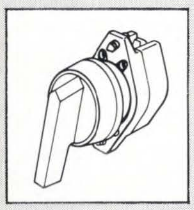
CIRCLE 349

EAO'S FAMILY OF OIL AND WATERTIGHT SWITCHES

FOR LIGHT, MEDIUM OR HEAVY DUTY APPLICATIONS







EAO's oil and watertight switches are light to heavy duty components featuring double sealed construction. Fully gasketed push-button actuators and rugged, self-sealing panel seals are the secrets to these switches' excellent oil and water-proof capability.

Series 04 heavy duty switches offer a modular system of pushbutton, keylock, rotary lever and emergency pushbutton actuators in combination with snap-acting or slow-make heavy duty contact blocks. Up to four contact blocks can be snapped onto any available actuator without tools and each contact block has two double break, self-cleaning silver contacts in two isolated chambers. Front rings are constructed of tough diallyphtalate or anodized aluminum with rugged, lightweight alloy mounting flanges.

Series 14 switches combine the full range of light to medium duty snap acting, low level or solid state Hall effect switch elements proven in our 01, 31, 41, 11 and 21 series switches with the rugged front panel construction of the industrial grade Series 04. These switches can be supplied with up to four contact blocks, each having gold plated snap acting contacts, and one double break snap acting self-cleaning switching mechanism. Low level and Hall effect versions feature universal terminals for PC board, wire soldering or optional quick connect terminals.

EAO's family of oil and watertight switches for light, medium or heavy duty applications. You can feel the difference.

EAO SWITCH CORP.

P.O. BOX 552, MILFORD, CT 06460
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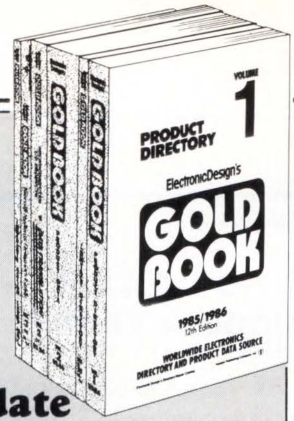
CIRCLE 129 ELECTRO '86 BOOTH NO. 1216-18



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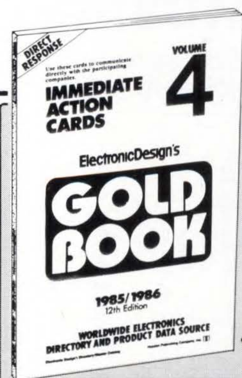

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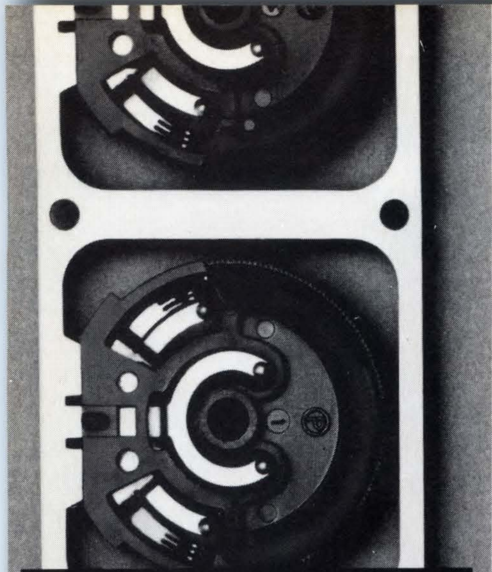
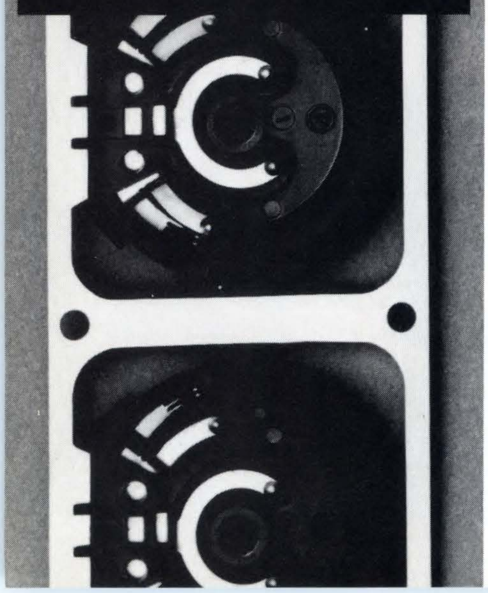


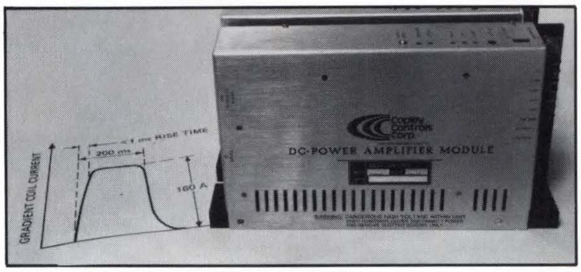


NEW PRODUCTS

POWER

ELECTRONIC DESIGN EXCLUSIVE

Kilowatt dc amplifier runs at 92% efficiency



Capable of continuously putting out 1.1 kW in the band between dc and 5000 Hz, the Model 220-10 amplifier dissipates just 84 W when driving a 15-A load with 75 V. With its 92% efficiency, Copley Control's module represents the most compact and efficient power source in its frequency range. Further, it can be paralleled to supply a continuous output power of 30 kW (450 A at 75 V) or as much as 48 kW of peak power.

The performance of the individual modules (and the paralleled units) is equal or superior to that of many 50% efficient linear audio amplifiers with cut-off frequencies of 10 to 20 Hz. The amplifier achieves its efficiency by pulse-width–modulating a 71-kHz carrier. Linearity error, for example, is less than 0.5% from dc to 700 Hz. Distortion is under 1% to 10 kHz, the small-signal bandwidth of the amplifier.

The basic unit can be considered a current-output device with a compliance voltage of 75 V. And it is its current output characteristic (rather than the more common voltage output) that permits the amplifier's output to be paralleled easily.

Interestingly, the inputs are not exactly connected in parallel. Instead, the basic ± 10 V differential input signal is applied to a so-called master. The control outputs from it are sent to a slave, and the control outputs from the slave drive the inputs of a second slave and so forth. All of the slaves have their outputs in parallel with that of the master.

In addition to a remote shutdown input, which inhibits the output, the amplifier incorporates four self-protection features: maximum current limiting, latching overtemperature shutdown (at 85°C), overvoltage shutdown if the 20-to-80-V supply exceeds 80 V, and undervoltage shutdown for all supplies.

The amplifier's dimensions are 7.7 by 12.9 by 2.25 in. At maximum load, its rear mounting surface must be kept at under 60°C. The power drain is 300 and 80 mA, respectively, from the ± 15 V supplies, and 22 A from a 20-to-80-V rail.

In quantities under 10, the Model 220S-10 Slave costs $975. The 220M-10 Master is priced at $1060. Delivery is four to six weeks.

Copley Controls Corp., 375 Elliot St., Newton, MA 02164; Barry Friedman, (617) 965-2410.
CIRCLE 303

Frank Goodenough

NEW PRODUCTS

POWER

ELECTRONIC DESIGN EXCLUSIVE

Military dc-dc converter reaches 10 W/in.^{3} at 60 W

Until now, designers of military electronic equipment have had to watch quietly from the sidelines as commercial-grade switching power supplies (particularly dc-dc converters) reach ever-higher power densities. The Powerslim 60R series of dc-dc converters dramatically alters that scenario. ATC Power Systems' converters handle 60 W in a package just 2 by 3 by 1 in., for a power density of 10 W/in.^{3}. And unlike their commercial counterparts, every component has been taken off a U.S. government Qualified Parts List. Not only are those parts tested and qualified, but also every one of them is in a hermetically sealed package.

For that reason, all of the power transistors are in TO-3 housings, and all of the rectifiers in stud mount DO-4 packages. Unlike some commercial supplies being pushed for military use, these units contain no plastic-packaged TO-220 or TO-218 power devices, small-signal plastic DIPs, or surface-mounted parts.

Each of the supplies contains an emi filter on its input that meets MIL-STD-461B. Some commercial supplies (claiming similar or even greater power density) leave such complex filters to be added externally by the user, no mean trick.

The first three members of the series, the 60R05V, 60R12V and 60R15V, operate from a nominal 28-V rail and meet their specifications even when the rail varies between 19 and 40 V. Their respective output voltages are within ±1% of 5, 12 and 15 V. Maximum current ratings are 12, 5 and 4 A. Minimum efficiencies run better than 70%, and line and load regulation are within 0.5%. At 1 MHz, ripple on the 5-V unit is under 100 mV, and it is under 150 mV on the other two. The recovery time for a 50% change in load is less than 300 μs, and overshoot and undershoot are less than 5%. The supplies also meet the input-surge specifications of MIL-STD-704B.

In quantities of 20, the 5-, 12-, and 15-V converters go for $850 each. Small quantities are available from stock.

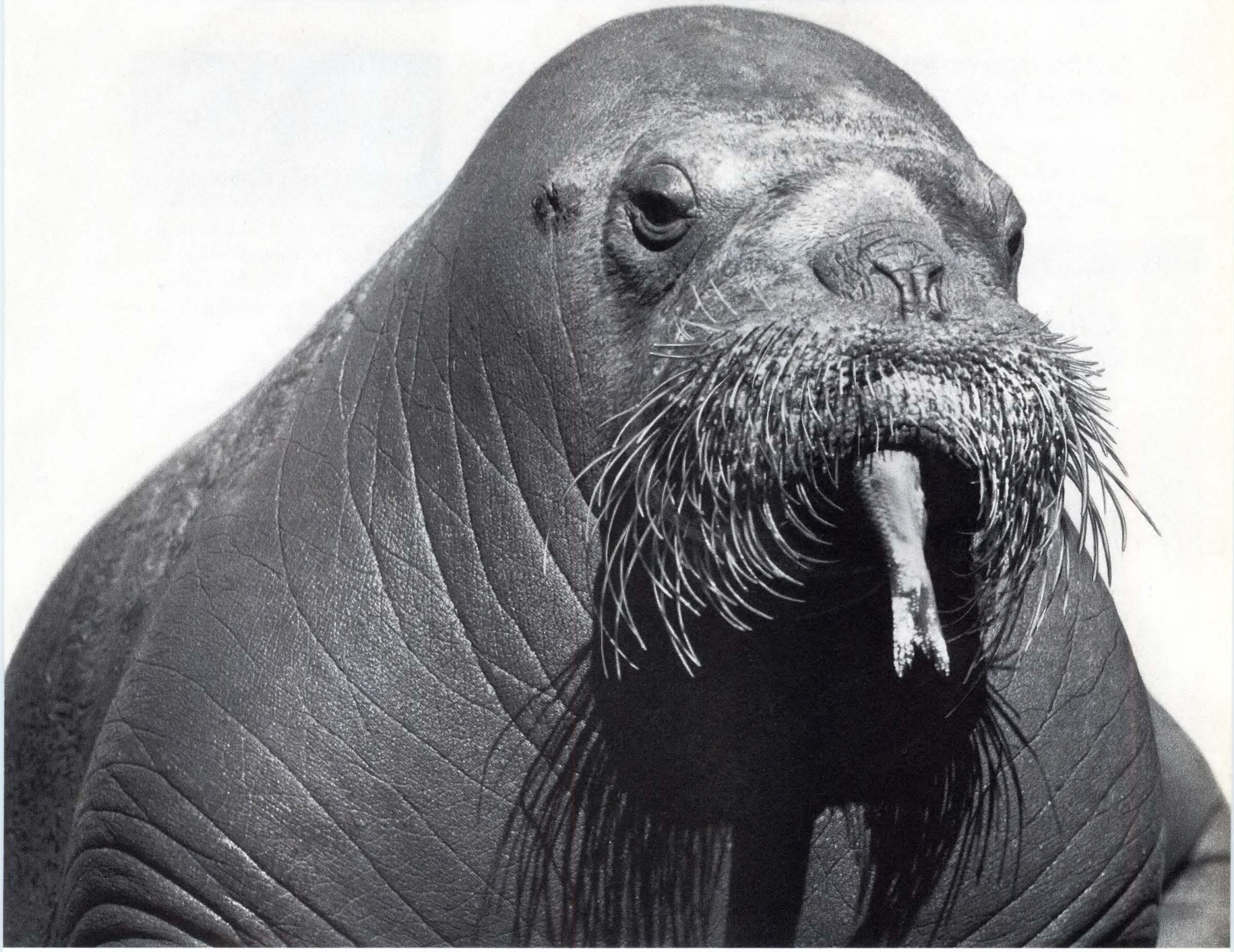
ATC Power Systems Inc., 472 Amherst St., Nashua, NH 03063; Charles Murch, (603) 882-1366.

CIRCLE 304

Frank Goodenough

Self-satisfied competitors may believe:

”Philips VMEbus offensive? We thought market shares are established.”



Philips is convinced:

market shares are not established as long as there are suppliers who claim to offer more. The background of a multi-discipline concern and large R&D resources dedicated to VMEbus are the basis for the long-term product strategy of Philips, which ensures we offer more. Let the best win!

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PHILIPS

Industrial Automation

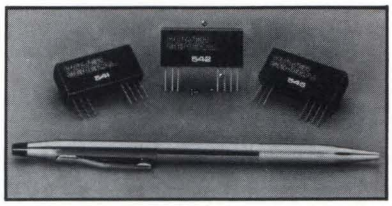
PHILIPS

CIRCLE 136

POWER

Dc-dc converter comes in SIP

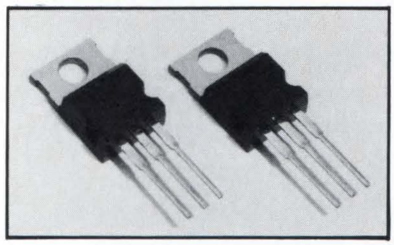
All models of the 540 series of 1-W dc-dc converters are housed in a single-in-line package with dimensions of just 1.25 by 0.55 by 0.33 in. Ideal for applications where space is critical, the device requires only 0.413 in.^{2} of board space and can be mounted directly at the point of load. The six members of the family provide outputs of 5, 12, and 15 V dc with an I/O isolation of 300 V. Line regulation is 0.5%. All units are short-circuit protected and operate from −25° to 70°C.



Power General, 152 Will Dr., P.O. Box 189, Canton, MA 02021; (617) 828-6216. $36.50; stock to four weeks.

