ALLIANCE'S 1-MBIT DRAM RUNS AS FAST AS STATIC RAMs/107

ZEHNTEL HALVES COST OF TESTING MIXED-LOGIC BOARDS/121

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Electronics®

U.S. MARKET FORECAST

PAGE 63

PUSHING FOR CONTINUED GROWTH IN 1988...

...BUT WALL STREET MAY BE SIGNALING A DIFFERENT DIRECTION

Before your company takes off, read our flight plan.

When your firm is aggressively planning to increase its market share you need a solid relationship with an experienced broadline semiconductor supplier—one with worldwide manufacturing and marketing capability.

A company that provides yours with TQRD; technology, quality, reliability—and delivers them dependably.

Signetics is that kind of company.

We recently published a 16 page article in *Electronic Business*. It's our assessment of the present—and our flight plan for the future.

Before taking off to assume a leadership position in your industry you should read it—we know your competitors will.

To get your complimentary reprint of this article write to: Signetics Corporation, Mail Stop 27A, P.O. Box 3409, Sunnyvale, CA 94088-3409.

Good reading and happy landings from Signetics. The company with one standard—zero defects. And one goal—customer satisfaction.

One standard. 0 defects.

Signetics

a subsidiary of U.S. Philips Corporation

National Semiconductor

Finally, graphics to match your imagination...now more than ever.

INTRODUCING THE FIRST EFFECTIVELY PARTITIONED VLSI ARCHITECTURE FOR TRULY FLEXIBLE GRAPHICS SYSTEMS DESIGN

Imagine a graphics architecture so powerful, you can achieve 16K-by-16K resolution. So effective, you can add virtually unlimited planes of color without degrading performance. So flexible, you can integrate it into an existing design or use it to build an entire range of new systems.

That's the Advanced Graphics Chip Set from National Semiconductor.

By using a multiple-chip, modular approach, the Advanced Graphics Chip Set avoids the design compromises and limitations of single-chip solutions.

That gives you two unprecedented benefits: *performance* and *flexibility*.

Which means you can design exactly the type of system you need with exactly the level of performance your application demands.

For example, you can integrate part of the chip set with an existing general-purpose microprocessor for a low-end display.

Or you can utilize the chip set's full capabilities for a high-end, high-performance, high-resolution CAE/CAD workstation or laser printer — with virtually unlimited planes of color. Yet with the same high-speed performance as a black-and-white application.

In fact, you can design an entire range of graphics systems without having to "reinvent the wheel" each time, by using the same hardware building blocks and the same central software in each of the systems.

THE ADVANCED GRAPHICS CHIP SET

Now expanded for even more design flexibility and freedom.

2 BitBlt Processing Units (BPUs). 20-MHz devices that control data movements within their own dedicated memory planes or between those planes and other memory planes in multi-color systems. AVAILABLE NOW.

4 Video Clock Generators (VCGs). Timing and control generators providing all the synchronization signals needed by a graphics system. Pin-programmable pixel frequencies for both low-frequency (125 MHz) and high-frequency (225 MHz) applications. AVAILABLE NOW.

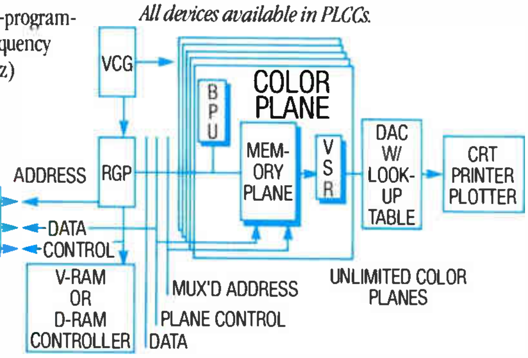
2 Video Shift Registers (VSRs). Parallel-to-serial shift registers capable of serial-output rates up to 225 MHz. Compatible with 10K ECL outputs or with 100K ECL outputs. AVAILABLE NOW.

3 Video RAM Controllers (VRCs). Memory-array controllers for dual-port video RAMs from 256K to 4 Mbits, including dual-access arbitration logic for multiple-CPU applications. AVAILABLE NOW.

A total of 11 chips — all introduced in a single year between Siggraph 1986 and Siggraph 1987. An unmatched commitment to graphics system design.

And soon another family member, now in beta-site testing: **Raster Graphics Processor (RGP).** A fully programmable, high-performance microprocessor specially tuned for graphics applications.

All devices available in PLCCs.



THE MULTIPLE-CHIP SECRET

The secret to all this flexibility and performance is our unique multiple-chip, modular approach. Rather than trying to squeeze all the important graphics functions onto a single chip — which would require some significant design and performance compromises — we've partitioned appropriate functions onto individual building-block ICs. This allows us to optimize the design of each chip, and allows you to optimize your own design for your particular application.

GRAPHICS WITHOUT LIMITS

What matters most about the Advanced Graphics Chip Set, of course, is what it does for *you*. And that answer is clear when you consider its high performance, its modular approach, its open architecture, and its programmability: It gives you graphics without limits. It gives you true design freedom. It gives you the opportunity, for the first time, to design a graphics system "custom fit" to your exact specifications.

So what are you waiting for? If you're tired of those limited single-chip solutions bogging down your designs, take a look at the Advanced Graphics Chip Set. And learn how you can design a graphics system to match your needs . . . as well as your imagination.

For more information and availabilities, just contact your local National Semiconductor Sales Engineer or write:

National Semiconductor
Advanced Graphics, MS 23-200
P.O. Box 58090
Santa Clara, CA 95052-8090

National Semiconductor

Circle 1 on reader service card

Electronics

Jeremy Young's first reaction when he met with the people from Quantitative Technology Corp. to discuss their Software Foundry was, "This sounds really great—if it works!" So Jeremy, our Features Editor, did what any good editor should do: he contacted users as well as others in the industry to talk about the product. What he found out is that not only does the "foundry" work but it's "Almost too good to be true," as we title the cover package beginning on p. 47.

YOUNG: Finding out if it really is too good to be true.

"What the company has been able to do," says Jeremy, "is combine retargetability with high-level optimization." Or, to translate into shorter words, optimization work is normally done in the context of a fixed and specific architecture. But the designers at Quantitative Technology, a small company in Beaverton, Ore., have developed optimization techniques that work with any arbitrary microcoded architecture.

"The thing that grabs you at first," says Jeremy, "is that we have been talking for years about software driving hardware. Now, at last, here's a practical way to design a computer to run particular software. In effect, you build the computer around the software so that what you wind up with is an application-specific processor."

But that's not all. As Jeremy describes it, there is another equally important aspect to the tool set and the story. "The Software Foundry eases the horrendous task of writing microcode. The industry can't find enough people to do the job, and when it does they are screaming to get out after a few years. But since the Foundry produces optimized microcode from high-level languages it eliminates that tedious task. So the new tools could help reverse the trend away from the microcode approach."

There's also a considerable financial return to be gained from the Software Foundry. "When I was doing reporting for the Inside Technology piece, I was told by experts in the field that they estimate the cost of microcode as 50¢ to $2 a bit. Then figure that microcode instructions are 64 to 256 bits wide apiece with many fields in them, and that a system may have 10,000 such instructions when it leaves the plant. We're talking big money here."

In talking to users, Jeremy turned up companies—most asked that their names not be used—that "are trying to get their hands on these tools even before they are announced." One company that didn't mind being quoted by name, Pixar, of San Rafael, Calif., finds that Quantitative Technology's optimizer is performing well in tests. And another, a major vendor of graphics and simulation hardware, expects to be using the tools very soon.

In view of the savings in labor and cost, their interest is not difficult to fathom. "You can sum it all up by pointing out that Software Foundry reduces the time needed to develop equivalent tools for a new machine from about 10 man-years to an estimated 2 man-months—the time it takes to write a configuration file," says Jeremy. Or, as a Pixar manager puts it, "It's doing things that no human being in his right mind would want to do."

Here's another instance where *Electronics* provides the information that gives you, our readers, the first look at leading-edge technology.

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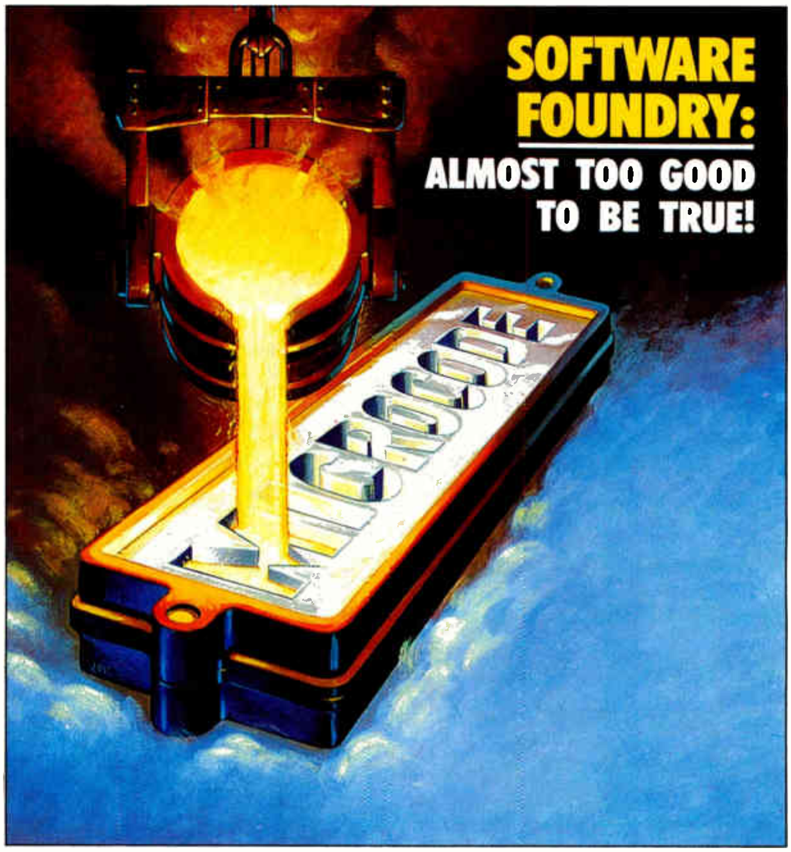
Electronics

VOLUME 61, NO. 2

COVER: JOEL NAPRSTEK



PAGE 47

NEW PRODUCTS

DEPARTMENTS

Narrow your horizons.

Put your hard disk controller on a single chip.

Twenty chips and a board is too much hardware for a hard disk controller. Any engineer would agree. So we focused our attention on turning all that into a single chip: the Am9590 Hard Disk Controller.

The Am9590 can control up to 4 drives allowing for any mix of hard and floppy drives. It supports ESDI, ST506/412 or standard double density floppy disk interfaces. Use the Am9590 with its companion chip the Am9582 Disk Data Separator to design your current ST506 system and you've got an easy upgrade to ESDI system performance for the next generation. Or you could always start that next generation now with the Am9590 as a stand alone.

On-chip DMA with data mapping.

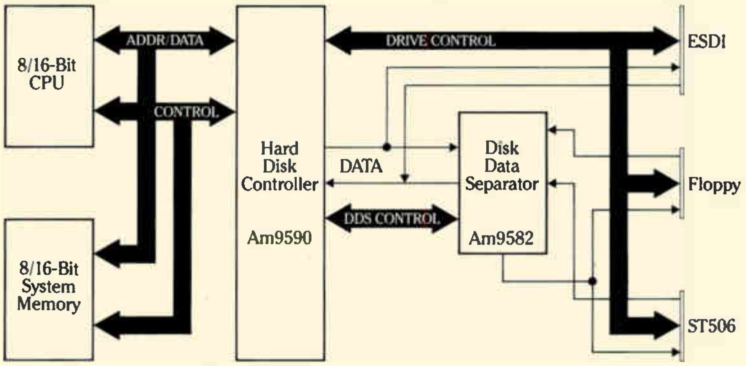
We gave the Am9590 on-chip DMA with data mapping (which will come in handy when you're working with UNIX). Then we added dual on-board sector buffers to allow for Zero Sector Interleave. This simple way of organizing sectors means that access time is bounded by drive capabilities—not controller limitations. And it leaves the CPU free to do the things it does best.