CIRCLE 350

Power MOSFETs handle 50 V

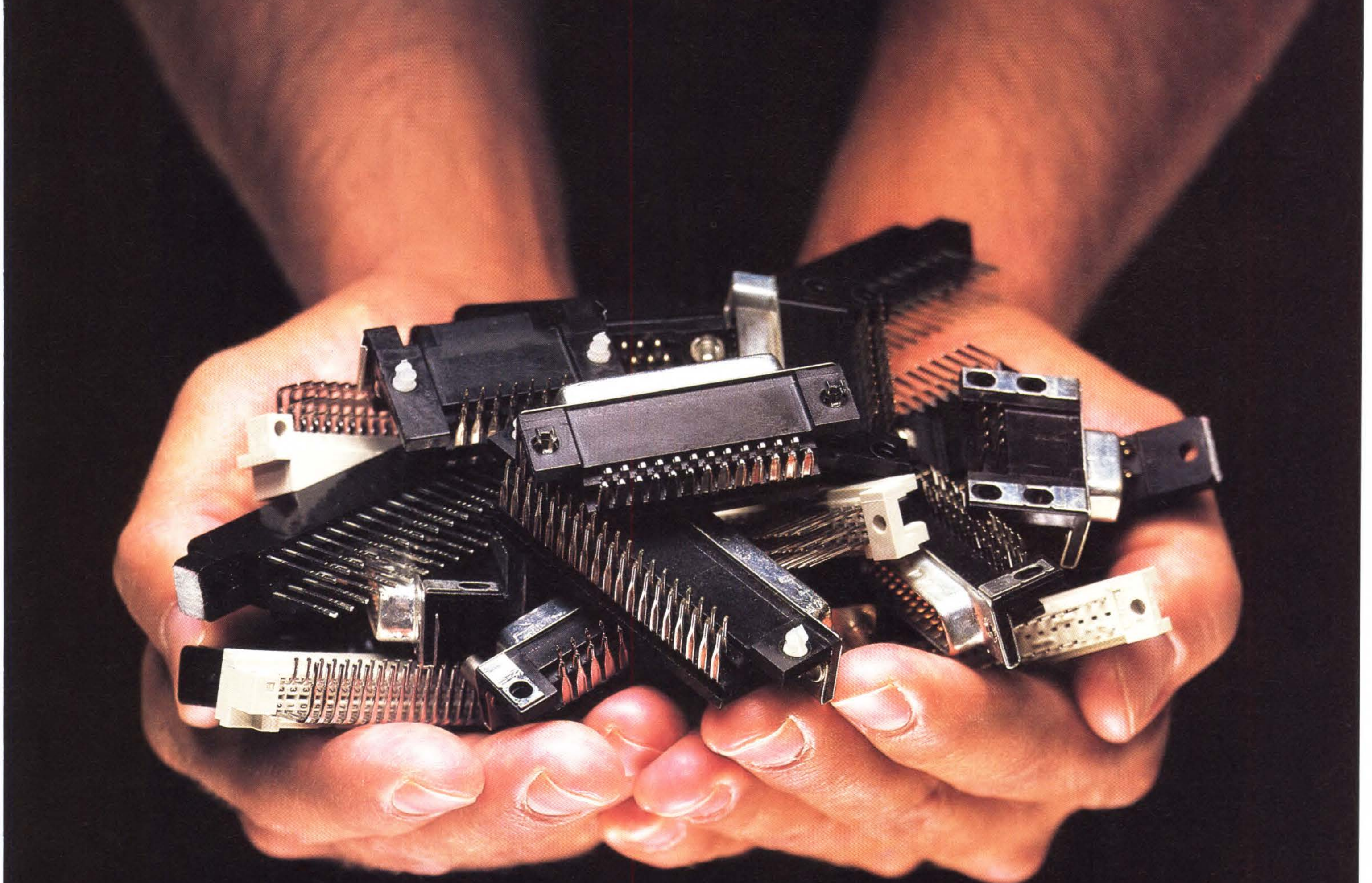


A series of 50-V power MOSFETs is designed especially for low-voltage applications, such as battery-powered portable equipment. One member, the FMP20N05, has an on-resistance of just 85 mΩ with a high power-dissipation rating of 75 W. Its current rating is 20 A at a case temperature of 25°C, and it has a usable current of 14 A at 100°C. The lower-cost FMP18N05 offers the same voltage and power ratings with an 18- and 13-A current rating at the same respective case temperatures. On-resistance for the FMP18N05 is 100 mΩ.

Fairchild Semiconductor Corp., 4300 Redwood Hwy., San Rafael, CA 94903; (800) 554-4443 or call local sales office. $0.96 (18N05) and $1.02 (20N05) in lots of 1000.

CIRCLE 351

At Holmberg, we're not handing you the same old lines.



What we are handing you is an outstanding line of high-quality connectors:

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- Crimp-snap
- Surface mount

Printed Circuit Card Edge
- Low cost cantilever contacts

DIN
- Standard and reverse

Our design innovations can provide you with substantial cost savings plus the greatest variety of mounting options available. At Holmberg, we'll do whatever it takes to make your job successful.

HOLMBERG® ELECTRONICS

The Innovation Connection

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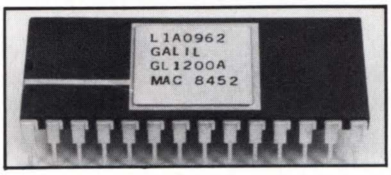
CIRCLE 138

NEW PRODUCTS

POWER

Motor control IC uses 10-MHz clock



A single-chip controller housed in a 28-pin DIP provides closed-loop position and velocity control of a dc motor. It operates with a 10-MHz clock and may be programmed to follow virtually any velocity profile at speeds ranging from 0 to 600,000 counts/s. The GL-1200-10 accepts position feedback from an incremental encoder, while position commands are accepted in pulse-train format. It compares the two inputs to form a 12-bit position error which is output for precise motor control.

Galil Motion Control Inc., 1928A Old Middlefield Way, Mountain View, CA 94043; (415) 964-6494. $23 (10,000 units); four weeks.

CIRCLE 352

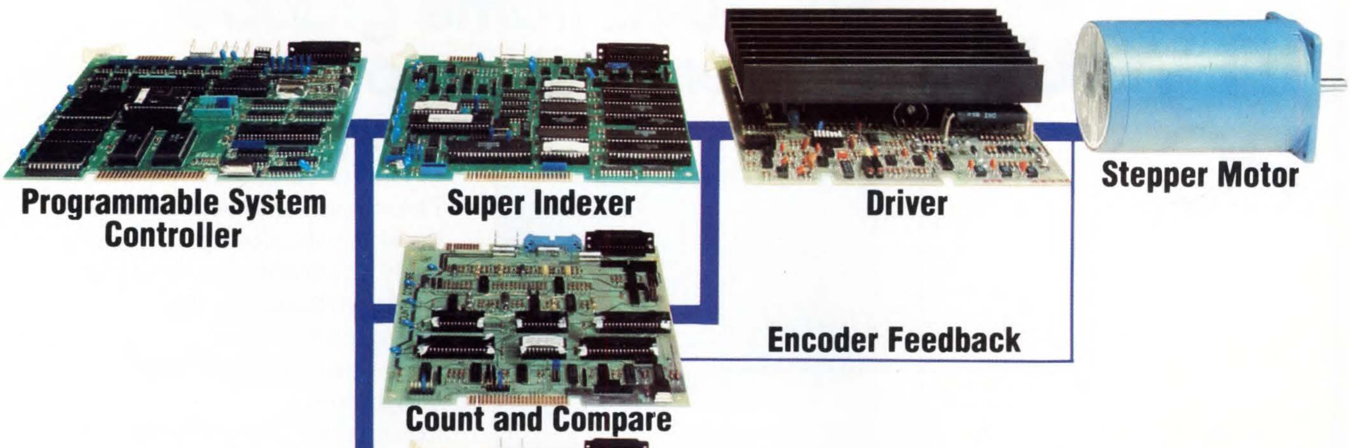
IC drives two-phase steppers

The TEA1012 is a 100-mA controller IC for driving two-phase stepping motors. It provides all of the required switching functions and a choice for driving the motor: constant-current chopper drive and bilevel voltage drive. Housed in a 16-pin DIP, the device has TTL-compatible inputs, a supply voltage range of 4.5 to 16 V, and a supply current rating of 6.5 mA (no load). Output current exceeds 50 mA.

Signetics Corp., 811 E. Arques Ave., Sunnyvale, CA 94088; (408) 991-2000. $2.58 (100 units).

CIRCLE 353

The MODULYNX® approach to programmable motion control.



Now you have a cost-effective alternative to system control . . . with Superior Electric's MODULYNX® Motion Control System. Because we've added four new products to our MODULYNX line that give you a new dimension in stepping motor and system control.

A smart systems controller.

Make our new Systems Controller Card the decision making "smarts" of your next motion control system. It provides you with a standardized RS232C interface. But it's also a single-board computer. You can develop your own program in the system's 4K RAM, then store it in the controller's E²PROM nonvolatile memory, where you can edit it anytime you want.

I/O Control.

With our new I/O Control Card, you can monitor and control events outside the motion control system. Each I/O Control Card has 8 inputs and 8 outputs and there is the capability of up to three cards to a bus. With this, the System Controller can control up to 24 inputs and 24 outputs—optically isolated.

Change velocity on the fly.

Our new Super Indexer Card is another major advance. This card is a microstepping indexer capable of 25,600 steps per revolution. It lets you change velocity on the fly. And with the MODULYNX Systems Controller, you can program whatever motion resolution you need—from 1/128 step to full step.

Position verification.

Then there's our Count and Compare Card. It provides position verification via encoder feedback. In conjunction with the System Controller, it also provides error-flagging and programmable auto-correction, as well as automatic monitoring of cycles outside the motion control system.

Tailor your own control system.

MODULYNX Motion Control products are individual circuit cards. Simply choose the ones you need for your system. A wide range of interfaces are available, from RS232C, IEEE488 or STD BUS to simple switches and TTL levels. We also offer a wide range of indexers, drivers and stepping motors from fractional to 2½ HP. MODULYNX products are also available in Eurocard format.

We're the first name in motion control. And now we can make your job even easier, by providing you with a single source for all these control capabilities.

For the name of the Superior Electric specialist in your area, write The Superior Electric Company, 383 Middle St., Bristol, CT 06010. Or call (203) 582-9561.

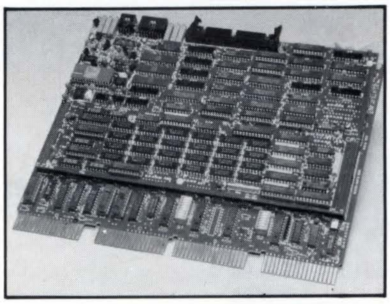
Superior Electric

MODULYNX® Motion Controls
SLO-SYN® Stepping Motors

CIRCLE 141

ELECTRONIC DESIGN EXCLUSIVE

50-, 60-Hz frame grabber delivers high resolution



Designed to operate on the Q-bus, the QVA/AFA-423 board set provides high-resolution image acquisition, digitization, and display in real time and at both 50 and 60 Hz. The QVG-423 motherboard contains the Q-bus interface, control, video timing and synchronization, overlay character-generator, display driver, and part of the display memory circuitry. The AFA-423 daughterboard contains input analog-to-digital converters, output digital-to-analog converters, input and output lookup tables, and the remaining display memory circuits.

The frame grabber board set features a 1536-kbyte memory, large enough to hold four 768-by-512-pixel 8-bit images at 60 Hz; 16 384-by-256-pixel 8-bit images at 60 Hz; or three 768-by-576-pixel 8-bit images at 50-Hz.

The product provides pan, zoom, scroll, alphanumeric overlay, and pseudo-color display functions. Its triple-port memory allows signal acquisition and display without CPU intervention. Individual bit planes of the image memory may be write protected.

Roger Allan

The frame grabber includes a PLL circuit for synchronization to the incoming video signal. Alternatively, the boards may be run by a 14.318 MHz internal clock.

Under software control, digitized video signals are passed through one of eight banks of 256-by-8-bit input lookup tables. The tables equip users to perform thresholding, offsetting, linearity control, and mathematical manipulation on a video image.

Stored video signals leave the frame grabber through three output lookup tables (one each for the colors red, green and blue). Each table consists of eight banks of 256-by-8-bit lookup tables, one of which is selected by software to achieve the desired effect.

The output lookup table signals are converted to analog form by three digital-to-analog converters. Those converters drive RS-170 and CCIR displays.

Three QVG/AFA-423 frame grabbers may be pixel-locked together to provide a 768-by-2048-by-24-bit pseudocolor image. Each board set accepts both composite and noncomposite, interlaced and noninterlaced signals.

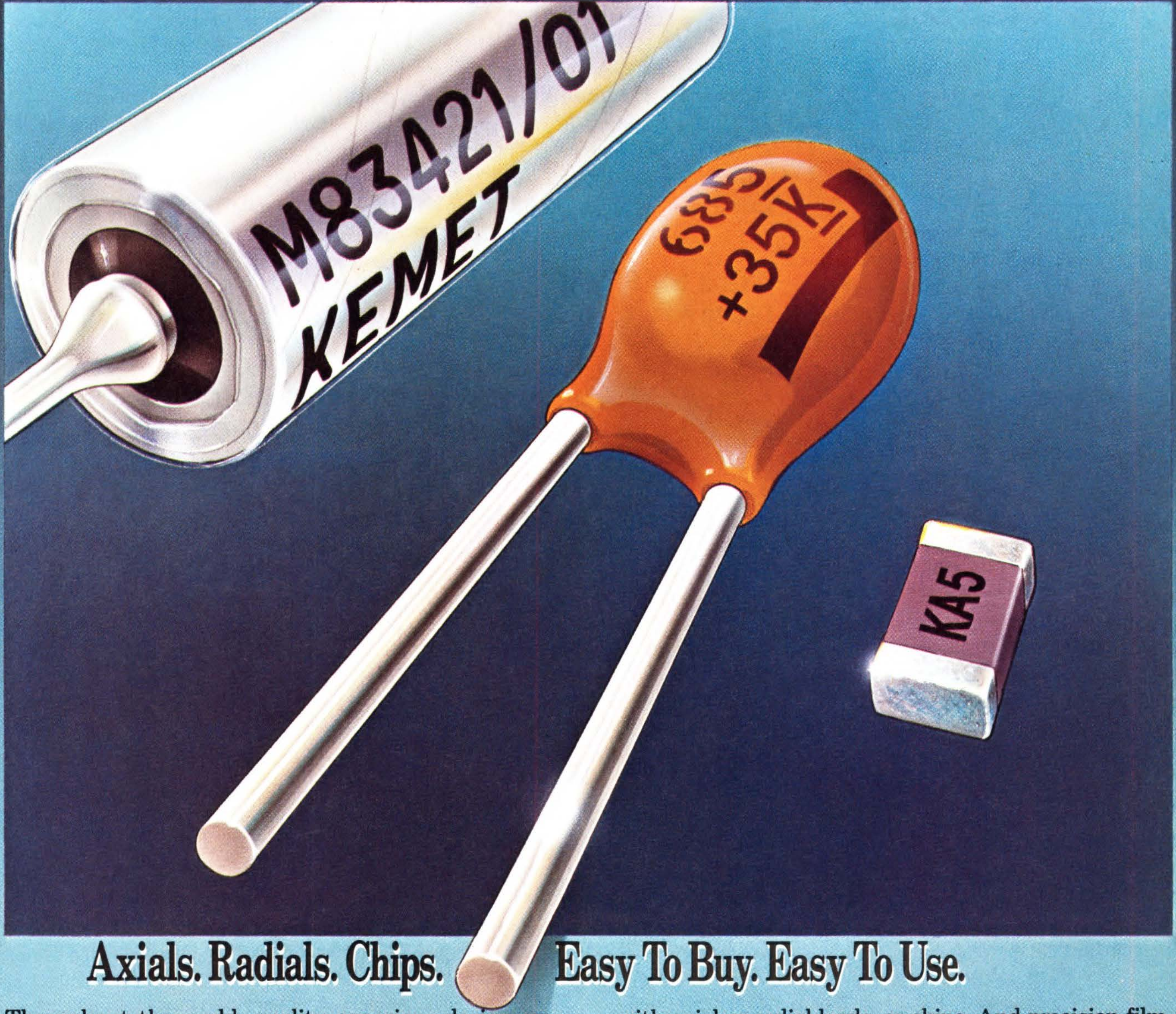
The board set operates from +5 and +12 V. The mother board measures 10.46 by 8.43 by 0.48 in., and the daughterboard 10 by 6.25 by 0.48 in.

The board set is priced at $7500 and is available within 30 days.

Datacube Inc., 4 Dearborn Rd., Peabody, MA 01960; (617) 535-6444.

CIRCLE 311

HIGHEST QUALITY: KEMET® Is The Source.



Axials. Radials. Chips. Easy To Buy. Easy To Use.

Throughout the world, quality-conscious design engineers prefer KEMET® capacitors for some very important reasons:

Quality — KEMET capacitors meet the toughest MIL and customer specifications. Even our commercial-grade products offer superior quality and reliability, with attention to your special needs.

Variety — KEMET offers an unmatched product selection, featuring all the types of capacitors you'll ever need. Solid tantalums in standard, miniature and microminiature sizes, with axial or radial leads. Or efficient chips. Multilayer ceramic units, molded or dipped, with axial or radial leads, or chips. And precision film capacitors, with parylene or metalized polycarbonate dielectric.

Delivery — We keep our promises, no matter what on earth you order or where on earth you're located.

Once you sample our application and selection assistance, you'll find we're easy to deal with, too. To get started, ask for our free KEMET Wall Chart. Then let us help you get down to business.

Sales Offices and Distributors Worldwide.
In U.S.A: (803) 963-6348; Telex 57-0496.
In Europe: 41-22-396512; Telex 845-911302.
In Asia: 852-372-31211; Telex 780-45162.

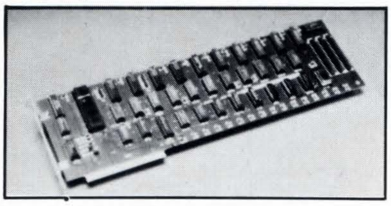
CIRCLE 143

Order KEMET

UNION CARBIDE ELECTRONICS DIVISION COMPONENTS DEPARTMENT

COMPUTER BOARDS

PCs come aboard Navy's NTDS bus



The PC-NTDS drop-in card interfaces directly with the Navy Tactical Data Systems bus (MIL-STD-1397) employed in most naval equipment. The board turns an IBM PC AT or look-alike into a low-cost tool for troubleshooting and testing. As such, the personal computer can replace AN/UYK machines and dedicated test equipment.

The board can operate with an 8-, 16-, or 32-bit parallel interface. It supplies a separate set of I/O to the NTDS bus (32 data, 4 control) as well as two RS-422 serial lines. The card can put out and accept data at the maximum NTDS rate, 250,000 32-bit words a second.

The board comes complete with all the necessary cables and software, and takes up less than 64 kbytes of memory in the PC.

Sabtech Industries Inc., 4091 E. La Palma Ave., Unit P., Anaheim, CA 92807; (714) 630-9335. $2850; up to 4 weeks.

CIRCLE 354

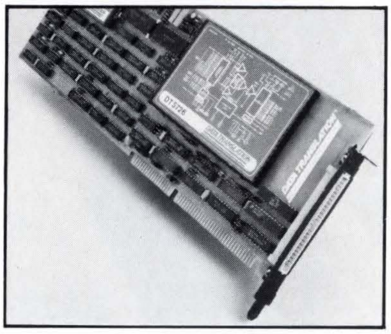
Graphic controller serves Q-bus

Two graphic controller boards plug directly into computers based on the Q-bus and communicate with the host CPU at full bus speed. The QG-1280 board set offers the needed resolution (1280 by 1024 by 8 bits) and speed (20,000 vectors/s) to utilize the MicroVAX II as a true engineering workstation. The QG-640 is a single-board graphic processor that provides a resolution of 640 by 480 by 8 bits. Respective prices are $4995 and $2995.

Matrox Electronic Systems Ltd., 1055 St Regis Blvd., Dorval, Quebec, Canada H9P 2T4; (800) 361-4903 or (514) 685-2630.

CIRCLE 355

Card for PC AT resolves 16 bits



A data acquisition board for the IBM PC AT offers 16-bit resolution and a throughput of 100 kHz—an order of magnitude higher than comparable high-resolution boards for the PC. The DT2827 has four channels of differential analog input, two 12-bit deglitched d-a converters, 16 lines of digital I/O, a channel RAM list, and clock.

Data Translation Inc., 100 Locke Dr., Marlboro, MA 01752; (617) 481-3700. $2495; 5 to 10 days.

CIRCLE 356

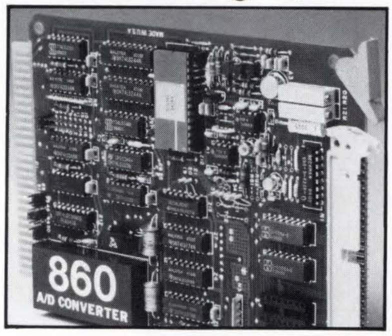
RAM card offers speedy response

The DSB-020PL is a 2-Mbyte dynamic RAM board designed for zero-wait-state operation when combined with Multibus CPU boards which contain either the Intel High Speed Synchronous Interface (HSI) or asynchronous iLBX memory expansion interface. It delivers a 187-ns maximum access time across the HSI/iLBX interface and offers flexible memory addressing to allow the board to work in a variety of applications.

Pascot Inc., Densan Division, 17981 Skypark Cir., Suite B, Irvine, CA 92714; (714) 261-5220. $971 with 2 Mbytes (100 units); stock.

CIRCLE 357

STD bus card has 12-bit analog inputs



Offering a convenient solution to interfacing microcomputers with the analog world is Octagon's 860 analog input card. The STD bus-compatible board has 16 single-ended (or 8 differential) channels with 12-bit resolution, programmable gain for low-level signals, and an on-board dc-dc converter. Conversion time is 25 μs. The instrumentation amplifier may be programmed for gains of 1 to 1000. Combining this with a sample-and-hold circuit and a 12-bit a-d converter, the data acquisition section achieves ±0.01 accuracy and throughput rates of up to 25 kHz.

Octagon Systems Corp., 6501 W. 91st Ave., Westminster, CO 80030; (303) 426-8540. $565.

CIRCLE 358

At last, software that solves your mathematical problems symbolically.

In seconds.

If it is still taking you weeks or months to handle rudimentary algebraic problems and extremely complex analyses, then make it your business to find out about MACSYMA.™

MACSYMA is the most comprehensive approach to symbolic mathematics ever created. Originally designed at MIT through research in Artificial Intelligence, MACSYMA has been continuously developed and enhanced since 1969.

But for all its sophistication, you can put MACSYMA to work on computers ranging from workstations to mainframes. Without previous programming experience. In fact, you can interact with it in an almost conversational way while you use it to explore problems in basic or advanced mathematics that you couldn't begin to approach using a pencil, chalk or numerical software. This comprehensive program can then generate FORTRAN code from derived MACSYMA expressions and answers.

3 weeks vs. 10 seconds.

For example, an engineer working for a major aerospace company was stopped by an integral dealing with turbulence and boundary layers. Pencil and paper in hand, he had been looking at:

$$\int (k\log(x) - 2x^3 + 3x^2 + b)^4\,dx$$

for more than three weeks. He always arrived at a different solution, never knowing which was the right one.

Less than 10 seconds after entering the problem into the computer, MACSYMA gave him the correct answer. Not just numerically, but in symbolic terms that gave him real insight into the physical nature of the problem.

How long would it take you or your staff to factor this expression?

$$3w^2z^6 + 2w^3z^4 - 10w^2y^2z^3 + 141xyz^3 + 45w^2x^3z^3 - 3w^2z^3 + 94wxyz - 2w^3z - 470xy^3 + 10w^2y^2 + 2115x^4y - 45w^2x^3$$

MACSYMA gives you the answer. In seconds.

$$(3z^3 + 2wz - 10y^2 + 45x^3)(w^2z^3 + 47xy - w^2)$$

What MACSYMA can do. For you.

MACSYMA arms you with hundreds of practical and real-world applications. It can:

- Do algebra, trigonometry and calculus
- Provide standard numerical techniques
- Generate FORTRAN output from MACSYMA expressions
- Simplify, factor or expand expressions
- Solve equations analytically or numerically
- Expand functions in Taylor or Laurent series
- Compute Fourier and Laplace transforms
- Manipulate matrices and tensors
- Plot functions in 2 or 3 dimensions
- Much, much more

Throughout the world, thousands of scientists, engineers and mathematicians are using MACSYMA in such diversified applications as electronics, structural engineering, CAD, acoustics, plasma physics, antenna theory, VLSI circuit design, control theory, numerical analysis, fluid mechanics, genetic studies, ship hull design, maximum likelihood estimation, ballistic missile defense systems design, underwater shock wave analysis, helicopter blade motion studies, and atomic scattering cross section analysis. And the range of use is expanding every day.

Easy computer algebra starts here.

MACSYMA is available right now from Symbolics,™ the leader in Symbolic processing. For a complete kit including a full capabilities brochure, just clip and mail the coupon or call (617) 577-7600.

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The most comprehensive software approach to symbolic mathematical computations.

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Company

Address

City State Zip

Telephone Extension

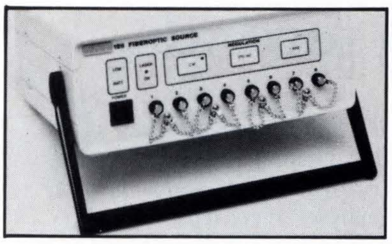
MACSYMA is available to colleges and universities at special rates.

CIRCLE 145

INSTRUMENTS

Laser source has 8 1300-nm outputs

Weighing only 7 lbs (including an internally rechargeable battery), Intelco's Model 128 light source produces eight laser outputs, more than any other such source. The lasers each have a wavelength of 1300 nm, within a 6-nm optical line width. The unit is designed for multifiber loss measurements in cable installations. It eliminates the need to manually switch from one fiber to another for splice testing.



Each of the eight outputs is stable to within ±5 nm and produces −15 dBm of power per port, with port-to-port variations of under 1 dB. The unit uses thermoelectrically cooled and temperature-controlled lasers that allow it to boast short-term and long-term output stabilities, after it is turned on for three minutes, of ±0.02 and ±0.1 dB, respectively.

The unit operates in one of three modes: internal continuous-wave, 270-Hz square wave, and 1000-Hz square-wave modulation. It employs standard FC optical connectors.

The instrument contains laser-control and timing circuitry that allow it to meet the Class 1 nonhazardous emission standards defined by the U.S. Bureau of Radiological Health. Its battery powers the source for over 14 hours of continuous use and recharges in less than 6 hours. The instrument may also be operated from an external 11- to 15-V dc source or from 110/220-V 50/60-Hz ac power lines.

The Model 128's dimensions are 10 by 10.25 by 3.75 in. It is rated to operate from 0° to 40°C. The source costs $13,900 and is available from stock to 4 weeks.

Intelco Corp., 304 School St., Acton, MA 01720; (617) 264-4485.

CIRCLE 301

Super Powers

Remote power supplies for microprocessors

Wall Units

+ 5VDC @ 750 ma
± 12VDC @ 80 ma
(W512750/1)

UL

Table Top Units

+ 5VDC @ 1.0 A
± 12VDC @ 310 ma
(T5121000/1)

UL SP

MPI's remote new plug-in units let you take the power supply out of your product and put it practically anywhere. Insert it directly into a wall plug, or rest it on a table top, desk top, bench, or any flat surface.

Designed for use with modems, calculators, appliances, games and a variety of other electronic products, MPI wall and table top power supplies are super-performers; providing outstanding dependability, flexibility and economy. They free up valuable board space, reduce weight and eliminate hazardous voltages, power supply heat and the need for costly cooling devices.

All MPI wall and table top models are UL listed.

Get the MPI super powers working for you. Check these exclusive features and specifications and call us today for details.

- **Multiple & single output**
- **Regulated low ripple**
- **UL and CSA listed**
- **Fully isolated outputs**
- **Comply with FCC EMI regs.**
- **High efficiency**

CIRCLE 147

Specifications:

Input:	120V ± 10% 50/60 Hz
Regulation:	+5V 5% overall
Regulation:	+15V or +12V 5% overall
Regulation:	−15V or −12V 5% overall
Ripple:	50 MV P-P
Operating Temp:	0°C to +40°C
Storage Temp:	−55°C to 105°C
Operating Altitude:	15,000′

Multi Products International
218 Little Falls Rd., P.O. Box 238, Cedar Grove, NJ 07009
(201) 239-8183 • Telex 219289 • Cable: MUPRINUSA-CEDG

SEE US AT ELECTRO 86, BOOTH #302.