On-board EDC.

The Am9590 even has on-board EDC. Select an error detection code (CRC-CCITT) or one of two error correction codes (Single or Double Burst Reed-Solomon). Or if you prefer, the Am9590 provides handshake interface to your own external ECC circuitry. All this adds up to maximum data integrity.

And it's easy to use. A comprehensive high level command set (with command chaining) allows for independent operation without constant CPU intervention.

You can even shorten your design cycle with an evaluation board, development software and a BIOS driver.



If all this sounds interesting, get in touch with us for more information. Once you've used the Am9590 Hard Disk Controller, you'll understand why the narrower view can be very broadening.

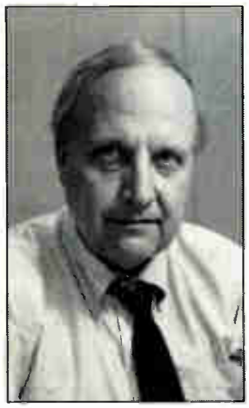
Advanced Micro Devices

901 Thompson Place, P.O. Box 3453, Sunnyvale, CA 94088
Call toll-free (800) 538-8450 ext. 5000; inside California call (408) 749-5000.

Circle 7 on reader service card

IT'S TIME TO BUY IN ON SEMATECH

Like it or not, Sematech is real; it's consensus time and we should take a leaf from the Japanese and close ranks now that the decision has been made



As far as the U.S. semiconductor industry is concerned, it's downright disloyal to question their manufacturing consortium. U.S. survival is at stake in this business, they say, and Sematech is one of the best ways to fix our production deficiencies. But many experts, good people for the most part, have criticized the plan ever since it was announced a year ago. I raised many of these issues last year [*Electronics*, Jan. 22, 1987, p. 8], and some of these arguments are just as valid today as they ever were. Some critics are still active. A day after Austin was announced as the site of the consortium, *The Wall Street Journal* quoted several of them, calling Sematech a government bail-out measure that's already lost its way.

I worry a lot too about the consortium working as planned, but I think it's counterproductive to keep trashing Sematech now that Congress has kicked in with its money and the consortium has started revving up in Austin (see p. 34). Now I think it's consensus time. Flawed or not, Sematech is real. We should take a leaf from the Japanese, who close ranks once the decision is made. So let's buy in on Sematech.

Sematech has already produced one result, says Charlie Sporck, National president and key man behind the consortium: increased industry cooperation. Early on, chip makers made it through some hairy negotiations: whether Sematech should sell its products and picking the technology driver. Then cooperation resulted in 13 competitors committing money and getting the U.S. government to participate. Not bad.

But the hard work has just begun. The first thing that chip makers have to do is to kick in with their own firm, hard-dollar commitments. It's time to ante up and make good on all this talk about cooperation. They also have to make the hard choices to provide their top production technologists and technologies.

A big step in the right direction will come from picking the right guy to run Sematech. The consortium most likely will rise or fall depending on who is ramrodding the operation. That a head hunter is now looking within member companies is another sign of cooperation. Charlie reports a solid candidate has been identified, but for my money, I'd like to see someone with the experience of a Fred Bucy, former Texas Instruments president. I would feel a lot better about Sematech if someone like Fred were running it. **ROBERT W. HENKEL**

THE SOFTWARE PROBLEM SOLVERS

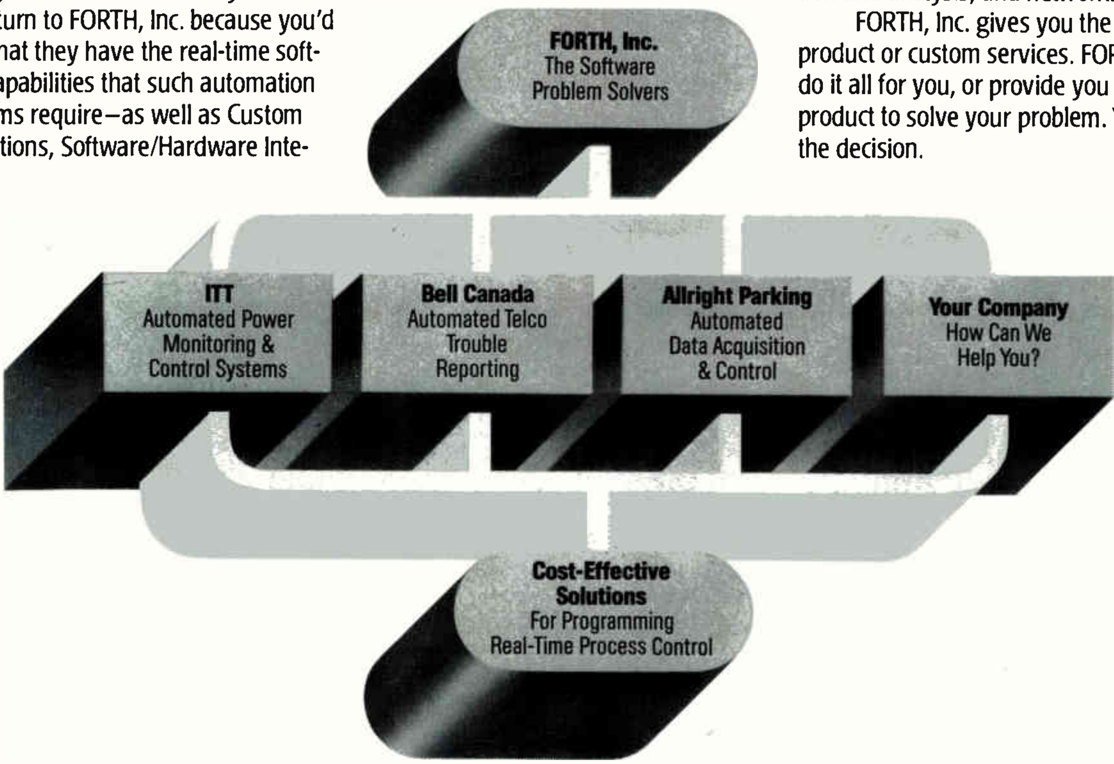
If you were ITT and had to automate power monitoring and control systems for telephone power plants, who would you turn to? And what if you were Bell Canada and your purpose was to automate the company's trouble reporting, analysis, and control procedures? Or suppose you were the Allright Parking Company and had to automate the data acquisition and distributed control of a large number of parking facilities?

If you knew what those companies know, you would do what they did. You would turn to FORTH, Inc. because you'd know that they have the real-time software capabilities that such automation programs require—as well as Custom Applications, Software/Hardware Integration, Installation and Training, Ongoing Maintenance, and Hot Line Support.

And if yours is not a custom application, FORTH, Inc. also offers its powerful family of polyFORTH software and related hardware products. These interactive development tools are compatible with the most popular computers from microprocessors to super-minis.

So, for applications-oriented products or expert help with your automation project, do what the major corporations are doing. Turn to FORTH, Inc., the "software problem solvers" who understand such real-time applications as process control, robotics, digital signal processing, machine vision, data acquisition and analysis, and networking.

FORTH, Inc. gives you the option—product or custom services. FORTH will do it all for you, or provide you with a product to solve your problem. You make the decision.



☐ Please send me your brochure that describes the polyFORTH family of products and your custom services.

☐ I have an application in mind, which is ______________________

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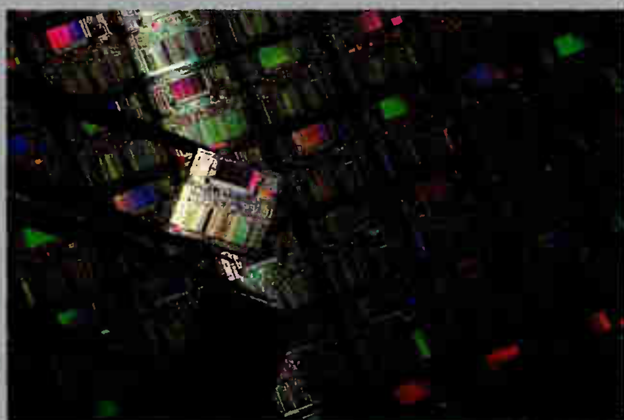
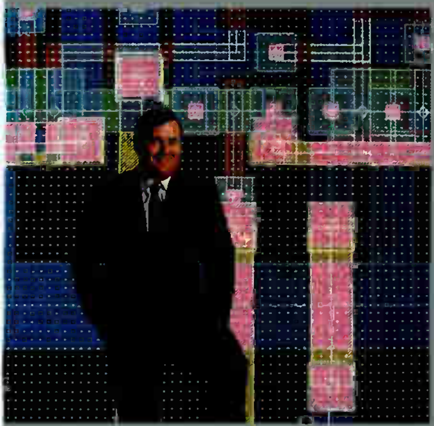
Digital has it now.



"Our Dracula™ layout design verification software was developed and based on Digital systems, and for very good reason," states ECAD President Jim Hill. "Our customers in Integrated Circuit design regard Digital's VAX™ systems as the standard. Recognizing that, we've developed a line of software products that have made us the standard of our industry."

According to Mr. Hill, Digital's unmatched software compatibility offers real benefits in creating customer acceptance. "We know that whatever Digital system the customer has purchased, our software will run on it successfully. That kind of confidence is rare in the IC design industry. And Digital's hardware and