INSTRUMENTS

Protocol analyzer uses IBM PC host

A hardware and software package for the IBM PC and compatibles performs remote data collection for protocol analysis. The FERAM remote acquisition module transmits data over an RS-232-C link. The user can select any one of 16 remote lines to be monitored using Frederick Engineering's line multiplexer, FEMUX. Once the data has been collected, it is forwarded to the personal computer for analysis with the FERAM software. An optional V.35 interface is available.

Frederick Engineering Inc., 54 Cessna Ct., Gaithersburg, MD 20879; (301) 926-6772. $1995.

CIRCLE 359

3-MHz synthesizer has settable phase

The VDS-3 digital frequency synthesizer with the phase rotation option permits phase shifting within a ±360° range in 0.36° steps. Phase accuracy is better than 0.1°, and controlled phase shifts are completed in less than half a microsecond. The basic unit covers dc to 3 MHz with 0.001-Hz resolution. The instrument is also available at the board level for OEM applications.

Sciteq Electronics Inc., 7380 Clairemont Mesa Blvd., San Diego, CA 92111; (619) 292-0500. $1995, plus $500 for phase rotation option; stock.

CIRCLE 360

Analyzers accept downloaded data

Two spectrum analyzers, the 495 and 495P, provide top performance in a portable package. The instruments cover frequencies ranging from 100 Hz to 1.8 GHz, with −130 dBm sensitivity, optimized for the baseband through UHF markets. With Option 05, the user can download frequently used measurement programs into nonvolatile memory. Unlike its manual counterpart, the 495P offers full programmability via a GPIB port.

Tektronix Inc., P.O. Box 1700, Beaverton, OR 97005; (800) 547-1512; in Oregon, (800) 452-1877. From $24,350.

CIRCLE 361

Software streamlines board test operations

A software system for collecting and analyzing board-test data links Teradyne's L200 series of VLSI board test systems for more efficient production, testing, and repair of pc boards. Called BoardWatch, the program uses an industry-standard network and relational data base to provide an open system for job plan management, paperless repair, and flexible management-report generation. It runs on VAX series computers and is compatible with DECnet/Ethernet communications links.

Teradyne Inc., 321 Harrison Ave., Boston, MA 02118; (617) 482-2700. From $75,000 to $200,000, depending on the number of L200's on the network.

CIRCLE 362

Voltmeters boast high speed

Two 6½-digit voltmeters are intended for systems and ATE applications. Both the 7061 and 7062 use a pulse-width technique to measure the input continuously at 24,000 times per second to produce a 4½-digit reading or 6½ digits with precision. Within 3 ms of an external hardware or software trigger, a 4½-digit reading can be taken and transmitted over the IEEE-488 bus.

Solartron Instruments, 2 Westchester Plaza, Elmsford, NY 10523; (800) CALL-SOL or (914) 592-9168.

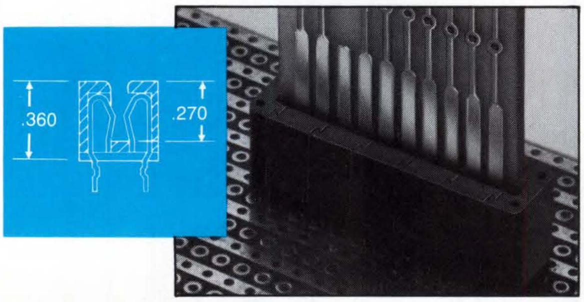
CIRCLE 363

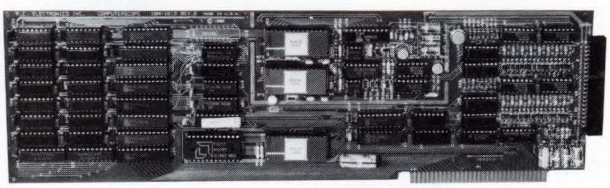
Noncontact meter reads 100 V FS

A sensitive electrostatic voltmeter is designed to measure electrical overstress. With a full-scale reading of 100 V, the instrument works at a distance to provide accurate readings to within 5 V. The EOS 100 offers four full-scale ranges (5% accuracy): 100 and 1000 V at 0.75 in. and 300 and 3000 V at 3 in.

Chapman Corp., 125 Presumpscot St., P.O. Box 10700, Portland, ME 04104; (207) 773-4726. $325.

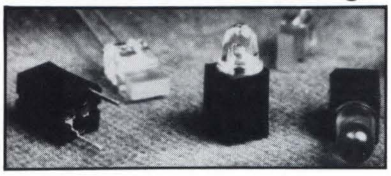
CIRCLE 364





COMPONENTS

LED sockets eliminate soldering



Electrically connecting LEDs to circuit boards can now be accomplished without soldering using the PCH and PCV series sockets. LEDs with dual leads on 0.100-in. centers are mounted horizontally in the PCH socket and vertically in the PCV. Specially formed finger contacts automatically adjust to varying sizes and shapes of leads to permit easy insertion and removal. In addition, the vertically mounted PCV allows the leads to be inserted from either direction.

Visual Communications Co. Inc., P.O. Box 986, El Segundo, CA 90245; (213) 822-4727. $0.25 (10,000 units); stock to two weeks.

CIRCLE 365

Switches shrink to micro-subminiature

The micro-subminiature G series of pc board toggle and rocker switches is approximately 30% smaller than those switches classified as subminiature or super-subminiature. They are available with straight-mounting, right-angle, or vertical terminations. Terminal spacing conforms to standard 0.100-by-0.100-in. pc board grids.

NKK Switches, 14415 N. Scottsdale Rd., Scottsdale, AZ 85260; (602) 991-0942.

CIRCLE 366

IDC connector has 50-mil centers

The 8800 series is a two-piece connector system with contacts on 50-mil centers for miniaturized interconnections. Board-to-board and wire-to-board mating capabilities are available. Standard IDC configurations range from 20 to 60 contacts.

Kel-Am Inc., P.O. Box 313, Eldon, MO 65026; (800) 233-2001 or (314) 392-7174.

CIRCLE 367

Moving?

1. For FASTEST service you must attach old mailing label in space below.

Please allow 6 weeks for change to take effect

If mailing label is not available print your old Company name and address in this box

2. Print your NEW business address here

NAME ________ TITLE ________

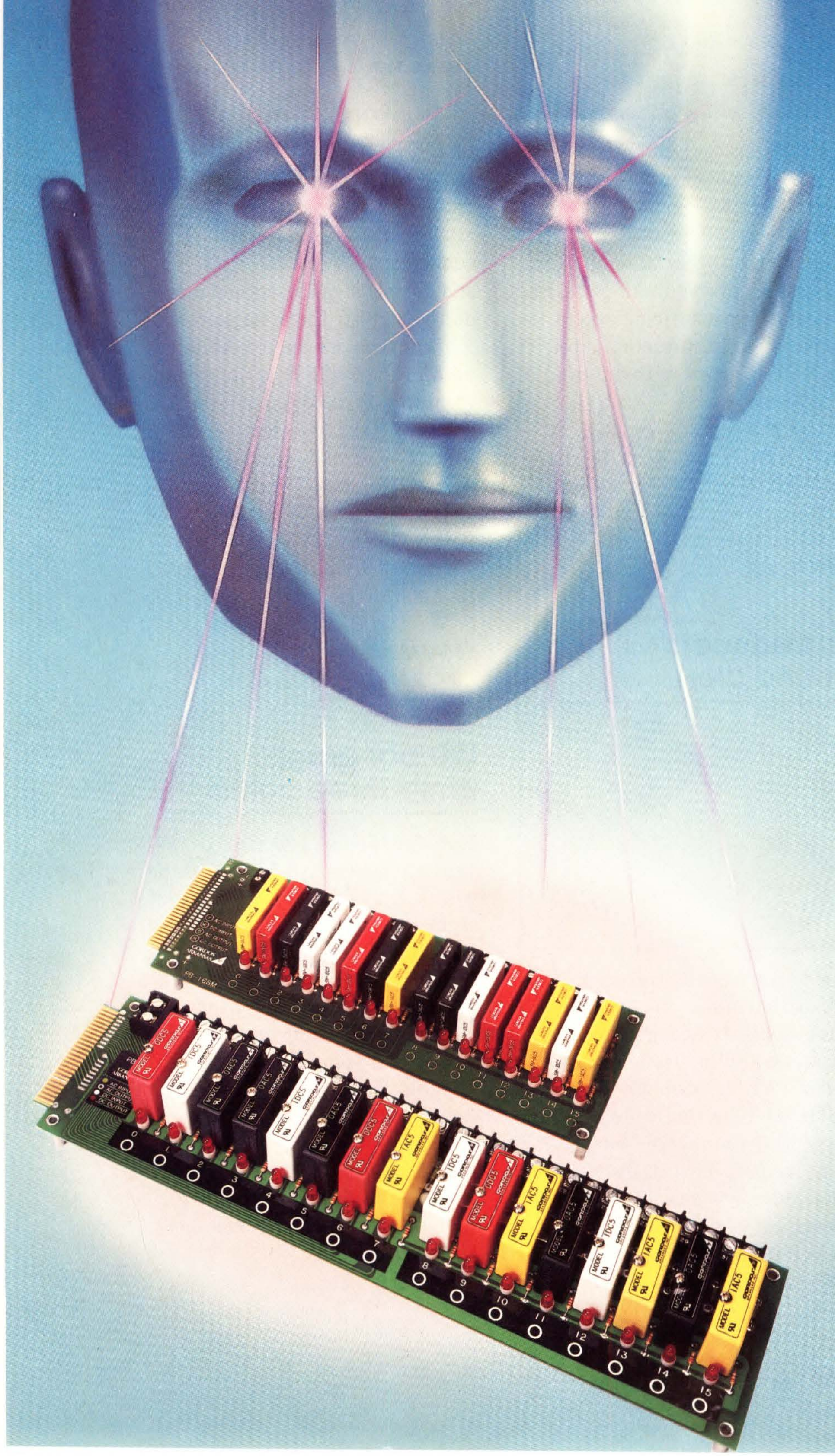
COMPANY ________

ADDRESS ________

CITY ________ STATE ________ ZIP ________

3. Mail to:
Electronic Design
P. O. Box 1036
Southeastern, PA 19398

GORDOS. Mini I/O Modules with the focus on innovation.



Reducing the size of Power I/O Modules by 40%, is one good example.

At Gordos, we put our years of surface mount and thick film design expertise to work and developed a Power I/O System that saves 40% in crucial panel space. Without sacrificing one spec of performance!

Flexibility of our new Mini I/O Modules is a plus at Gordos. Mounting boards which accommodate 16, 24 or 32 modules are available. The module comes with a positive snap-in design which will also fit in conventional boards for field interchangeability. Positive cable connections can be made with an optional pin/socket connector and the board is compatible with existing cable interfaces.

Modules are available for 120 or 240 VAC output, 3 to 60 VDC output, 120 or 240 VAC input and 5 and 24 VDC input. Plus, each module provides 4000 volt optical isolation between the computer logic voltage and the load side.

The new Gordos Mini Power I/O Modules. Small in size, big on performance. For more information on Mini I/O Modules, conventional I/O Modules, Solid State Relays or Custom Hybrid Circuits, call us at 800-643-3500, or write for descriptive literature.

GORDOS

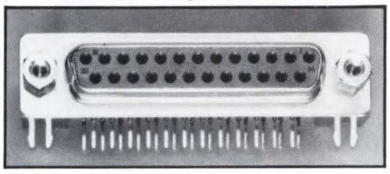
GORDOS ARKANSAS
1000 North Second Street
Rogers, Arkansas 72756
TWX 910-720-7998

CIRCLE 150

NEW PRODUCTS

COMPONENTS

Connector employs retention system

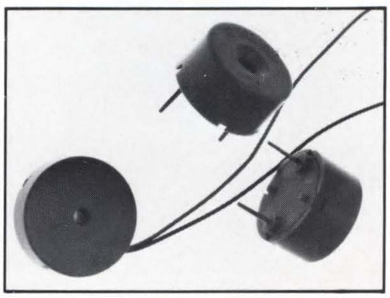


Two fork springs located at each end of a D subminiature connector open upon insertion into a pc board and hold it firmly in place during wave soldering or other assembly processes. Available in 25-, 15-, and 9-contact versions (female only), the connector has a current rating of 5 A and a dielectric withstanding of 1200 V ac rms.

LZR Electronics Inc., 8174 Beechcraft Ave., Gaithersburg, MD 20879; (301) 921-9440. $1.75 (25-pin version) in lots of 1000; stock to eight weeks.

CIRCLE 368

Transducers sound alert



Solid-state piezoelectric transducers are used to initiate an audio alert in such applications as computers, printers, and instrumentation devices. The board-mounted Model 13DB-4P is 15 mm wide by 9 mm high, with 10-mm pin spacing. The wire lead Model 15DB-4P is 16.8 mm wide by 4 mm high, ideal for mounting in tight spots. Both devices provide an output of 73 to 80 dB at 4096 Hz.

Kyocera Electronic Components Group, 11425 Sorrento Valley Rd., San Diego, CA 92121; (619) 454-1800. $0.42 (10,000 units); four to six weeks.

CIRCLE 369

D connectors withstand 200°C

High-temperature D subminiature connectors are offered in 25-, 15-, and 9-contact variations and mount on the pc board in a single row of 1.27-mm contact centers. Materials used in the SMT D-series permit them to withstand temperatures in excess of 200°C for short periods of time. The devices are compatible with all standard D subminiatures conforming to MIL-C-24308 and IEC publication 807-2.

Positronic Industries Inc., 423 N. Campbell, Springfield, MO 65806; (800) 866-2322 or (417) 866-2322.

CIRCLE 370

LED bar graph emits three colors

Part of the Jupiter line, the LL7164-11 is a 10-segment LED bar graph with a gray face and translucent segments. The device emits the color green (GaP) in the first five positions, yellow (GaAsP/GaP) in the next three, and high-efficiency red (GaAsP/GaP) in the final two positions. Pin spacing is standard 0.100-in. dual-in-line on 0.300-in. centers with an overall package size of 0.995 by 0.400 in.

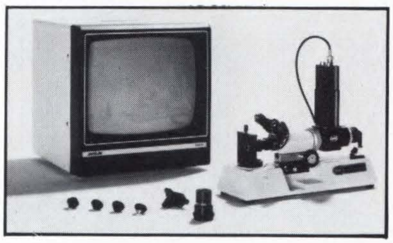
Industrial Electronic Engineers Inc., 7740 Lemona Ave., Van Nuys, CA 91405; (818) 787-0311. $2.75 (100 units).

CIRCLE 371

NEW PRODUCTS

PACKAGING & PRODUCTION

Microscope inspects optical fibers



An inspection microscope, the F-ML1 is a portable, self-contained instrument for viewing optical fiber cleave quality, surface defects, and core definition with magnification up to 400×. Suitable for production, laboratory, and field use, it accommodates bare and connectorized fibers with snap-in adapters. A video monitor is available for high-volume inspection.

Newport Corp., P.O. Box 8020, Fountain Valley, CA 92728; (714) 965-5406. $1975; $1600 for monitor; stock.

CIRCLE 372

Programmers get generic interface

Designed to work with any of Intel's existing line of universal PROM programmers, the iUP GUPI (Generic Universal Programmer Interface) is a single module that lets designers program a wide variety of devices. These include EPROMs, EPLDs, and microcontrollers in pin grid arrays, plastic leaded chip carriers, and up to 68-pin DIPs. An opening in the top of the module accommodates any of a series of low-cost adapters.

Intel Corp., Literature Department, W-295, 3065 Bowers Ave., Santa Clara, CA 95051; (503) 681-2279. $790; adapters cost $200 to $250.

CIRCLE 373

READER FEEDBACK

(continued from p. 89)

pose of the action was to divert "attention from the plight of the automobile industry." He makes these wild claims and offers nothing at all to support his viewpoint.

Costlow's conclusions do not seem to be based on solid facts. Who, or what, are his sources? I would appreciate seeing a response to this letter in print.

James Burd
Northride, Calif.

Sometimes satire just doesn't work. Terry Costlow's column was intended as a tongue-in-cheek look at recent events in the Star Wars program, comparing it to what might have happened if *the personal computer industry had been government-supported. In this case, apparently Terry's gift for journalistic understatement did not serve him as well as it usually does.*—Ed.

Too much unneeded work

Your Feb. 20 column (p. 33) voices my own suspicions very well. Thanks. The suspicions have been percolating since my days in the U.S. Civil Service in the 1950s, when I realized that the Lab Director had put sixty employees to work making and testing stuff that worked half the time, and had one employee paid to try to find out how to improve the score. ("When the job is finished, so are you," one cynic said.)

In ordinary speech about DOD, the billions don't go for Defense, but the Defense Spending; the usage is more accurate than the brass.

I bet somebody squawks about your column. The fact that Uncle Sam plays the Red Queen, moving money around just to keep people busy, has got to be on someone's taboo list.

After a century of innovation in Labor Saving Machinery and sixty years of the forty-hour week, we work more than ever just for the necessities. The most likely explanation is that the extra time is applied to unnecessary work. Such as selling stuff that is not needed, and organized snooping, and redundant bombs.

I once noticed that R&D spending nationally had gone up by a factor of over 100 while the number of patents issued per year stayed about the same, and wrote an article about it in the *Patent Office Society Journal*.

Lawrence Fleming
Innes Instrument Co.
Pasadena, Calif.

Corrections

Due to an editing error, a statement by Microsoft Corp. chairman Bill Gates forecasting future microcomputer software was garbled. He actually said that further development of software for 8088 based machines would continue to evolve *on a parallel track with projects to exploit the advanced features of 80286-based systems.*

The correct phone listing for Kepco Inc. in the March 13 issue table of programmable power supplies manufacturers (p. 164) is (718) 461-7000.

Be sure to see Electronic Design's Professional Opportunities Section. It starts on page 268.

Q

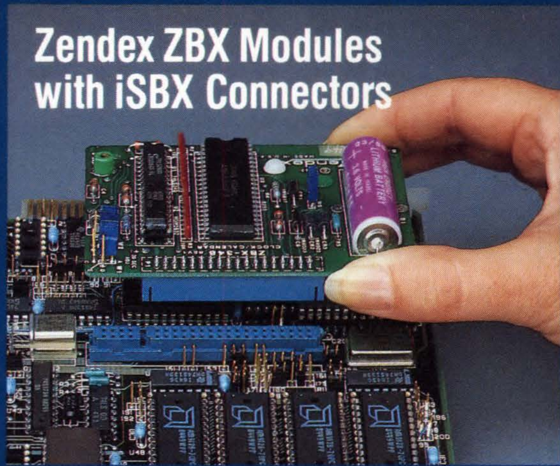
STD

MBI

PC

VME

MBII

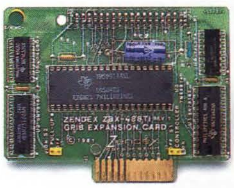
Bus + 

= Complete Expansion Flexibility

Need to expand your Bus? Zendex has made it easier than ever!

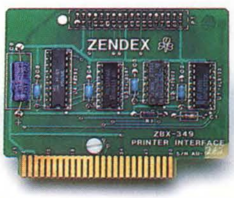
That's right. A simple iSBX* connection allows you to upgrade virtually any Bus structure with a wide variety of Zendex ZBX Expansion Modules. No more compatibility headaches. Just an easy, trouble-free way to make your system more powerful and flexible.

Zendex Corporation manufactures a broad range of standard and custom designed ZBX Expansion Modules, as well as Single Board Computers, I/O Boards, Disk Controllers, Design Aids, Chassis, CP/M Compatible Systems and RMX-86 Compatible Systems. Check the ZBX Modules below and give us a call. You'll be surprised to find how easily you can give your system the flexibility and power you need.



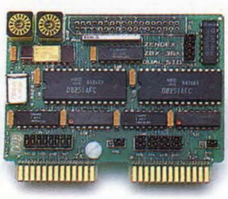
ZBX 488
IEEE-488 Interface Module

- Complete intelligent interface to IEEE-488 1978 standard.
- Standard protocol handled automatically in Talker, Listener or controller operations through a TI TMS-9914 GPIB adaptor chip.
- RMX-86 drivers available.



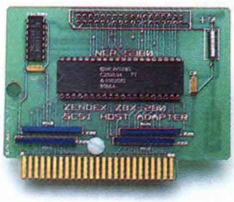
ZBX 349
Centronics Printer Interface Module

- Provides direct interface to Centronics compatible parallel printers through the SBX bus.
- Includes an eight foot interface cable which plugs into a 50 pin edge connector on the board.
- Generates data strobe and latches data for use by printer.



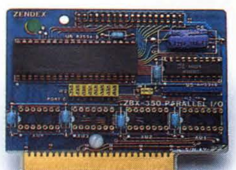
ZBX 361
Dual Serial I/O Expansion Module

- Provides two RS 232C serial communications channels using two 8251A programmable USARTs.
- Two 26 pin edge connectors for mating with standard 3M type connectors.
- Switch selectable dual baud rate clock with 16 variable rates from 50–19.2K baud.



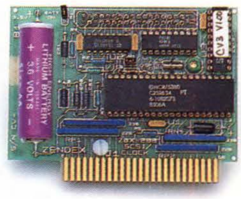
ZBX 280
SCSI Interface Module

- Supports floppy disk drives, Winchester drives and streaming tape drives.
- Supports I/O and DMA modes with DMA transfers up to 1.5M bytes/sec.
- Utilizes NCR 5380 chip which provides complete control of the SCSI bus and full handshake signals.
- RMX-86 drivers available.



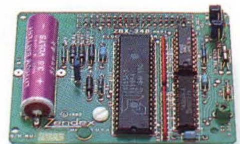
ZBX 350
Parallel I/O Expansion Module

- Provides 24 programmable I/O lines configured as three 8-bit ports through one 8255 programmable peripheral interface.
- One of three modes: basic I/O, strobed I/O or bidirectional bus interface to external buses.
- Four 14 pin sockets.



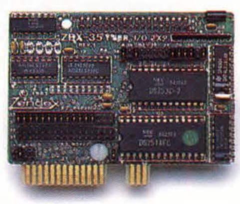
ZBX 288
SCSI with Clock/Calendar

- Full ANSI X379.2 interface.
- Utilizes NCR 5380 chip.
- Same clock/calendar features as ZBX 348.



ZBX 348
Clock/Calendar Module

- Provides seconds, minutes, hours, day, date, month and year to any host single board computer.
- Lithium battery provides power for five years.
- Accurate to within ±5 seconds per month.
- RMX-86 utilities available.



ZBX 351
Serial I/O Expansion Module

- Provides one RS232C or RS 449/442 programmable USART with software selectable baud rates through one 8251A programmable communications interface.
- Two general purpose programmable 16-bit timer/event counters are available to the host board.

ZENDEX

6700 Sierra Lane Dublin, CA 94568
415/828-3000 TWX 910-389-4009

CIRCLE 191

iSBX TM Intel Corp.

PRODUCT NEWS

Surface relays get gull-wing leads

For the first time reed relays are available for surface-mounting applications requiring the gull-wing lead formation. **Electronic Instrument & Specialty Corp. (Stoneham, MA)** is offering the packaging option on all its catalog and custom molded-DIP reed relay designs. The company chose the gull-wing over the J-type lead for quality control reasons: The visible gull-wing leads simplify inspection and testing and reduce flux buildup around solder joints. The DLS series of surface-mount relays, an enhanced version of the popular DL series, will be available by the third quarter in minimum quantities of 1000 units with a delivery time of six to eight weeks.

CIRCLE 374

Motorola discontinues 8-bit chips

Motorola Inc.'s Microprocessor Products Group (Austin, TX) is discontinuing the manufacture of several 8-bit chips. These include the MC6822 industrial interface adapter, XC6829 memory management unit, the MC6835 ROM-based CRT controller, MC6839 floating-point ROM, MC6846 ROM-I/O timer, MC6847YP and MC6847T1 video display generators, MC6808 microprocessor unit, and MC6845R1 CRT controller. They will be available for lifetime buys at closeout prices for one year with delivery scheduled within two years.

CIRCLE 375

6809E microprocessor comes in CMOS

The Semiconductor and IC Division of Hitachi America Ltd. (San Jose, CA) has introduced the first CMOS version of the industry-standard 6809E 8-bit microprocessor. Hitachi's HD6309E offers all the advantages of CMOS, including increased reliability, low power consumption, and reduced package size of the end product. It operates at up to 3 MHz, 50% faster than the NMOS version, and the device architecture permits 16-bit math calculations. Housed in a 40-pin plastic DIP, the 3-MHz version sells for $9.50 in lots of 100.

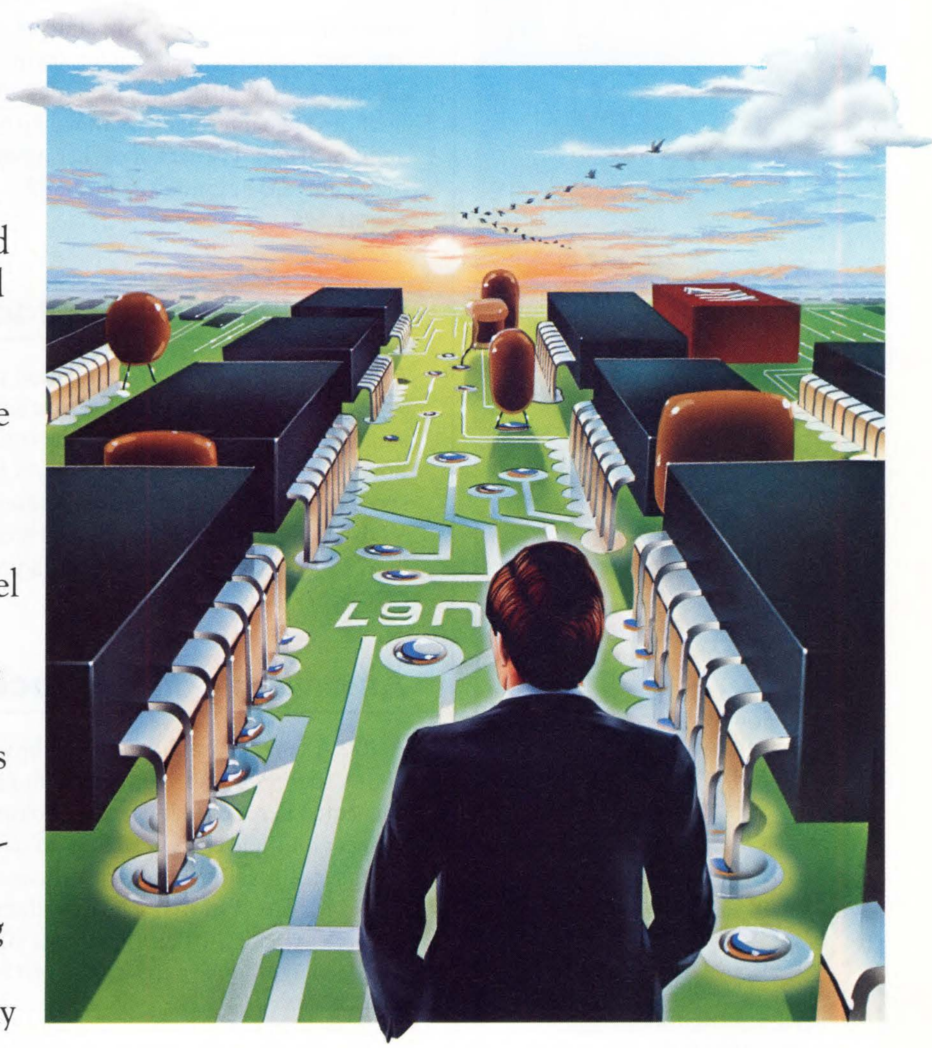
CIRCLE 376

Power amps get DESC approval

Elantec Inc. (Milpitas, CA) has been named the first source approved by the Defense Electronics Supply Center (DESC) for four amplifiers defined by three recently issued DESC drawings. The drawings cover the ELH0021 (8508801YX), a 1-A operational amplifier; the ELH0041 (8508701ZY), a 0.2-A power amplifier; and the ELH0101 (8508902YX) and ELH0101A (8508901YX) 5-A power amplifiers. Elantec is also the only supplier of these devices that is fully compliant with Revision C of MIL-STD-883.

CIRCLE 377

For the long view on Multibus, take a close look at Zitel.



If you're shipping Multibus*-based products or considering a new design, it pays to look again at what you expect from a vendor. Is it high capacity and fast dynamic RAM? Advanced processor architectures? Software compatibility with Intel? On-time delivery? Competitive pricing? Consider what Zitel can do for you.

Zitel's track record as a source of board and system level memory products for major OEM's is second to none; we've been delivering memory systems to leading corporations since 1979. And we couldn't have gotten where we are without the highest standards in design integrity, manufacturing quality, and service.

We're a substantial, publicly held company. We have the experience and resources to deliver—on time! Our engineers will work with you to smooth out the rough spots in system integration. Or design a fully custom card.

Zitel is committed to Multibus. To being a leader. And we're expanding our open bus product line to meet your future needs.