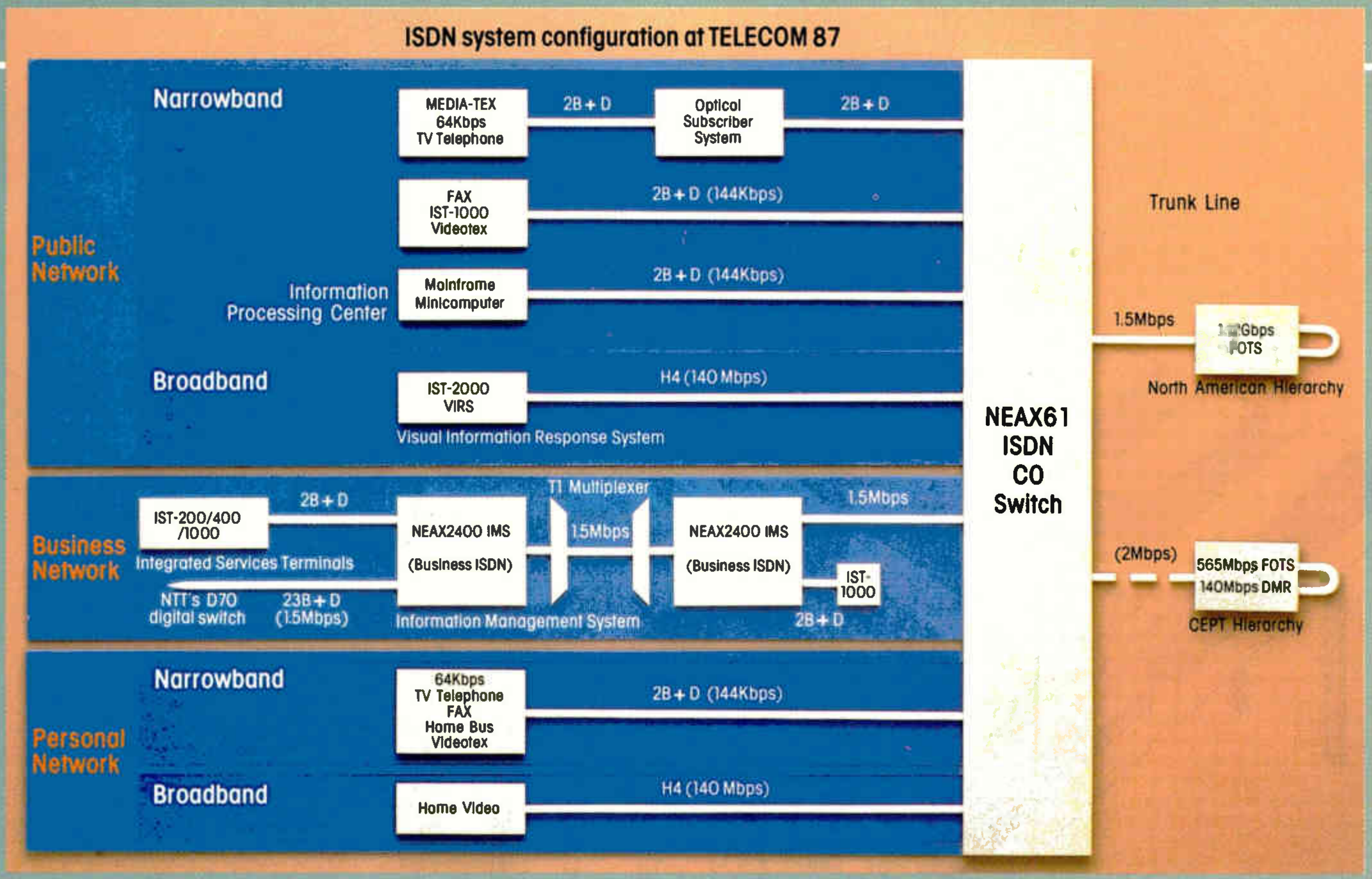
"ECAD seized an 80% world market share – the key was writing our design software to the industry standard, Digital."

software consistency helps us deliver a better product, faster and at a lower cost."

"We're aggressively pursuing a worldwide market," Mr. Hill adds. "And Digital has the worldwide presence to help us sell each market with strong local support. Our software and Digital's systems sell each other. ECAD and Digital have evolved a strategic partnership, one that gives us a proven competitive advantage in the marketplace."

To get your competitive advantage now, write to: Digital Equipment Corporation, 200 Baker Avenue, West Concord, MA 01742. Or call your local Digital sales office.

digital™



Digital switching system: NEAX61

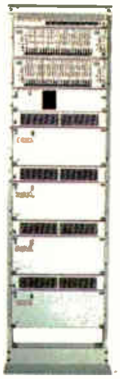
The core of the demonstration was the NEAX61. It displayed integrated broad- and narrowband switching capability, as well as 1.5Mbps high-speed packet switching.

Network management system (NMS)

The NMS efficiently monitors/controls switching and transmission networks. For easy trouble-shooting, it offers expert system technology which guides users to the source of system problems.

1.12Gbps FOTS

The 1.12Gbps Fiber Optic Transmission System (FOTS) demonstrated its ability to combine 16,128 voice channels into a single-mode fiber.



AT THE R&D ZONE

NEC's intensive R&D efforts, ranging from components to total systems, gave visitors a glimpse of many futuristic visions come true.

4Gbps FOTS

This ultra high-speed system utilizes 1.55μm DFB LDs and InGaAs APDs and transmits over 30km without repeaters.

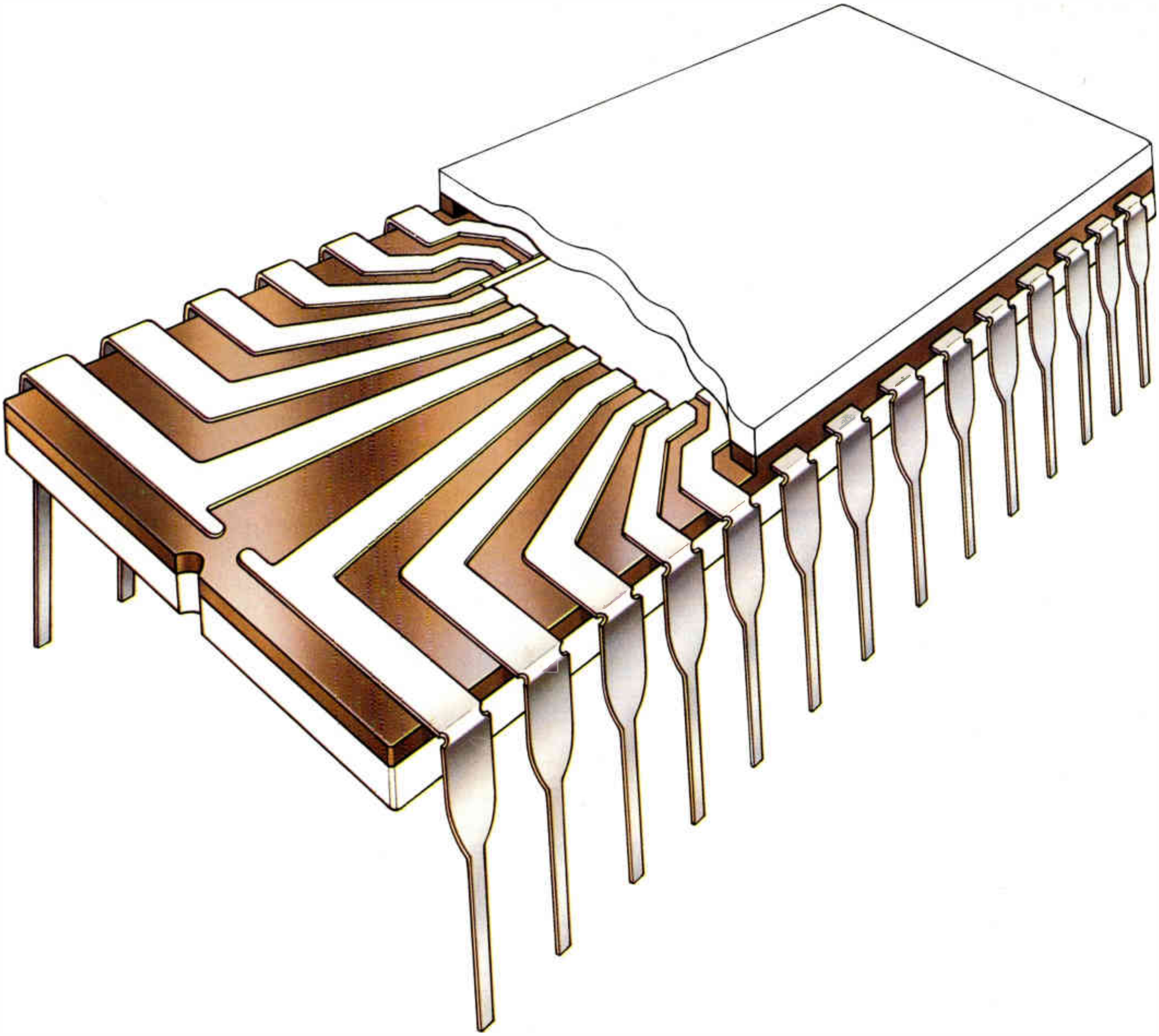
Photonic switching

NEC's display included a photonic switching system with 8×8 matrix optical switches. The system demonstrated 140Mbps broadband switching capability using IST-2000 video communication terminals.

High resolution CCD color camera

A compact HDTV camera, featuring 1.24-million pixel CCD chips, showed the latest advance in CCD technology.

NEC



LS-2010 Composite Sealing Glass

Passes 270°C solder dipping test without preheating

Whether you're dealing with millions of ICs a month or just a few hundred, when it comes to sealing ceramic packages, the two most important numbers are the sealing temperature and flexural strength of the sealing glass: 430°C and 720kg/cm² would be excellent.

Where can you find numbers like these? At Nippon Electric Glass, the world's largest supplier of sealing glasses and manufacturer of LS-2010 composite sealing glass.

LS-2010 also provides higher hermeticity even after solder dipping at a temperature of 270°C, and does so without preheating.

More numbers to think about...a short, 10-minute sealing time...a low thermal expansion coefficient of 65 and a low dielectric constant of 12.5. Together they add up to more consistent quality from lot to lot, higher packaging yields, and superior dependability and performance.

Contact NEG today. We'll show you how our numbers can help improve your numbers—the ones regarding package reliability.

For further information please contact the following:

Nippon Electric Glass Co.,Ltd.

Chicago Representative Office: 3158 Des Plaines Avenue, Suite 227, Des Plaines, Ilinois 60018. Phone: 312-297-7020 Fax: 312-390-0583

ELECTRONICS NEWSLETTER

ASHTON-TATE AND MICROSOFT TEAM UP—AND SYBASE IS THE WINNER

When two of the top names in personal-computer software team up to bring mainframe data-base performance to networked PCs, the biggest beneficiary may turn out to be Sybase Inc., of Berkeley, Calif. The two PC software giants, Ashton-Tate Corp. and Microsoft Corp., will jointly market SQL Server, a version of Sybase's relational data-base management system that's been modified to run on a local-area network server under Microsoft's OS/2 operating system. SQL Server will provide transaction-processing performance, data integrity, security facilities, and other features of minicomputer- and mainframe-based systems to personal computers on LANs. Ashton-Tate will offer a user-interface front-end product that maps its dBase language to SQL, or the structured query language—but other companies, including Sybase, will offer competing front ends. Users stand to win from the arrangement if the potent Ashton-Tate/Microsoft marketing combination establishes Sybase's superset of the ANSI SQL specifications as a de facto standard. □

EXTENDED-QUALITY FM STEREO MAY BE JUST AROUND THE CORNER

The first major improvement in FM stereo radio broadcasting since the service was authorized in 1961 may finally be implemented this year. Prototype receivers equipped for FMX Extended Range Stereo debuted this month from 10 different Japanese manufacturers at the Winter Consumer Electronics Show in Las Vegas. "We're hoping that by the Summer CES, receiver manufacturers will be taking orders," says Emil L. Torick, co-inventor of FMX. "We expect that at least 100 broadcasters will be on the air [with FMX] by the end of 1988." Developed jointly by CBS Inc. and the National Association of Broadcasters, FMX promises to significantly reduce noise and double FM stereo reception area, while maintaining compatibility with conventional FM stereo broadcasts [*Electronics*, April 16, 1987, p. 39]. Sanyo Semiconductor Corp. of Santa Clara, Calif., released the first FMX receiver/decoder chips in November, and Inovonics Inc. of Santa Cruz, Calif., will offer FMX broadcasting equipment beginning this month. □

DID FAILED CHIPS DELAY LAUNCHING OF JAPANESE ROCKET?