Call or write us for more information. Once you start getting Multibus boards from Zitel, you'll never look back.

*Multibus is a registered trademark of Intel Corporation.

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Zitel International, 97 Rue Souveraine, 1050 Brussels, Belgium, Phone: (322) 511-7833, TLX. 25515

zitel®

CIRCLE 193

PRODUCT NEWS

Option links emulator, logic analyzer

A new feature available on **Zax Corp.'s** (**Irvine, CA**) ICD series of emulators allows them to interface directly with logic state analyzers, such as Northwest Instruments' interactive state analyzer. The combination merges a logic analyzer's sophisticated trigger, qualification, data acquisition, and measurement capabilities with the emulator's debugging mechanisms and loan facilities. The interface—optional on all emulator models—is offered at no additional cost. Owners of earlier models not incorporating the interface may purchase upgrade kits for $599.

CIRCLE 378

Simulator provides graphic output

Allspice, an analog circuit simulation program for the IBM PC, is now a suite of programs that can generate graphic output, manage a library of standard components, and link the components to the user's circuit. Additionally, Allspice will include a GaAs FET model for microwave or high-speed digital circuit simulation. **Acotech** (**Menlo Park, CA**) is offering the VDI-based graphics output post-processor for the Allspice program at a cost of $225. A package containing both programs sells for $575.

CIRCLE 379

Amplifiers can be stacked in series

A 100-A current amplifier, which broke the weight and size barrier for 100-A sources by cutting the weight and panel height by half, can now be connected in series to increase the output compliance voltage. Test labs that connect multiple current sources in parallel to deliver 1000 A at 3 V can now reconnect the same sources in various series-parallel combinations for 200 A at 15 V or 500 A at 6 V. The manufacturer, **Shepherd Scientific Inc.** (**San Diego, CA**), reports that the Model 100 current sources can be stacked up to five deep to produce a maximum of 15 V. Prices start at $4150.

CIRCLE 380

SCSI chip lowers power requirement

NCR Corp. (**Dayton, OH**) has released a CMOS version of its 5380 Small Computer System Interface (SCSI) chip. The new device, designated the NCR 53C80, offers reduced power requirements and increased performance without sacrificing low cost, flexibility, and space efficiency. Although functionally equivalent to its NMOS counterpart, the single-chip controller has gained four ground lines to minimize the effects of ground plane noise and to allow output buffers to switch more quickly.

CIRCLE 381

PRODUCT NEWS

68020 interface links to analyzer

The HP 64675 preprocessor interface is the first in a series of MC68020 microprocessor support products from **Hewlett-Packard Co. (Palo Alto, CA).** It provides an interface between MC68020-based systems and an 80- or 120-channel HP 64620S logic state/software analyzer. Software supplied with the interface displays measurements in MC68020 assembly language. The module installs in two HP 64650A general-purpose preprocessors, which connect to the analyzer. Interface prices start at $4000.

CIRCLE 382

Autorouter speed quadruples

Personal CAD Systems Inc. (Los Gatos, CA) offers enhanced versions of its entire PC-based CAD software line—PC-Caps, PC-Logs, and PC-Cards—under its latest release. By changing memory address routines and overriding certain system default routines, autorouting completion times have been improved by as much as 400%. Other enhancements include increased drawing speeds on large schematic and circuit board designs, automated editing, and more detailed documentation. Pricing remains the same as for the previous release, starting at $4950.

CIRCLE 383

Pascal is certified for MS-DOS

Oregon Software's (Portland, OR) Pascal-2 has become the first MS-DOS Pascal compiler to be certified at the highest level of the international standard. Certification assures users that the software conforms to ANSI, FIPS, and ISO standards. Validated at Level 1 of the ISO standard, it supports conformant array parameters, providing users with the ability to write flexible arrays. Pascal-2 runs under MS-DOS on the IBM PC and AT. It is also available as a cross-compiler from VAX/VMS to MS-DOS.

CIRCLE 384

Hayes modem shrinks to half-card slot

A new version of the Smartmodem 1200B internal modem board from **Hayes Microcomputer Products Inc. (Atlanta, GA)** works in either full or half-size card slots. Installation in a half-size slot frees the longer slots for other peripheral boards. The modem card offers all of the features of the previous version, including call-progress monitoring, rotary and DTMF or PABX dialing commands, Hayes standard AT command set for compatibility with other Hayes modems, and 1200- or 300-bits/s transmission speeds. Full production quantities will be available by mid-summer. Estimated retail price is $549.

CIRCLE 385

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Editor
ELECTRONIC DESIGN
10 Mulholland Dr.
Hasbrouck Heights, NJ 07604

PRODUCT NEWS

Boards increase test system I/O

Expanding the usefulness of its PC1000 test and measurement system, **Vistar Corp. (Tampa, FL)** has introduced several products that extend the IBM PC-based system's control functions and number of test points that can be monitored. The PC1852 is a single board with a 16-to-1 (or 8-to-2) relay multiplexer, 16 digital driver outputs, and 8 digital inputs. Another version, the PC1854, provides the same digital I/O, minus the multiplexer. Screw terminal mating boards are also available for both the PC1852 and PC1854. Prices range from $90 to $375.

CIRCLE 386

Static RAMs get high-speed option

To expand the number of options available to memory designers, **Electronic Designs Inc. (Hopkinton, MA)** is offering high-speed versions of its static RAM modules. The 4k-by-8-bit CMOS RAM, designated the 88H04C, can now be specified for an access time of 25 ns for both commercial and military applications. Similarly, the 88H16C, a 16k-by-8-bit part, is available in commercial and MIL-STD-883 equivalent processed versions with speeds of 35 ns. Two 16k-by-4-bit military modules, the 84H16C and 84H16CL, are also available with 35-ns access times (25 ns commercial).

CIRCLE 387

Peripheral chips support CMOS μPs

An extensive family of CMOS peripheral chips has been developed by **Oki Semiconductor (Sunnyvale, CA)** for use with the company's families of 80C86/88-2 and 80C85A-2 microprocessors. The circuits provide the critical elements needed for complex low-power applications, such as hand-held terminals and data collection systems. Devices include a static RAM-timer with I/O, 8-bit I/O port, DMA controller, asynchronous interface, interval timers, peripheral interface, interrupt controller, clock generator, bus controller, and ROM with I/O. Prices range from $3.70 to $8 (plastic DIPs) in lots of 100.

CIRCLE 388

IBM PC AT gets faster processor

An 8-MHz microprocessor is now available on the IBM PC AT, boosting by more than 30% the processor speed of previous AT models. **IBM Corp. (Boca Raton, FL)** has also doubled the storage capacity of its popular PC XT. The three new XT models come with 256 or 512 kbytes of memory and one or two 360-kbyte 5¼-in. disk drives. The new models are also available with 20 Mbytes of fixed-disk drive storage—twice that of earlier XTs.

CIRCLE 389

ANNUAL REPORTS

Annual and interim reports provide more than financial information. They often include the first public disclosure of new products, new techniques, and new directions of a company. Reports often contain superb analyses of the industry that a company serves.

Amp Inc. Electrical and electronic connection devices.
CIRCLE 390

Andersen Group Inc. Analog rf devices, digital video products, and ultrasonic imaging products and services.
CIRCLE 391

Bishop Graphics Inc. Printed circuit design products.
CIRCLE 392

Corning Glass Works. Specialty materials, electronics, and telecommunication products.
CIRCLE 393

Eaton Corp. Electronic and electromechanical products, automotive components, and defense electronics.
CIRCLE 394

Ferro Corp. Coatings, colors, ceramics, thermoplastics, and specialty chemicals.
CIRCLE 395

General Electric Co. Main businesses include lighting, construction equipment, major appliance, motor, transportation, aerospace, and factory automation and turbine.
CIRCLE 396

GenRad Inc. Test and measurement instruments and systems.
CIRCLE 397

Gould Inc. Information systems, instrumentation and automation systems, defense systems, and materials and components.
CIRCLE 398

Hazeltine Corp. Display systems, communication systems, and electronic identification for the military.
CIRCLE 399

Honeywell Inc. Major lines of business are aerospace and defense, control products and systems, and information systems.
CIRCLE 400

Intergraph Corp. Interactive computer graphics systems.
CIRCLE 401

Kearney-National Inc. Electrical power distribution equipment; electrical and electronic components.
CIRCLE 402

Measurex Corp. Computer control systems for manufacturing processes.
CIRCLE 403

Moniterm Corp. High-resolution video display monitors.
CIRCLE 404

North American Philips Corp. Brand-name products include Philips, Ohmite, Dialight, Amperex, Airpax, Mepco/Centralab, and many more.
CIRCLE 405

RTE Corp. Transformer products, capacitors, power supplies, and line conditioning equipment.
CIRCLE 406

Star Technologies Inc. Very-high-speed scientific computers for specific applications.
CIRCLE 407

Stratus Computer Inc. Fault-tolerant continuous-processing systems.
CIRCLE 408

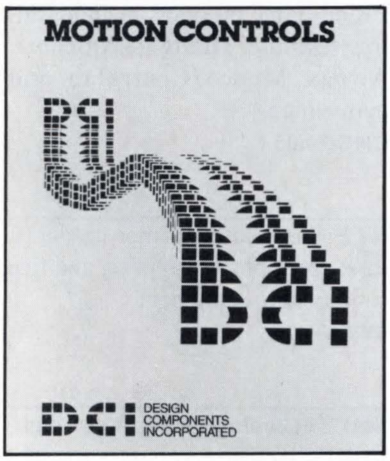
Tektronix Inc. Electronic measurement, design, display, and control instruments and systems.
CIRCLE 409

TeleVideo Systems Inc. Video display terminals, computer systems, file servers, and printers.
CIRCLE 410

Tracor Inc. Passive electronic countermeasures systems, military telecommunication terminals, commercial navigation systems, analytical instruments, and electrical and electromechanical components.
CIRCLE 411

Vitramon Inc. Monolithic ceramic and porcelain capacitors.
CIRCLE 412

Motion control



A 12-page brochure provides engineering selection and application data on high-performance stepping control drives and accessories. The literature presents both packaged stepper controls as well as individual motion components such as drivers, keypad controls, position displays, and others.

Design Components Inc., 1 Kenwood Cir., Franklin, MA 02038; (800) 341-4811 or (617) 528-7300.

CIRCLE 413

Differential transformers

Bulletin 107 discusses the theory and application of linear variable differential transformers (LVDTs). It also provides a complete showing of all the Columbia units. The devices described cover a variety of ranges and sizes. Also featured are oscillator demodulators and digital display systems for pressure and displacement control.

Columbia Research Laboratories Inc., MacDade Blvd. and Bullens La., Woodlyn, PA 19094; (215) 872-3900.

CIRCLE 414

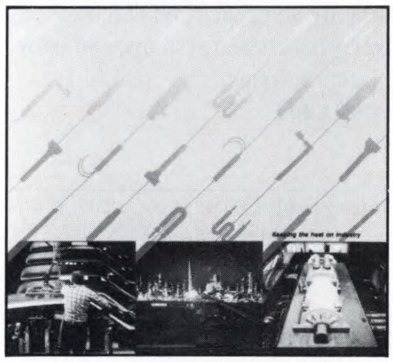
Building an automated drill

An application note describes the functions, features, drive methods, and source programs of an automated drilling machine using the Cyberpak High Stepper motion control system. The general approach used to provide this functionality is common to many automation projects and should prove informative to engineers and designers of hardware and software functions of stepping motor machine and robotic control systems.

Cyberpak Co., P.O. Box 38, Brookfield, IL 60513; (312) 387-0802.

CIRCLE 415

Heaters and controls

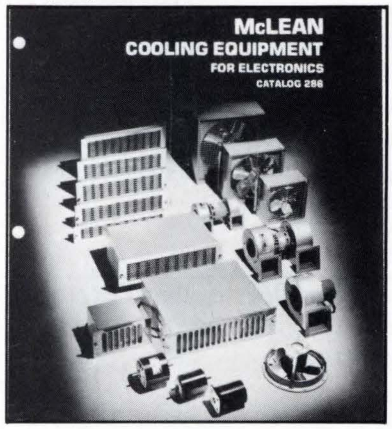


Of interest to OEMs and design engineers, this 160-page catalog contains technical data to assist in the calculation of heating requirements and the selection of proper heaters and controls. The catalog introduces Wellman's new line of heating cable and describes the company's expanded line of heater controls and accessories.

Wellman Thermal Systems Corp., 1 Progress Rd., Shelbyville, IN 46176; (317) 398-4411.

CIRCLE 416

Cooling equipment



Air-moving devices and accessories for cooling electronics are the subject of McLeans catalog no. 286. It is composed of a combination of technical discussions and product pages describing packaged blowers, centrifugal blowers, fans, cooling accessories, and MIL-specified equipment. A primer on basic design and selection is followed by an introduction to the company's motor products, acoustic noise determinations, and a discussion of dust filters.

McLean Engineering, 70 Washington Rd., Princeton Junction, NJ 08550; (609) 799-0100.

CIRCLE 417

Getting the most out of T-1

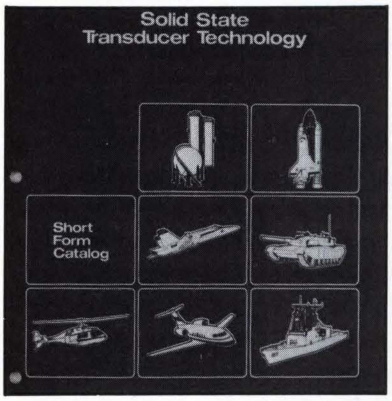
Four technical backgrounder brochures discuss how telecommunication users can maximize the efficiencies and cost effectiveness of T-1 transmission facilities. Digital voice is the subject of two brochures, while the other two deal with facilitating T-1 networking.

Timeplex Inc., 400 Chestnut Ridge Rd., Woodcliff Lake, NJ 07675; (201) 930-4600.

CIRCLE 418

NEW LITERATURE

Solid-state transducers



Describing a wide range of solid-state transducers, this eight-page short-form catalog contains descriptive information on Kulite's complete line of pressure transducers. Product types include miniature and instrument, flight-qualified, and environmentally protected. Also described are P-1 converters, accelerometers, semiconductor strain gauges, and load cells.

Kulite Semiconductor Products Inc., 1039 Hoyt Ave., Ridgefield NJ 07657; (201) 945-3000.

CIRCLE 419

Darlington transistor modules

A 48-page catalog provides data on single and dual Darlington power transistor modules. The Transipack series is available in a variety of packages, all with parallel-connected fast-recovery inverse diodes. Electrical, mechanical, and thermal specifications are included in the literature, along with circuit diagrams, dimensional drawings, and performance curves.