A swarm of controversy swept east from Japan into California last week when it was reported that some U. S.-made chips being used in a Japanese rocket failed inspection just prior to launching. The parts, apparently voltage regulators, were made from dice fabricated by National Semiconductor Corp., and later packaged and tested to S-level space standards by TRW Inc. The parts were tested and operational when they left TRW, says a company spokesman, but when tested prior to lift-off—a common practice with rocket-based equipment—alleged "anomalies" turned up. TRW says it is now working to resolve the matter, and although the company insists the chips did not fail, it will replace the chips if necessary. □

GM WILL OFFER ANTILOCK BRAKES ON MOST MODELS BY 1991

General Motors Corp. has finally developed its own computer-controlled anti-lock braking system, but the system—a $925 option on a select group of 1988 GM cars—doesn't yet bring the technology to the masses. GM figures to drive down the cost with specification modifications and high-volume production, so that by 1991 it can offer the systems for only $300 to $350. Current specifications for GM's system, which is based on a pair of customized Motorola 68HC11 8-bit microprocessors, require that it be able to handle driving speeds up to 185 miles per hour, but GM says the spec could be lowered to 120 MPH instead to limit the system's computational load. □

PRODUCTS NEWSLETTER

ARDENT'S SOFTWARE PACKAGE MAKES INTEGRATING 3-D GRAPHICS EASY

Look for Ardent Computer Corp. to make it easy for third-party developers of high-performance simulation and design applications to add dynamic three-dimensional visualization to their products—significantly increasing their value without investing thousands of programming worker-hours by computer-graphics experts. The Doré (for Dynamic Object Rendering Environment) software package is a high-level library of subroutines for drawing objects that includes an object-oriented scene data base and multiple levels of scene-rendering software. The Sunnyvale, Calif., company plans to license Doré for a one-time fee of $15,000, plus $5,000 a year after the first year for source-code maintenance. It will be available this month. □

SOFTWARE CUTS PLD DESIGN TIME FROM MONTHS TO WEEKS

Those ultra-dense, 30,000-fuse programmable logic devices that used to take months to design and program can be finished off in a couple of weeks even by inexperienced designers with the PLDesigner software from Minc Inc. The Colorado Springs, Colo., startup's tool boasts a library of more than 1,800 devices and automates the time-consuming, endlessly iterative process of deciding which fuses to blow to achieve the right logic. It accepts waveforms, Boolean equations, truth tables, and state-machine language as inputs and can be programmed with weighted priorities on cost, speed, and number of PLDs, depending on the solution the designer wants to use. Once the underlying logic is derived, six proprietary algorithms reduce the solution to its most efficient form—a step rarely taken now because of its complexity—and a fuse map is generated. PLDesigner runs on an IBM Corp. Personal Computer AT or compatible. Available now, it costs $1,950. □

FUJITSU'S ECL RAMS SOLVE THE PIPELINE-MEMORY TIMING PROBLEM

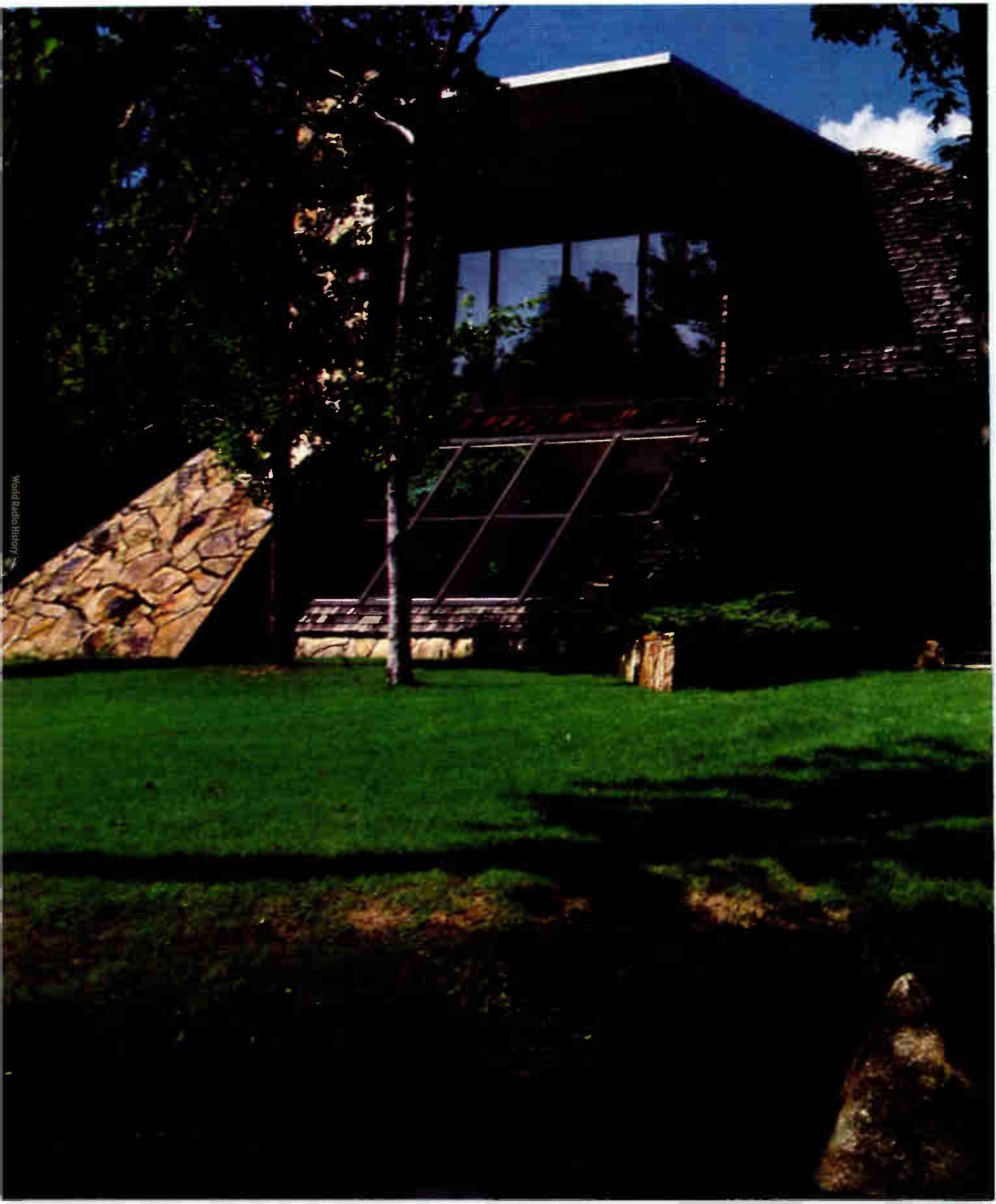
Designers working with pipelined-memory system architectures can simplify the knotty timing problems they present by using Fujitsu Microelectronics Inc.'s family of emitter-coupled-logic random-access memories that feature identical setup and hold times. Fujitsu's engineers turned the trick by teaming an on-board write-pulse generator with latched inputs and outputs. The MBM10476LL-9 and MBM100476LL-9 are organized as 1K by 4 bits and have 9-ns cycle times. The MBM10486LL-13 and MBM100486LL-13 are organized as 4K by 4 bits and have 13-ns cycle times. The chips are compatible with either the 10K or 100K ECL industry standards, says the Santa Clara, Calif., company. Available now in sample quantities, the 1-K-by-4-bit devices cost $55 each and the 4-K-by-4-bit devices, $75 each. Production quantities will be available later in the first quarter. □

FORTRAN RUNS 15% TO 30% FASTER WITH NKR'S COMPILER FOR 68000 FAMILY

Original-equipment manufacturers can deliver an immediate 15% to 30% boost in Fortran program performance—and get a head start in moving Fortran applications to new processor architectures—with NKR Research Inc.'s NKR Fortran compiler. The San Jose, Calif., company achieved its performance gains over other compilers by custom building an optimizer and its library instead of using an optimizer that is shared among languages. Aimed at work stations using Motorola Inc. 68000-family microprocessors, the compiler includes a Fortran extension used in Digital Equipment Corp.'s VAX/VMS environment. NKR's use of cutting-edge Automatic Code Generation technology means the complier can be retargeted to a new processor in less than six months, instead of a year or more. Evaluation copies are available now to OEMs for as little as $100 depending upon the platform. □

What do you need to build on a rough application concept?

AT&T. The comp



onents of success.

Whether you're building a visionary home—or a breakthrough product or system—getting from concept to completion demands more than bricks and mortar, or metal and silicon.

There are other components that can make a critical difference in meeting your market window on time, and on budget.

We call them the components of success—ready for immediate delivery from AT&T.

The component of commitment: here today, here tomorrow.
AT&T is in the components business to stay. We have formed a separate unit, AT&T Microelectronics, to bring our more than 100 years of electronic components experience to the marketplace. And, we have the capital, people, and technical savvy to meet our commitment to the future.

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Nicolet

INSTRUMENTS OF DISCOVERY

Circle 30 on reader service card

On the business side, the fundamental question, one that is answered at the highest levels, is what architecture to chose for equipment. As analyst Crugnale puts it, "I don't see it. [Committing to TRON] represents incredible risk, with no commensurate payoff. What does it bring to the party?"

What's more, says Crugnale, the Japanese probably will fail to market the chips adequately in the U. S. because they do not understand the importance of an aggressive marketing campaign. To have a chance of establishing TRON, Crugnale estimates that a minimum of $50 million would be needed. But he predicts that less than $1 million will actually be devoted to selling it.

Historically, Japanese chip makers have fared poorly in the computer and operating-system side of the U. S. market, points out William Strauss, president of Forward Concepts Inc. in Tempe, Ariz. He recalls the effort surrounding the MSX operating system developed by Microsoft Corp. for use in Japan in the early 1980s. The Japanese then pushed it in the U. S. during 1985 as an alternative to MS-DOS, he recalls. "It died aborning," notes Strauss. He gives the TRON 32-bit chip family about the same chance of achieving success in the U. S.

INTEGRATED CIRCUITS

NEW CHOICE IN CROSSBAR SWITCHING: THE IC

SUNNYVALE, CALIF.

Standard digital-logic chip managers at Advanced Micro Devices Inc. think they've got a big winner that can thrive in the age of semicustom integrated circuits. The silicon plum is a digital crossbar-switch chip.

Similar in concept to the old relay arrays found in telephone central offices, the chips can act as a flexible, reconfigurable intersection of bidirectional ports tying together multiple buses, parallel processors, and memory banks. The AMD managers, like rival engineers at Texas Instruments Inc., give credit to parallel-processing trends for a chance to snare sales from both small-scale integrated logic and gate arrays as multiprocessor architectures proliferate in everything from low-end embedded microcontrollers to desktop work stations and supercomputers.

Roy Selinger, AMD's marketing manager for logic and interface products, says the market potential for multiple-bus connecting crossbars is about 5% of the world's $2.2 billion standard-logic business. "That means we are shooting at about $75 million to $100 million in 1988," he says, referring to the 1.2-μm CMOS parts. One reason for the high hopes is that gate-array implementation would use up a lot of silicon to match the output-drive capability of AMD's crossbar chips.

This month, AMD will become the first company to apply low-power CMOS to digital crossbar switching in its 4-bit-by-4-port Am29C982 and 9-bit-by-4-port Am29C983. The two are expected to be the first in a family of what AMD calls Multiple Bus Exchange chips. They are going up against a much larger 16-port bipolar digital crossbar switch introduced by TI last summer. TI's SN74S8840 has 64 input/output pins arranged in 16 separate 4-bit bidirectional ports. Both companies expect others to join them as the market grows.

The major differences between AMD and TI strategies center around how much complexity and how many bidirectional data ports should be fed to the infant parallel-processing movement. AMD managers in Sunnyvale believe 16 ports is overkill at this early stage; TI officials say they know best since they defined the 8840 based on their experiences with its close cousin, a three-port bipolar transceiver introduced in 1979 called the 74LS440. AMD spent three years defining its four-port chips' features with key customers in an attempt to find a smaller array oriented toward more applications, Selinger says.