Semikron Inc., 11 Executive Dr., Box 66, Hudson, NH 03051; (800) 258-1308 or (603) 883-8102.

CIRCLE 420

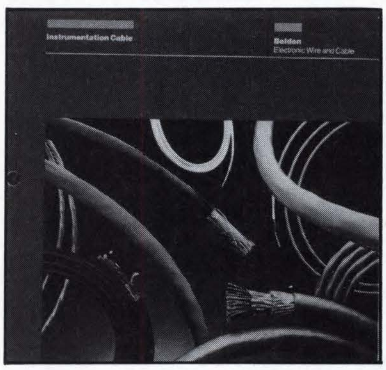
NASA-developed software

The 1986 edition of the COSMIC software catalog describes 1100 NASA-developed computer programs. Application categories include structural mechanics, expert systems, turbomachinery analysis, control systems and robotics, computer graphics, thermal analysis, image processing, and dozens of other areas relating to NASA projects.

COSMIC, The University of Georgia, Computer Services Annex, Athens, GA 30602; (404) 542-3265.

CIRCLE 421

Electronic wire and cable



Cables designed for a variety of electrical and electronic applications are described in a 24-page catalog. Included are descriptions of each cable's applications, construction, and features, along with product illustrations, gauge size, physical characteristics, electrical specifications, and other technical data to assist users in their cable selection.

Belden Electronic Wire and Cable, P.O. Box 1980, Richmond, IN 47375; (800) BELDEN4 or (317) 983-5200.

CIRCLE 422

NEW LITERATURE

Flat cable connectors

Complete technical specifications and diagrams for a line of flat cable connectors are provided in a 28-page brochure. The line includes headers and sockets that are interchangeable with industry-standard flat cable connectors. Other items described in the publication include card-edge connectors, premounted DIP and pc board transition connectors, flat cable, and pin and socket strips.

Amlan Inc., 97 Thornwood Rd., Stamford, CT 06903; (203) 322-1912.

CIRCLE 423

Radio-frequency components

Vanguard's 29-page brochure describes a line of miniature and subminiature rf components. Specifications, as well as dimensional drawings, are provided for such products as wideband transformers, chip inductors, toroidal inductors, variable inductors, pulse transformers, reactors and power transformers, and custom rf filters.

Vanguard Electronics Co. Inc., 1480 W. 178th St., Gardena, CA 90248; (213) 323-4100.

CIRCLE 424

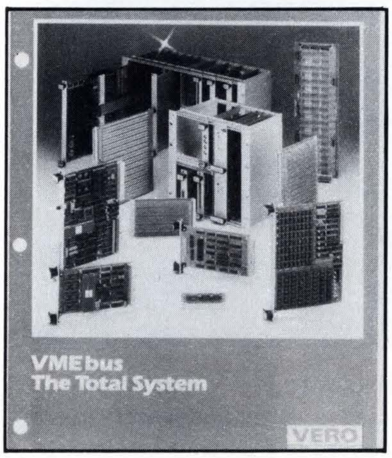
In-circuit board tester

A 16-page brochure describes the HP 3065 family of in-circuit board test systems and how these products can increase user productivity in the test workcell. It focuses on such topics as test capabilities, reliability and service support, and programming and networking functions. Several photographs and diagrams provide an overview of the capabilities of the test system.

Hewlett-Packard Co., Inquiries Manager, 1820 Embarcadero Rd., Palo Alto, CA 94303; call local sales office.

CIRCLE 425

System components for the VMEbus



A complete line of VMEbus components are presented in a 36-page catalog. Modules include 68000-based CPUs, high-density static and dynamic memories, peripheral and communications interfaces, and analog I/O functions. These are supported by a full line of VMEbus backplanes and card frames, prototype boards, and power supplies. All components conform to both IEC and DIN specifications.

Bicc-Vero Electronics Inc., 40 Lindeman Dr., Trumbull, CT 06611; (203) 372-0038.

CIRCLE 426

Catalog of technology reports

Electronic Trend Publications, a technology market research company, is offering a 24-page catalog of reports for the electronics industry. Report topics include semicustom ICs, GaAs ICs, digital signal processors, 32-bit microprocessors, VHSICs, VLSI device packaging, surface-mount technology, LSI/VLSI automatic test equipment, CAE workstations, laser-based IC processing equipment, and management guides for PC-driven expert systems and technology licensing.

Electronic Trend Publications, 10080 N. Wolfe Rd., Suite 372, Cupertino, CA 95014; (408) 996-7416.

CIRCLE 427

VMEbus product directory

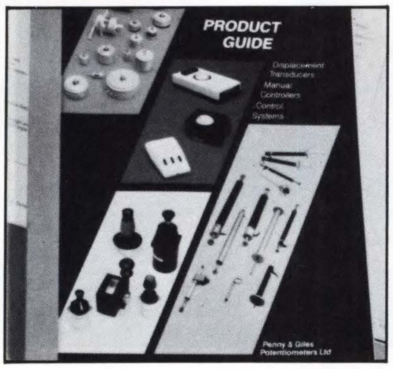
The VMEbus International Trade Association has published the Winter 1986 edition of the *VMEbus Compatible Products Directory*. This edition, which is 50% larger than the midyear 1985 book, lists over 1500 products from more than 150 manufacturers. It covers microcomputer boards, subsystems, bus interfaces, software, accessories, hardware packaging, and more. It also contains an expanded cross reference.

VITA, 10229 N. Scottsdale Rd., Suite E, Scottsdale, AZ 85253; (602) 951-8866. $14.95.

CIRCLE 428

NEW LITERATURE

Measurement and control



A comprehensive product guide contains information on measurement and control instrumentation. It provides complete specifications on a line of potentiometers, displacement transducers, manual controllers, and ancillary equipment such as voltage-to-current converters and power supplies. The instruments are suitable for a wide range of industrial, marine, and avionics applications.

Penny & Giles Ltd., 1640 Fifth St., Santa Monica, CA 90401; (213) 393-1497.

CIRCLE 429

Electronic components

A fully illustrated catalog presents 40 pages of electronic components for a variety of audio/video, appliance, and computer-related applications. Technical specifications are provided for all products, which include over 30 styles of carbon and cermet potentiometers, as well as fixed resistors, capacitors, attenuators, switches, surge suppressors, and block components.

Noble U.S.A. Inc., 151 Stanley St., Elk Grove Village, IL 60007; (312) 364-6038.

CIRCLE 430

PROFESSIONAL NOTEBOOK

BY CAROLE PATTON

U.S. industry "hooked" on foreign engineers, concludes NSF survey

Engineering activists rail on about them, legislators have proposed—unsuccessfully—to change them, but somehow immigration laws aimed at shipping foreign engineering students home after graduation tend to stick in our craw. There is, after all, something decidedly un-American about it. How can our melting-pot nation spend millions to relight Liberty's torch in New York Harbor, yet slam the door on freedom-seekers?

But new evidence from the National Science Foundation demands re-evaluation, and some answers. An NSF survey of 300 top U.S. firms—together employing 75% of all engineers and scientists working in American industry—indicates that more than half (52%) employ foreign engineers in the electronics industry alone. In fact, nearly one out of ten engineers working in American industry today is foreign.

Just how much of a job threat do those figures pose? Based on the NSF's survey, 14% of all engineers and scientists hired by the 300 firms between June 1984 and June 1985 were noncitizens. Silicon Valley companies hired two foreigners out of every three engineers. American industry, concludes the survey, now has a "substantial dependency" on foreign supplies of scientists and engineers.

Under current immigration laws, foreign citizens who immigrate to the U.S. but have no family here can be sponsored by a U.S. employer. In fact, according to the NSF, in 1984 alone two-fifths of the foreign engineers and scientists hired were company-sponsored. To get a certification from the Department of Labor, an employer must prove that no qualified U.S. worker was available for the job. Most electronic companies polled said they sponsored foreign engineers without permanent resident status, and two-thirds of those sponsors said they even paid all costs, including application and legal fees.

The United States is one of the few countries in which a foreign student can work and go to school at the same time. All it takes is the school's permission—and a rubber stamp of approval from the Department of Immigration.

Meanwhile, the American Electronics Association reports 60,000 fewer jobs available this year than last.

Even more telling is the latest Deutsch, Shea & Evans index: Engineering recruitment—at rock-bottom levels during most of 1985—remains mired. The company's high-technology recruitment index draws on employment ads for degreed engineers and scientists seen in key U.S. papers and journals. (1961, the base year, was equal to 100.)

Figures for February dipped to 119 from 128 in January. In addition, the three-month running average for January hit 115, a full 11 points below last January.

Companies polled by the NSF say the foreign applicants are more qualified: 35% have doctorates, 25% have a master's degree. In comparison, 12% of the American engineers hold a PhD, 29% a master's. Older engineers who can't get jobs—ostensibly because they're "overqualified"—won't be amused by this one: the same companies say they hire foreigners because of a "shortage" in qualified U.S. candidates . . . That's a laugh, given today's job market.

Foreign engineers may earn more PhDs, but they are not inherently better qualified than U.S. engineers. Most companies hire on the basis of job experience, and engineers themselves say they keep technically "fit" by practicing their profession. As for the shortage theory, it's been debunked so well—and so often—it isn't worth comment.

THAT'S NOT FAIR

What is worth talking about are immigration policies that permit a company to control an employee's green card, essentially turning him or her into an indentured servant. Moreover, present laws allow companies to save even more with foreign engineers—noncitizens are exempt from payouts for unemployment and social security taxes.

Some change is under way. This year, for example, foreigners who work more than 182 days in the U.S. will pay some income tax to Uncle Sam. But why not make non-U.S. citizens completely equal under taxation laws? Those dollars could be refunded when, and if, the alien returns home.

Nobody wants to deny opportunity to anyone. But something is seriously wrong with present policies. Government systems that make hiring foreigners more profitable than domestic prospects encourage exploitation of both groups. It's important to keep the torch burning, but let's not burn ourselves in the process.

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Electronic Systems Engineers
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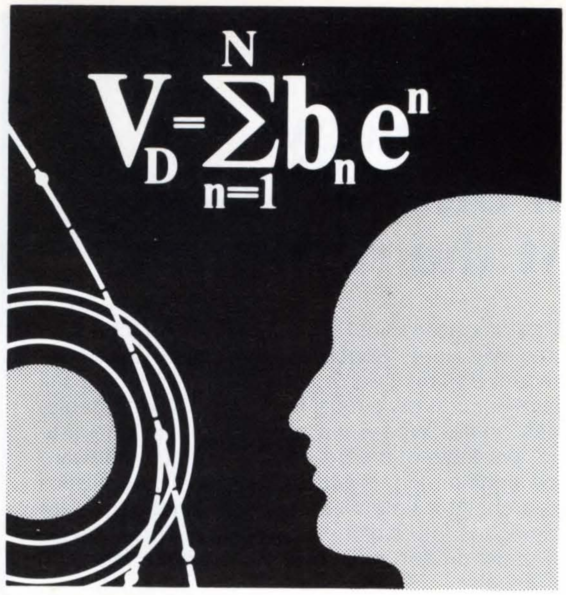
Strategic Components Engineers — Sole responsibility for strategic planning and delivery of a project's identified electrical and hardware parts. Requires direct experience in applying MIL-SPEC E5400, P11268 and MIL-STD 965, 785, 454. Prefer BSEE with 5-7 years related reliability and components analysis experience for a defense contractor or semiconductor reliability organization. Contact Jonn Nolitt.



Sr. Fuze Engineers — Participate in radar proximity fuze systems development. Requires extensive radar experience for application to surface approach fuzing, plus proposal preparation and effective customer briefings. Prefer BSEE with a minimum of 5 years related experience. Contact Bob Eddy.

Sr. Electrical Engineers — Task leader responsibility on microcomputer controlled fuze programs. Experience in digital/microprocessor and analog circuit design in mil-spec environment. Will lead major design tasks. Prefer BSEE with 5 years related experience. Contact Bob Eddy.

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Range Instrumentation Engineer — Requires BS in EE or a scientific discipline, plus a minimum of 2 years experience in missile range instrumentation design, fabrication and installation, or related hardware and firmware applications. A thorough understanding of circuit or firmware design with systems applications is essential.

Radar Engineers — Will be involved in conception, design, fabrication and installation, requiring BSEE and 7 or more years related experience. MSEE preferred.