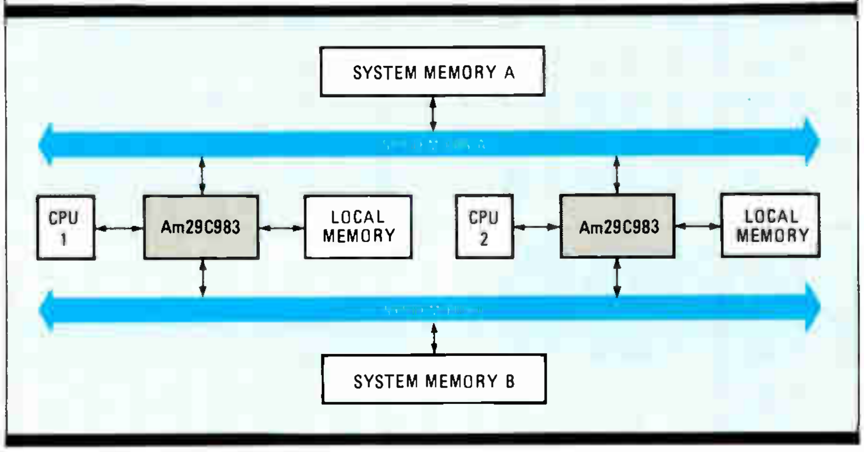
AMD's 29C982 is housed in a 28-pin plastic dual in-line package and sells for $8.50 each in 100-piece lots. The 29C983 comes in a 68-lead plastic chip-carrier for $24.50 in similar quantities. The TI 8840, which can have its 16 ports configured to serve sixteen 4-bit, eight 8-bit, or four 16-bit buses, is housed in a 156-pin ceramic grid array at $72 in 100-piece quantities.

TWO CHOICES. AMD's Multiple Bus Exchange chips are expected to replace up to 20 discrete logic devices apiece. The 4-bit 29C982, which has a die size of 23,000 mil², is for small systems, including embedded parallel-processing control architectures, Selinger says. The 9-bit 29C983 includes latches that can be used to provide byte-wide parity, system diagnostics, and byte-wide compression-expansion for communications between buses with different bandwidth.

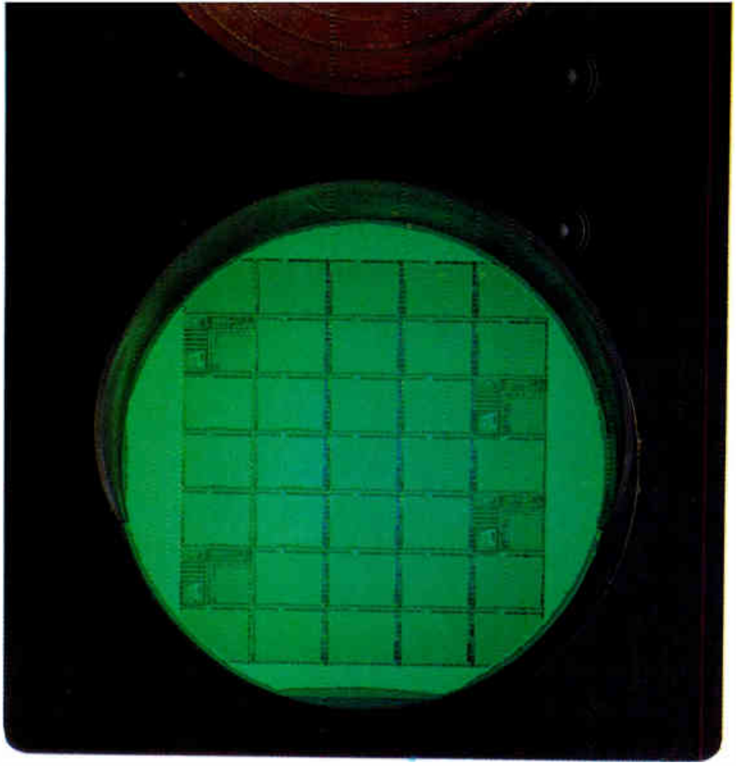
Although TI may differ with AMD on the means to make standard-logic digital crossbar switches a success story, it also believes they are poised to give semicustom ICs a run for their money. Christopher A. DeMonico, TI strategic marketing manager for VLSI advanced logic, says the six-month-old 8840 is already replacing gate-array-based crossbar designs, which often require up to four ICs to deliver the high percentage of metal interconnect needed to interface multiple buses. "It is a high-density metal function. And the bidirectional port is one feature not yet generally available in ASICs," he adds.

DeMonico says one of TI's telecom customers is using the 8840 in a new digital private branch exchange to switch connections to main trunk lines, replacing 240 SSI logic parts per crossbar chip. In a small computer system, the 8840 is being used to interface two incompatible microprocessors to five shared memory banks, eliminating 180 SSI devices per IC. *–J. Robert Lineback*

CROSSBAR CHIP



Advanced Micro Devices' digital crossbar-switch chip can be used to connect multiple buses. Along with a similar part from TI, it is aimed at an estimated $75 million to $100 million market.



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TC511001 - 85	1 Mb x 1	CMOS	85 ns	Nibble	18 pin
TC511001 - 10	1 Mb x 1	CMOS	100 ns	Nibble	18 pin
TC511001 - 12	1 Mb x 1	CMOS	120 ns	Nibble	18 pin
TC511002 - 85	1 Mb x 1	CMOS	85 ns	Static Column	18 pin
TC511002 - 10	1 Mb x 1	CMOS	100 ns	Static Column	18 pin
TC511002 - 12	1 Mb x 1	CMOS	120 ns	Static Column	18 pin
TC514256 - 85	256K x 4	CMOS	85 ns	Fast Page	20 pin
TC514256 - 10	256K x 4	CMOS	100 ns	Fast Page	20 pin
TC514256 - 12	256K x 4	CMOS	120 ns	Fast Page	20 pin
TC514258 - 85	256K x 4	CMOS	85 ns	Static Column	20 pin
TC514258 - 10	256K x 4	CMOS	100 ns	Static Column	20 pin
TC514258 - 12	256K x 4	CMOS	120 ns	Static Column	20 pin

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TC55257L-10	32K x 8	CMOS	100 ns	100µA MAX	28 pin
TC55257AL-12	32K x 8	CMOS	120 ns	100µA MAX	28 pin
TC55257AL-85L	32K x 8	CMOS	85 ns	30µA MAX	28 pin
TC55257AL-10L	32K x 8	CMOS	100 ns	30µA MAX	28 pin
TC55257AL-12L	32K x 8	CMOS	120 ns	30µA MAX	28 pin

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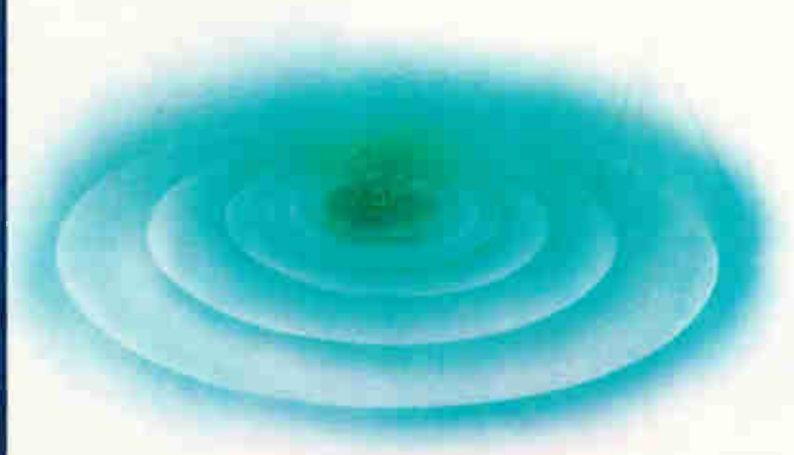

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INTERNATIONAL WEEK

HAMBURG R&D LAB STARTED BY PHILIPS

Philips has begun construction of a microelectronics development center, which represents the first construction phase of a $300 million megabit-memory circuit design and production facility planned in Hamburg, West Germany. When completed in early 1989, the five-story development center will employ some 250 engineers and technicians. The Dutch company expects to invest some $156 million in its new Hamburg facility this year alone.

NEC TO BUILD DISK DRIVES FOR SIEMENS

NEC Corp, Tokyo, will expand its cooperation with Siemens AG by supplying 9-inch hard-disk drives to the Munich company, beginning next April. Siemens will use the disk drives in its 7500 series of mainframe computers. NEC will supply two types of drives with memory capacities of 400 and 800 Mbytes. During the next four years, NEC expects to sell more than 12,000 units, worth 8.5 billion to 10 billion yen. NEC has been under contract with Siemens since 1985 to supply 5-inch hard-disk drives initially, and then 3.5-inch hard-disk drives, 5-inch floppy-disk drives, and laser-beam printers.

JAPAN FIRMS TO STUDY INDUSTRIAL HDTV USES

Eleven of Japan's leading electronics manufacturers will study jointly how high-definition TV can be applied to industrial uses, such as printing, cinema, audio-visual educational tools, and medical equipment. The two-year HDTV Study Committee, which is being set up this month by the government-supported Kansai Electronics Industry Development Center, Osaka, will standardize hardware and software for HDTV. The committee's first goal is to develop a standard for switching and transmission systems to handle HDTV image data. The standard will be the basis for the design and fabrication of VLSI chips needed to make equipment such as multiplexers and demultiplexers compact and inexpensive.

BOSCH IN ANTISKID DEAL WITH AKEBONO . . .

Robert Bosch GmbH, the Stuttgart, West Germany, automotive electronics and communications equipment maker, and Japan's Akebono Brake Industry Co., Tokyo, have agreed to cooperate in electronic anti-skid systems for commercial vehicles. According to the pact, Bosch will license Akebono to manufacture and sell its systems in Japan. The agreement also calls for common development of anti-skid systems for both air and hydraulic brakes, also for commercial vehicles.

. . . AND EXPANDING IN COMMUNICATIONS

Bosch GmbH also has beefed up its interests in telecommunications, by doubling its stake in ANT Nachrichtentechnik GmbH, a 7,000-employee, $800 million communications equipment maker in Backnang, West Germany. Bosch took over the 40.8% share that Mannesmann AG, a German steel pipe producer, held in ANT. Bosch's acquisition is still subject to approval by West Germany's Cartel Office.

CANDELA, MITSUI JOIN IN VENTURE

Candela Laser Corp., the Wayland, Mass., manufacturer of flashlamp-excited dye lasers, is teaming up with Mitsui & Co., the trading firm based in Tokyo, to form Candela International Corp. Taking advantage of the weak U. S. dollar, the joint venture, also in Wayland, expects to capitalize on its price advantage, particularly in Japan. The arrangement will give Candela Laser's engineering, medical, and scientific laser systems access to 213 Mitsui offices in 88 countries. In addition, Candela International will market high-technology medical equipment from other manufacturers.

JAPAN TO SET UP MAP TEST CENTER

The International Robotics and Factory Automation Center in Tokyo plans to establish a Manufacturing Automation Protocols test center in Japan in early 1989. The plan follows the World Federation of MAP Users' Group's decision to set a worldwide MAP standard and to make MAP tools interchangeable. The center will do conformance tests on manufacturers' MAP products. Similar test centers already have been established in the U. S., the UK, and West Germany.

U. S., CANADA GET IBM JAPAN'S LINK

IBM Japan's remote channel-to-channel system, which has been adopted as an IBM worldwide standard, has just made its debut in the U. S. and Canada. IBM Japan claims that computers connected by the RCTC system can efficiently send and receive large volumes of data at 1.536 Mbits/s on a high-speed digital circuit regardless of the distance between the two computers. The capacity is six times greater than the capacity of IBM Japan's time division multiplexer. The RCTC system became available in the domestic market last June for 1.2 million yen.

BRAZIL KILLS TARIFFS IN SOFTWARE BILL

In the face of U. S. threats of sanctions against Brazilian exports [*Electronics*, Nov. 26, 1987, p. 30] Brazil's President Jose Sarney has approved a bill extending copyright protection to software. Absent from the bill is a provision that would have imposed up to a 200% tariff on imported software, says the Computer and Business Equipment Manufacturers Association, Washington, which views the revised bill as a positive sign.

ERICSSON JOINS BROADBAND PROJECT

LM Ericsson, of Stockholm, Sweden, has joined the Research in Advanced Communication in Europe program. Sponsored by the European Communities, the program will develop a European broadband communication network for the 1990s. The Swedish telcommunications and information systems equipment maker will participate in nine RACE research and development projects in areas such as customer premises network, broadband customer access, broadband switching, optical switching, mobile engineering, and software. In three of the projects, worth $130 million over three years, Ericsson will play a major role.

CANON CAMERA GIVES BETTER PICTURES

An electronic still camera from Canon Inc., Tokyo, will boast greatly improved picture quality when it goes on the market next month. The single-lens reflex camera has a charge-coupled-device image sensor with 1,212 pixels horizontally, providing a total of almost 482 lines. Shutter speeds range from 1/8 to 1/2,000 second. The camera is designed to record either 50 TV fields or 25 TV frames on a standard 2-in. floppy disk. Despite the large number of pixels, the CCD has an effective imaging area equivalent to a 2/3-in. camera tube. The camera is priced at 590,000 yen for just the camera body.

INTERNATIONAL PRODUCTS

CONTROLLER CHIP CUTS KEYBOARD REDESIGN TO WEEKS

MATRA HARRIS COMBINES 8032-COMPATIBLE CONTROLLER WITH 4 KBYTES OF ROM

A new single-chip keyboard controller from Matra Harris Semiconductors SA combines 4 Kbytes of easily customizable read-only memory on-chip with a widely used microcontroller architecture. This combination gives manufacturers the best of two worlds: a standard solution that also lets them cut redesign time for software changes and hardware enhancements from months to a few weeks.

The 80C752 is fully compatible with the instruction set of Intel Corp.'s 8031 and 8032 microcontroller. It also packs input/output port multiplexers on-chip—replacing logic most keyboard controllers now implement in 10 or more additional small-scale integration and medium-scale integration discrete devices.

"Rather than having to redo everything from scratch and reinvesting, you do it once," says Stephane Schmoll, Matra Harris marketing manager. "And when you want to adjust the software, there is very little to modify."

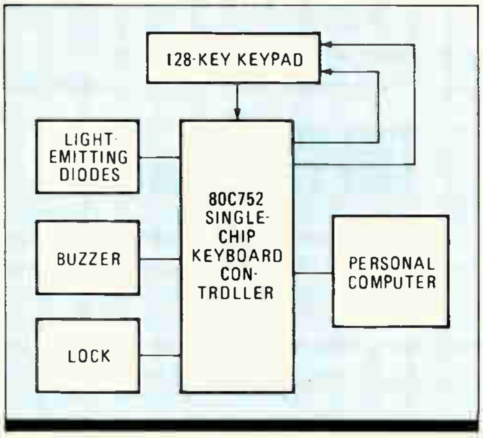
THREE WEEKS. The 4 Kbytes of Matra Harris' Quick ROM and some input/output options can be customized in three weeks instead of the two months generally required by foundries. That's because Matra Harris customizes at the end of the layering process, rather than the conventional method of customizing in the third or fourth layer.

"In our system," says Schmoll, "customizing takes place in the eleventh or twelfth layers, much like the gate array process. So you can build up, put it on the shelf, and when a client asks for something customized, do that in the last operation in a few days."

Fabricated in the company's advanced CMOS process that boasts an 0.8-µm effective gate length, the chip also includes 256 bytes of random-access memory, three 16-bit timers/counters, 32 input/output lines, and a programmable serial port.

In another design innovation for keyboard controllers, the St. Quentin Yvelines, France, company protects the program in ROM from pirating by integrating a fuse on chip that can be blown to frustrate all but the most costly reverse engineering methods.

The 80C752 has eight comparator inputs to directly interface with capacitive as well as mechanical types of keypads. "These are usually outside of the microcontroller but we included them in the chip," says Schmoll. Outputs are able to drive up to 12 mA for external light-emitting diodes, a buzzer, or serial transmission links several meters long. In a typical configuration with a personal computer keyboard, for example, the 80C752 might be customized to implement a standard key for a security lock, a buzzer to warn users when they do something wrong, and up to five LEDs, depending on the range of the equipment, for indicating the status of standard functions such as scroll or numerical locks.



EXTRAS. The 80C752 can control status LEDs, a buzzer, and security key besides the normal keypad.

The chip handles modifications and upgrades of every type of personal computer, terminal, point-of-sale or banking terminal, work station, or portable entry system. It fits with a variety of low-cost, low-to-high performance keyboards and easily accommodates the addition of accessories such as a mouse, LCD display or magnetic card or bar code readers, making potential application of the device virtually unlimited, says Schmoll.

The 80C752 can handle basic keyboards without need for additional circuitry. For more sophisticated systems, such as work stations, cash registers, or process control panels, the extra logic can be included in a single gate array or programmable logic device without having to modify the basic keypad scanning technique.

Matra Harris got the idea from several major keyboard manufacturers who separately asked the company to develop a customized solution to minimize costs, Schmell says. "Once we studied this we saw there was little difference in what was being requested so we asked [the companies] to instead let us put a new standard in our catalog that will meet 90% of everybody's needs," he says.

Matra Harris has also made it easy to develop specific applications by providing a version without ROM, the 80C732. This can be used for debugging or limited production by hitching it to external program memory and latches. Then, for lower cost full production, it can be directly replaced by the 80C752 by just removing external circuits and straps, says Schmoll. In both cases, the same printed-circuit board and software routines can be used.

Along with the circuit specifications, examples of applications and sample software routines are provided to customers, as is a schematic for a breadboard of the circuit. This breadboard is made with a standard 80C32 and standard external components such as latches and comparators so that designers can emulate their applications without a specific emulator.

LOW POWER. Power dissipation can be expected to be under 25 mA at 5 V, 12 MHz—no more than other electronic keyboard controllers for PCs. This benefits portable units, such as data entry terminals that run on batteries, where every milliwatt counts, says Schmoll.

Potential customers include both keyboard manufacturers and companies who design them for inhouse equipment. Since many applications use the Intel microcontroller's architecture—and others are likely to be tempted to switch to it—Schmoll sees the potential market as expanding quickly into millions of devices.

Samples of the 80C752 and the 80C732 will be available in the second quarter of 1988 in 44-pin plastic leadless chip carriers or 44-pin flatpack packages. The devices

2 mA – WOULD YOU ACCEPT LESS?

Completely without power is not possible, but Toshibas' new 2 mA LED lamps actually only need a little more energy than a candle does. That is to say almost none. And that pays off – especially for battery operation; for low current applications; or where you need direct drive at TTL or CMOS output power levels.

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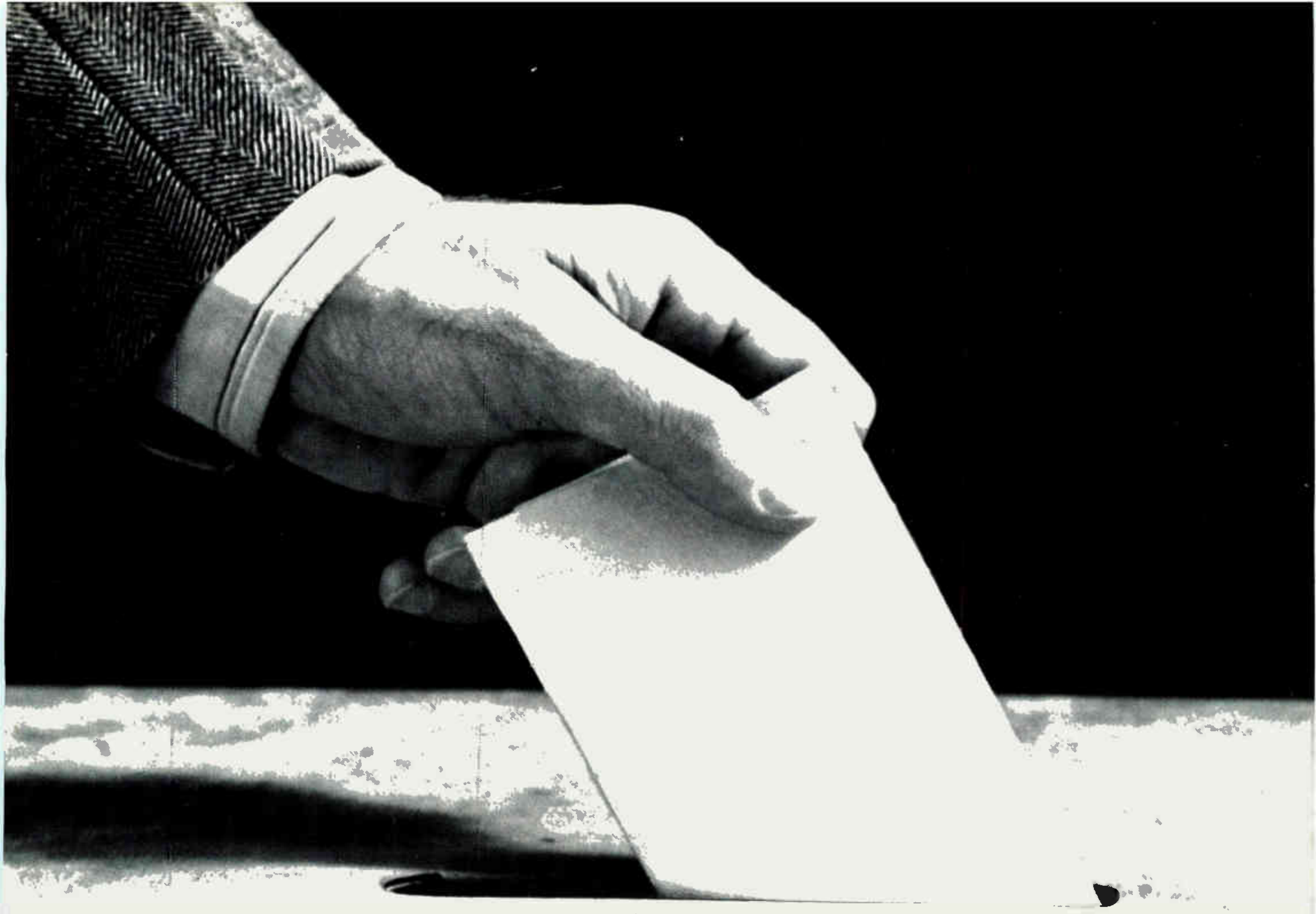

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INSIDE TECHNOLOGY

THE SOFTWARE FOUNDRY: ALMOST TOO GOOD TO BE TRUE

Building an application-specific processor will become a more attractive option for many companies, thanks to QTC's new tool kit, which tunes a design for top speed and automates the tough, expensive task of writing the microcode

by Jeremy L. Young

A tool set from a small company in Beaverton, Ore., promises to change the way custom microcoded processors are designed and to vastly simplify the development of software for them. Quantitative Technology Corp.'s Software Foundry tools let their users see clearly the consequences of decisions made during the design of hardware and software for these specialized, high-performance processors—the majority of which are built with microcoded architectures like those dictated by the use of bit-slice chips.