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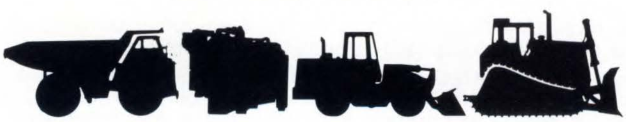

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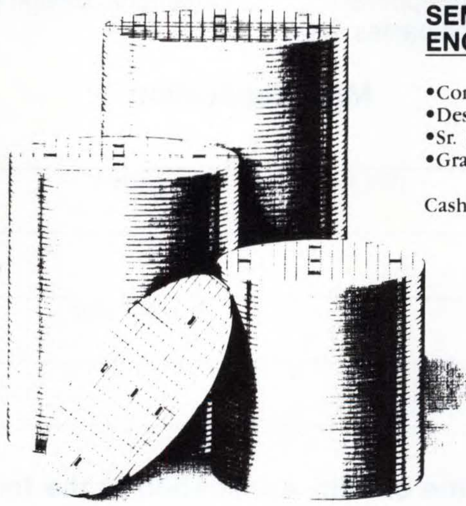

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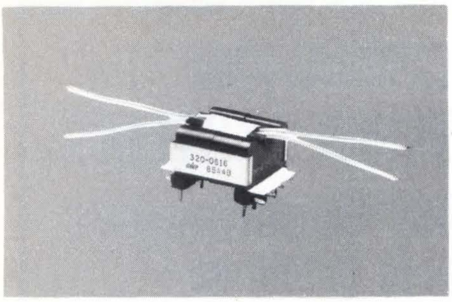

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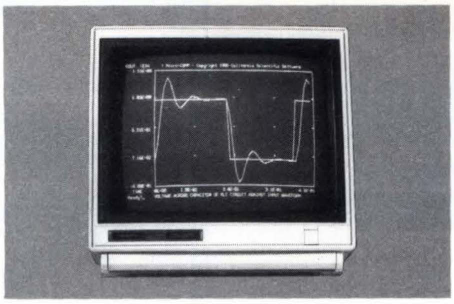
TRANSFORMERS **251**



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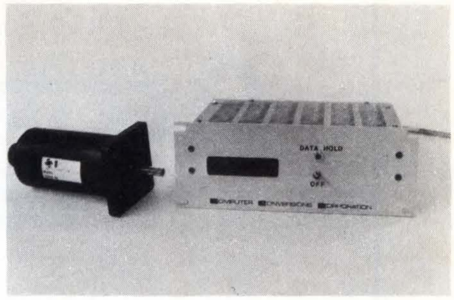

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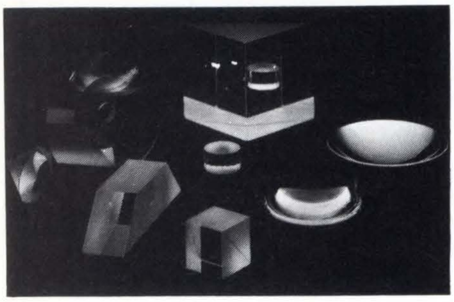

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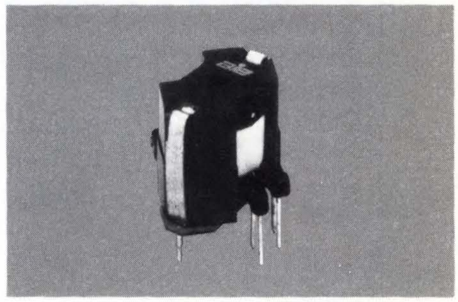
ANALYZER CONTROLLER **255**



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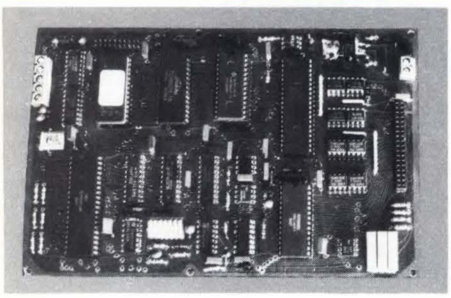

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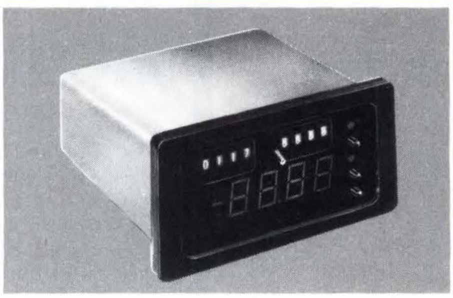

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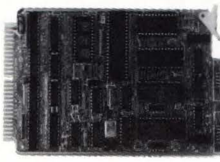
WinSystems STD BUS

CROSS REFERENCE/INTERCHANGEABILITY GUIDE



MOSTEK, Pro-Log, and INTERSIL STD BUS Plug Compatible Cards . . . WinSystems offers over 78 functional and nearest replacement STD and CMOS STD Bus boards including the MDX-CPU2A, CPU2B, UMC2, SIO2, PIO, DRAM and 7304, 7507, 7605, 7706, 7709, 7710, 7805, 78C13, 7815, plus more. For a complete Cross Reference Guide call: **WinSystems, Inc.**, PO Box 121361, Arlington, TX 76012; 817/274-7553.

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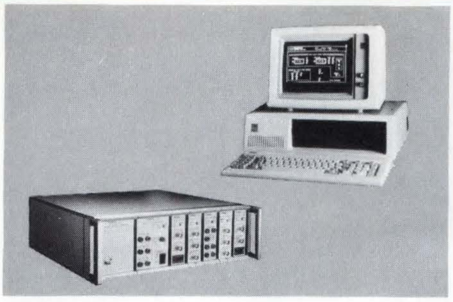

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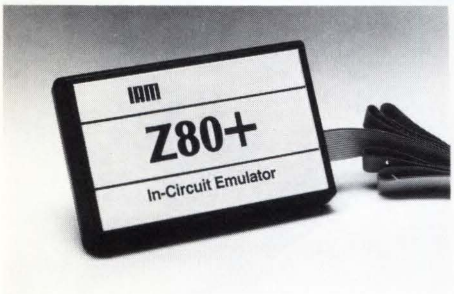

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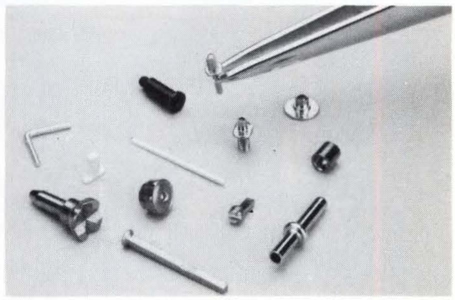

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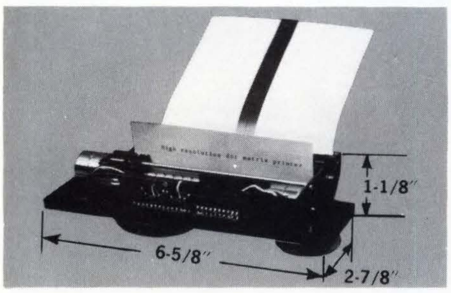

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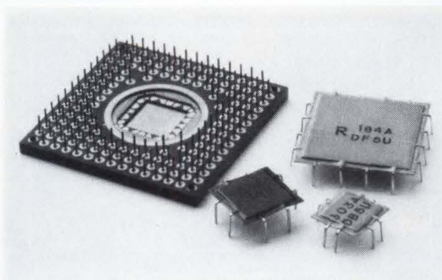

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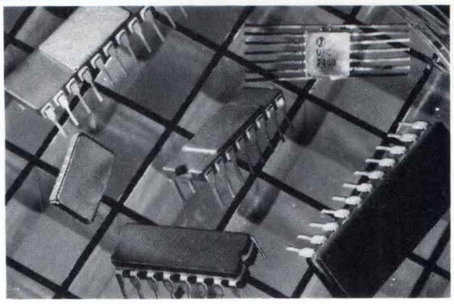

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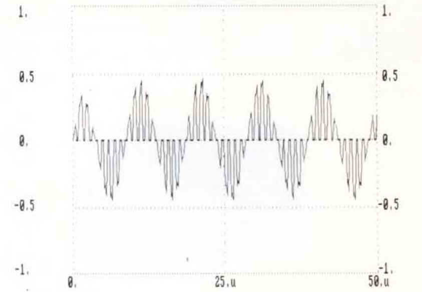

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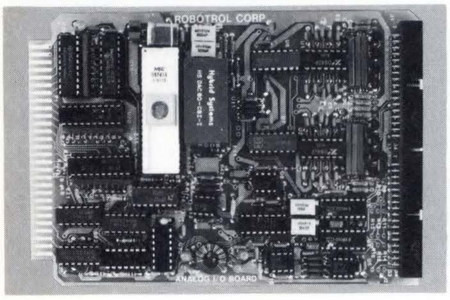

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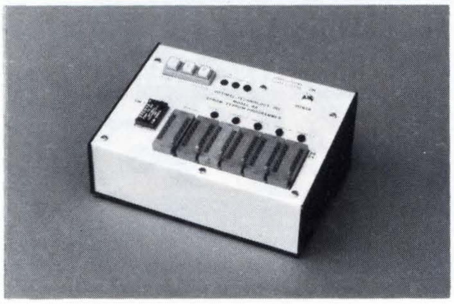

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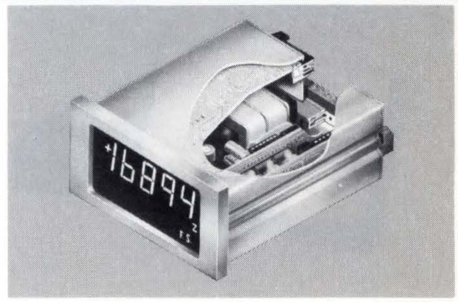

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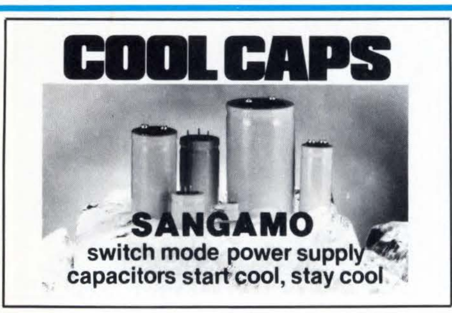

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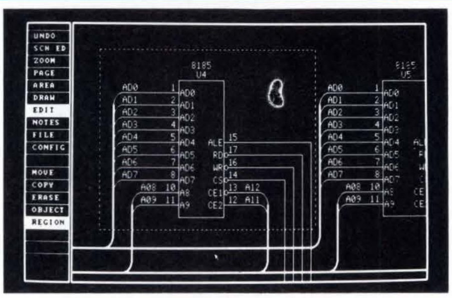

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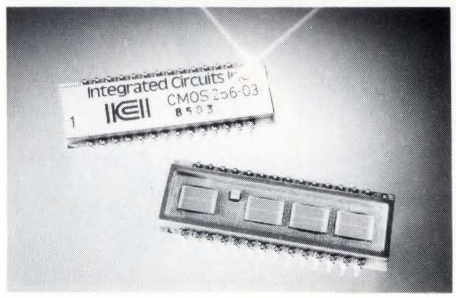

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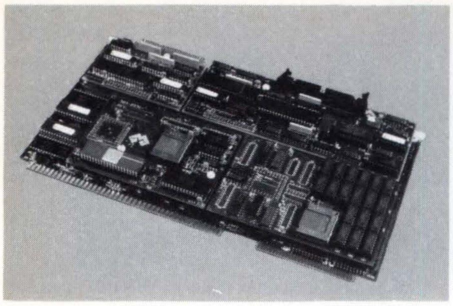

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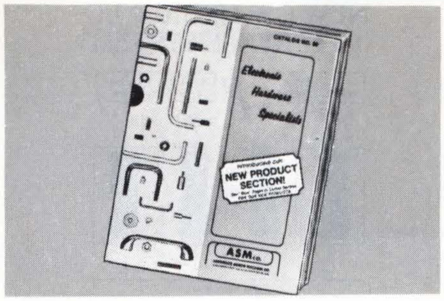

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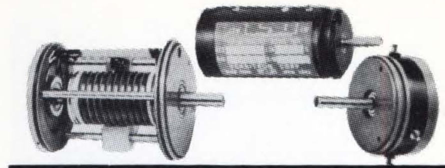

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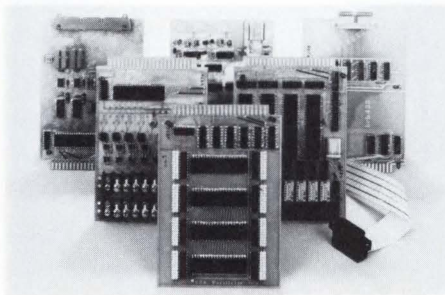

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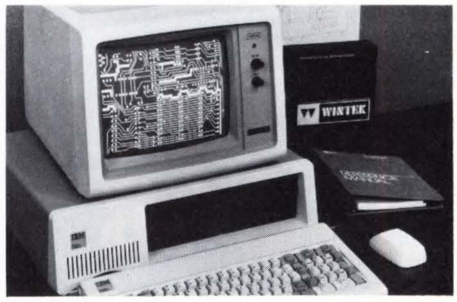

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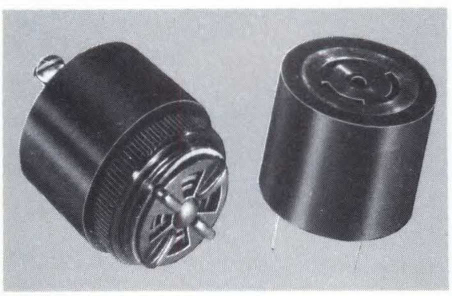

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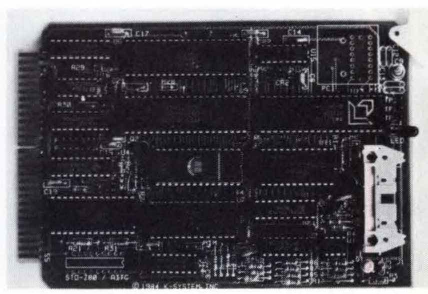

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K-SYSTEMS, INC. **286**

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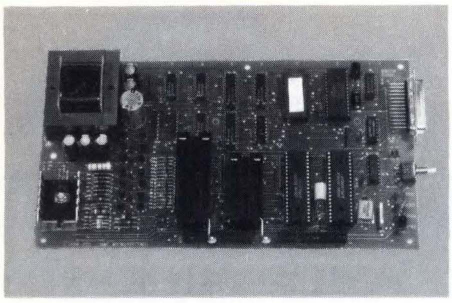

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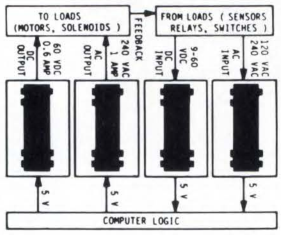

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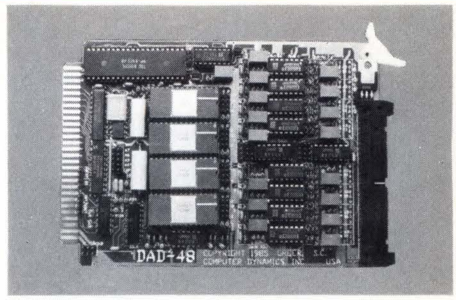
MODULES **288**



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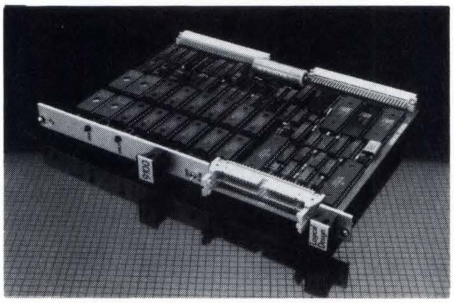

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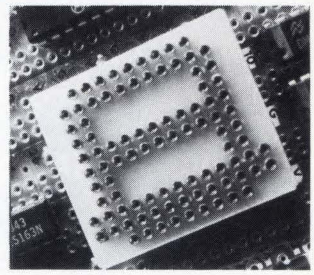

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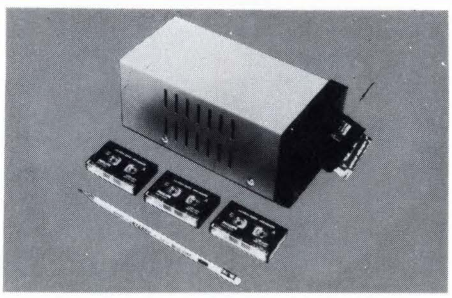

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