These processors may also be built with unique combinations of other standard parts—such as digital signal processors or floating-point chips—or application-specific chips. The new tools will move them to market much faster, in large part by eliminating the expensive and agonizing process of writing microcode by hand.

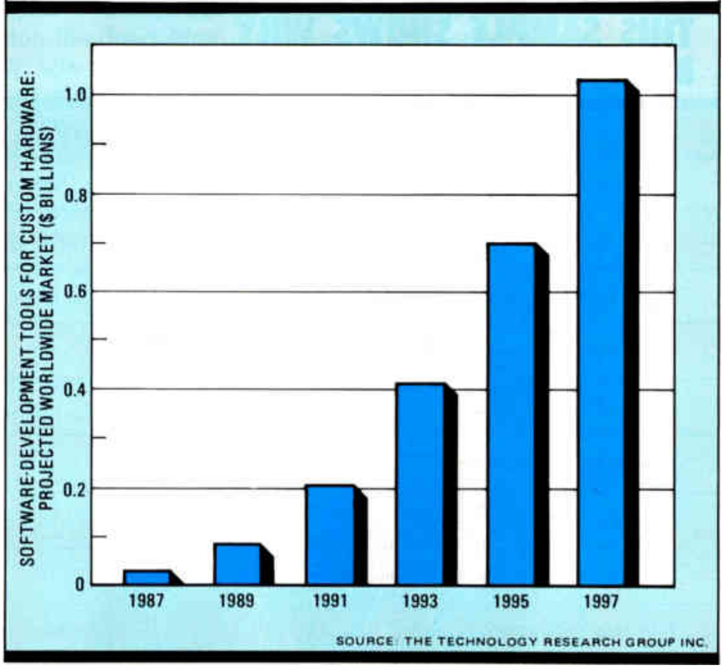
The QTC package includes a compiler, optimizer, assembler, simulator, debugger, and linker (see p. 49). Because these tools can be adapted to new and complex architectures, they can be used by designers and programmers of application-specific processors: graphics engines, embedded systems for avionics, flight simulators, machine-vision systems, and the like. These are systems designed to run a particular algorithm or set of algorithms. And they are systems for which speed is crucial: they do jobs for which general-purpose processors are not good enough.

The QTC tools squarely address the problems associated with writing the software for such hardware, thereby filling an important void in the software-engineering tool market. With them, hardware and software design can be tightly linked, and development can proceed on both fronts at the same time. Simulation tells the hardware team how design changes will affect software-execution speed—before a prototype is built. Software engineers will also be able to see how code modifications will work on the proposed hardware. Hardware changes can be explored without disrupting software development.

On the software side, the tools address the awesome difficulty of writing microcode. It is a painfully hard job—one that is now done "with stone axes and chisels," says an early user of one QTC tool: very few programmers do it well. And writing microcode for a given project is much more work than designing the hardware it runs on. With QTC's optimizing compiler, code can be written in a high-level language: C, to start, and next year, Fortran. This promises tremendous savings in project dollars and time to market.

Tools like those of the Software Foundry either simply have not been on the market before or have been piecemeal solutions, such as compilers written for one hardware architecture. As a result, the current market for software-development tools for custom hardware is not large: only about $30 million in 1987, estimates Andrew

QTC's TOOL KIT TARGETS A FAST-GROWING MARKET



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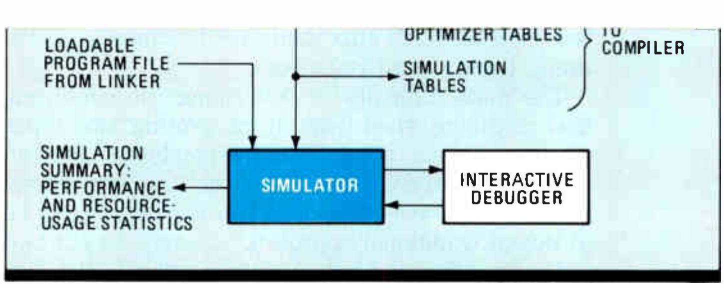

1. FEEDBACK. With QTC's Software Foundry, a designer describes a computer in a configuration file and then explores modifications through simulation.

INSIDE TECHNOLOGY

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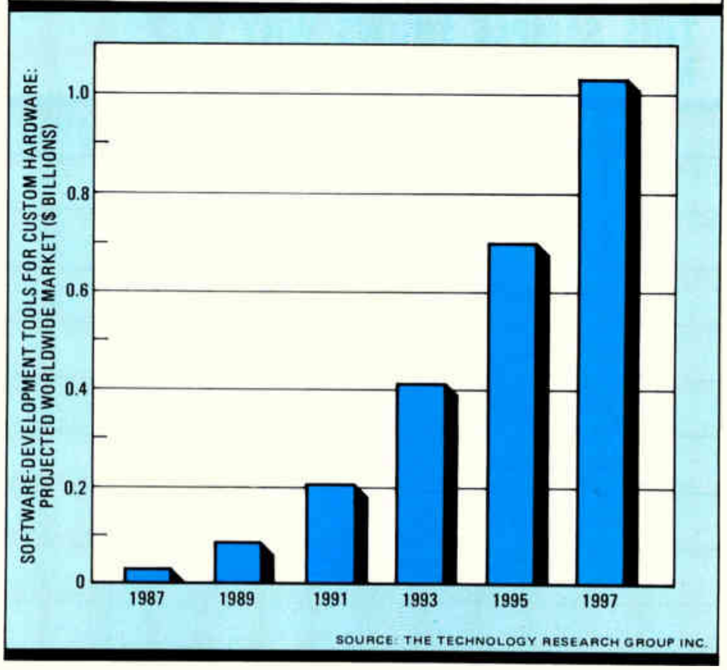


Rappaport, president of the Technology Research Group Inc., Boston. But Rappaport thinks this market will grow fast as more capable tools—like QTC's—become available. He sees it passing the $200 million mark in 1991 and reaching $1 billion in 1997 (see chart).

And the introduction of the Software Foundry gives QTC a big jump on the competition. For tools directed at low-level microcode development, "this is a case where that company is the only company—at least for the time being—with a product like that," says Rappaport.

The Software Foundry could revolutionize the design of custom processors by making it possible to develop hardware and software simultaneously

Indeed, QTC "seems to have the jump in a lot of areas," says Robert Pendleton, a project engineer for microcode tools and software-engineering practices at a leading vendor of computer graphics and simulation hardware. "Everyone else is talking about writing a retargetable optimizer in 1988, starting from scratch," but QTC's product represents its third generation (following two prototype systems), and one that uses extremely sophisticated optimization techniques, he says. Pendleton's company underwrote two years of the university research the tools build upon.

What's more, says Pendleton, "no one else is even talking about producing a simulator generator"—a system that produces a simulation module from a hardware-configuration file. But as the major link between the hardware and software design processes, the simulation capability "is one of the key pieces" in the QTC package.

THIS SAMPLE SHOWS WHY MICROCODE CAUSES HEADACHES

Fields within instruction word	Length of field (bits)
Control of sequencer with stacks and pipelined-operation facilities	24
Cluster of arithmetic logic units and register banks	32
Cluster of multipliers	6
Address generation and address-register banks	16
Cluster of memory units	6
Input/output bus control	16
Internal bus control	16
Immediate field (for specifying constants or branch targets)	16
Total length of instruction word	132

If the market potential is vast, so is the potential of the Software Foundry to revolutionize the design of custom processors. "Coming up with the best system involves figuring out the best trade-offs between what you do in the hardware and what you do in the microcode," says Rappaport. With the arrival of application-specific chips, designers now have "the ability to do radically different architectures" quickly and economically, he adds. "All of a sudden you have a microcoding problem that doesn't necessarily target a static architecture. Development tightly intertwines hardware development and microcoding—and really creates a nightmare." With QTC's tools, "you can say, 'now let's simulate [code on] a hardware target we haven't implemented yet, and let's use simulation as a means to optimize without forcing iterative loops around hardware development.' And that's really interesting."

Pendleton agrees. The ability to simulate software as it will run on a proposed system means "you can test it before you have to build it—to see how well that chip will really perform and how much of the hardware is actually going to be used—and explore different configurations."

Even if the QTC tools are used to produce microcode for an existing machine, however, they still represent a major boon: slashing costs. Many firms rely on unique microcoded architectures to give them a competitive edge, but "microcode is expensive to write, expensive to design, expensive to maintain," says Pendleton. "And then when you build a new processor you throw it away and start over from scratch."

Pendleton estimates the cost of microcode as "between 50 cents and $2 per bit," which adds up quickly because microcode instructions tend to be very wide—from 64 to 256 or more bits each—with numerous fields within them controlling the many resources in the machine (see table, left). A system may contain 10,000 such instructions when it first goes out the door; and more come later to add new capabilities.

A programmer must keep track of what's going on in all those fields in the instruction word, which may involve multiple adders or multipliers in a single-instruction, multiple-data parallel architecture. And speed-enhancing pipelining means that things happening in one cycle affect what must happen in the next. "Pipelining makes programming these things very difficult," says Pendelton. "You get both pipelining and wide words and it gets very painful."

That's why the Software Foundry is so important, says Mickey Mantle, product software manager at Pixar, San Rafael, Calif. "People who can microcode correctly and keep in mind what the 60-odd assorted fields they're trying to track in the instruction word are all doing at the same time are scarce." QTC's optimizer works well in tests so far, says Mantle, and should save a lot of project time: "It's doing things that no human being in his right mind would want to do." □

QTC MAKES IT EASY TO DESIGN CUSTOM PROCESSORS

A complete tool kit tightly links the design of hardware and software for on-the-spot evaluation of changes and for automated microcode development

by Jeremy L. Young

Designers and programmers of specialized microcoded processors will find in the Software Foundry a product they have been sorely lacking—an integrated set of tools that tightly links hardware and software design. This tool kit from Quantitative Technology Corp. lets engineers evaluate design iterations—both hardware and software—as they make them, without waiting for a final version of either. And it makes the tedious and costly process of writing microcode by hand obsolete with a compiler that produces highly optimized microcode from code written in a high-level language.

Some of the tools, which run on Digital Equipment Corp. VAX systems, are available now, and others will arrive during the spring and later in the year. The full package is priced at $50,000 for a work-station-level system.

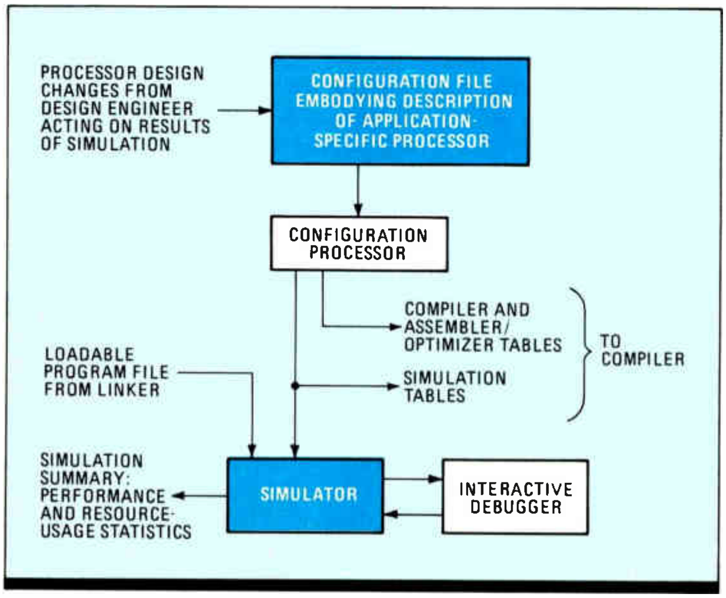
For these six tools—C compiler, optimizer, assembler, linker, simulator, and debugger—to work with any architecture, they must all be retargetable. That is, they must readily adapt to new and highly complex architectures, including those involving high degrees of parallelism (of the single-instruction, multiple-data type) and multiple-level pipelining. The Beaverton, Ore., company provides this adaptability by means of a configuration file. Written in a configuration language reminiscent of the Prolog artificial-intelligence language, the file describes the target hardware and all its peculiarities of resources, timing, and interconnection.

Once a file is written, the full QTC tool set is in business. Now the design team can compile software and simulate it as it will run on the hardware. Indeed, simulation is the key to integrating the two development processes: changes in hardware or software can be evaluated, and their interrelations seen. Designers can examine the performance trade-offs between implementing functions in hardware or software and make informed decisions about overall system design.

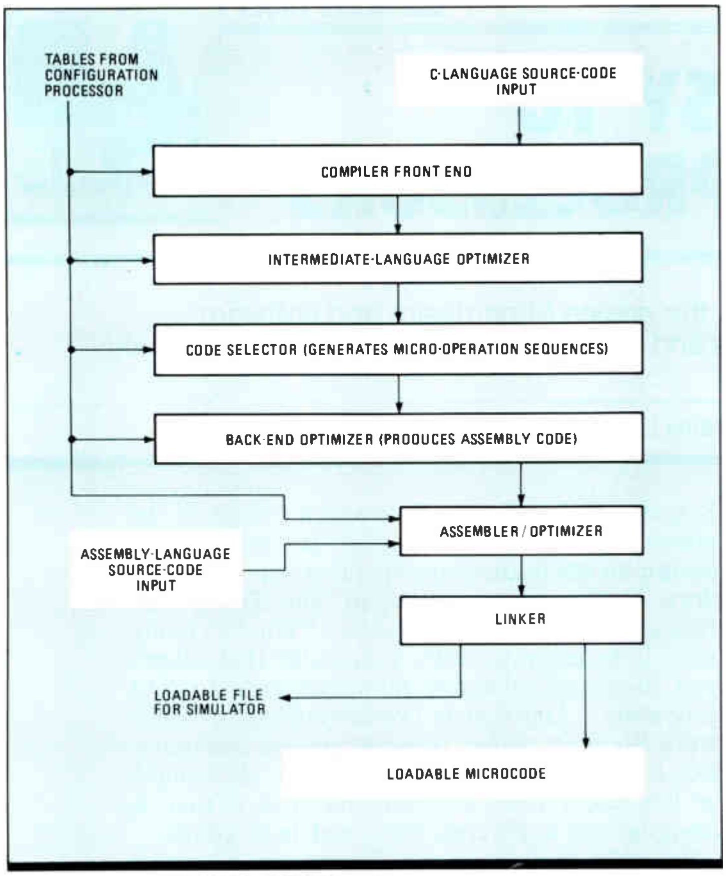
But teams working with existing microcoded systems, whether built with bit-slice and other standard chips or application-specific integrated circuits, will want to consider the Software Foundry simply for the leverage it brings to the microcode-development process. It's not hard to design an application-specific processor, says Andrew Rappaport, president of The Technology Research Group Inc., Boston: "What's really hard is to come up with a compiler that allows you to target relatively high-level code to that processor." And that is precisely what the Software Foundry makes possible: once a configuration file describing a processor exists, the compiler lets users write software for it in C (QTC is bringing out a Fortran front end next year).

To make it all work, QTC brings very advanced optimization techniques to bear within the family of tools. Many of the techniques work as well on hand-written assembly code, if the user prefers that to writing in C. Loop rolling and unrolling, trace scheduling, and the efficient use of parallel and pipelined hardware resources are among the forms of optimization carried out automatically.

The linchpin of the system is the configuration file with its description of the system under design, which is used by all the tools. To make such



1. FEEDBACK. With QTC's Software Foundry, a designer describes a computer in a configuration file and then explores modifications through simulation.



2. EASY MICROCODE. QTC's retargetable compiler generates highly optimized microcode for application-specific processors.

files possible, QTC developed a language to write them in, no small task itself. The compiler and simulator need very different kinds of data, and a big part of the accomplishment was "in putting together a unified language that handles all the information needed by the tools," says Bob Norin, QTC's vice president of product development.

"The compilation tends to look at the machine in what I would call a behavioral way, how the machine behaves," says Bob Mueller, director of research. For such a task, "you can often use higher levels of abstraction and work your way a little bit away from the details of the machine." But with the simulator, "you're interested in understanding exactly how the machine is reacting under the stimulus of microcode," Mueller continues. "This is low-level and structural rather than behavioral." The assembler also relies on low-level descriptive information on the microcode syntax and the machine's operations, timing, and resources.

The main difficulty in developing the configuration language, then, was in integrating two types of data. "There must be correspondence between the behavioral-level and the structural-level representations," says Mueller. "The cop-out would be to take a traditional approach," namely, to put two radically different kinds of information in the configuration file. "That's the easier way to do it," he says, "but it puts a substantial burden on the person doing configuration when it comes time to debug." And debugging is crucial—if the file is incorrect, the tools will generate incorrect code. "One of the goals of our system is to integrate the descriptive notation in such a way that it's easier to validate and see if there's correspondence" between the two kinds of data it contains, says Mueller. "I think that's a unique aspect of what we're doing."

The staff at QTC has programmed more than 30 hardware architectures, Norin points out. "Had we not seen the way that people are designing architectures, and had we not had some experience in developing configuration files, extracting information from schematics, and developing our own microcode languages, I don't think we would have had the perspective to build in a lot of the generality that we have."

That generality makes the Software Foundry applicable to the broadest possible range of microcoded processors, and should give designers of new systems tremendous flexibility in exploring possible hardware configurations. Such exploration could not be done without simulation.

Simulation technology is well understood, and creating QTC's simulator was not such a technical challenge as designing the retargetable optimizing compiler, says Mueller. But until now, no simulator has been "an integrated product in an integrated retargetable system," with a compiler, assembler, and other tools, he says.

Once a configuration file is written, a module called the configuration processor produces tables for the simulator, as well as the assembler and various stages of the compiler (see fig. 1). An application program written in C can then be compiled and an output file generated to drive the simulator. This output file contains information on the system's performance (how fast the program runs) and on how efficiently the hardware resources are being used.

It is the simulator that intimately links the hardware and software-development processes. The hardware designers on a project, for example, no longer have to guess about what effect hardware changes will have on the performance of the system: they can find out quantitatively through simulation of the very software their system is designed to execute.

Furthermore, the hardware team can keep making improvements, large and small, to their architecture while the writing of software proceeds without disruption. In the past, a change in the hardware often meant that all the microcode written up to that point was useless, and the software team had to go back to square one. With the Software Foundry, the configuration file can be changed to reflect a hardware modification and the software simply recompiled.

Then, too, the Software Foundry makes it much easier to deal with difficulties posed by ASICs. Often these chips don't work exactly as intended: the timing may be slightly off, per-

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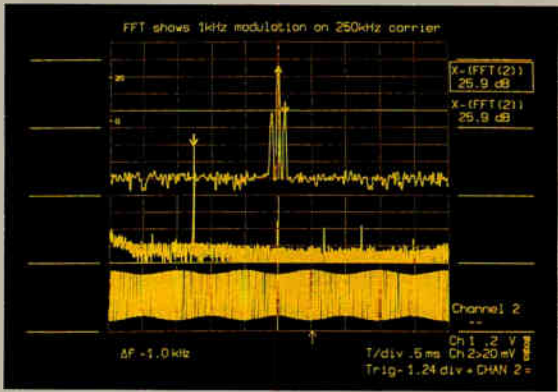

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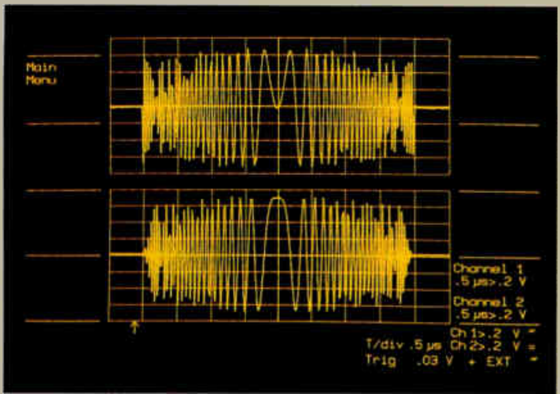

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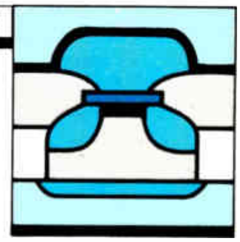


NATIONAL'S ALTERNATIVE TO 'ALL-IN-ONE' GRAPHICS ICs

The new raster processor is the centerpiece of a family of graphics building blocks designed to remove the limited architectural options of the single-chip approach

Designers of graphics systems who feel constrained by the limited architectural options available with the current generation of "all-in-one" graphics chips will welcome a new raster graphics processor from National Semiconductor Corp., Santa Clara, Calif.

Designated the DP8500, it is the centerpiece and final element in a family of graphics building blocks that partition onto separate chips functions such as frame-buffer processing, bit-plane-data manipulation, video-data conversion, clock generation, and memory control. What makes this possible is the architecture of the DP8500 raster processor, which separates arithmetic logic units for addressing and data processing, functions normally combined into a single ALU in conventional designs.

As a result, system designers can build graphics systems which perform both pixel and bit-plane operations equally well, says Roger Reak, director of graphics processing at National. Pixel-oriented systems are used in high-resolution, three-dimensional, and color-graphics applications; bit-plane-based systems are important in such functions as byte-oriented and text-processing applications. With all-in-one chip solutions, graphics processors are usually optimized for one or the other.

At 20 MHz, the 2-μm CMOS 8500 is the fastest component of its type on the market, Reak says, featuring a 100-ns bus cycle time on back-to-back vector and block operations. With a line-drawing speed of 300 ns/pixel, four times faster than its closest competitor, typical system performance ranges from 10 million to 160 million pixels per second.

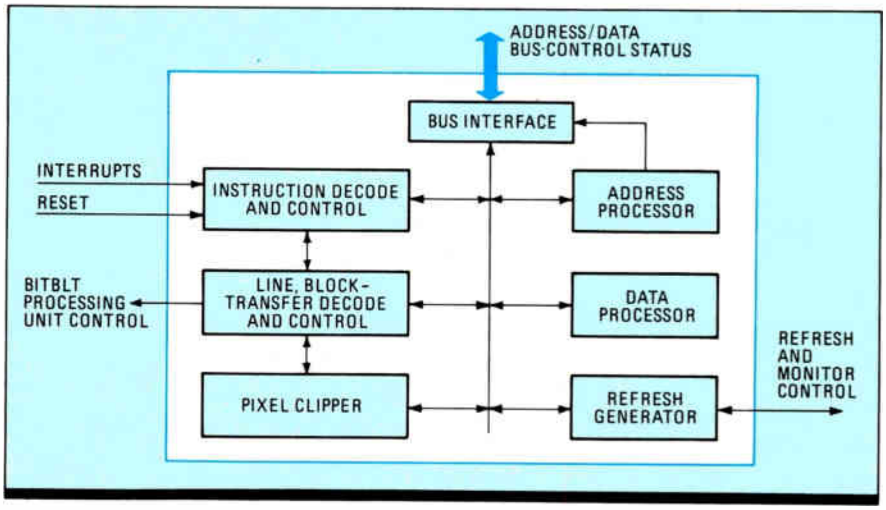
Being sampled now, with production quantities expected by the third quarter, it joins a family of devices which includes the already-introduced 20-MHz DP8510 bit-block transfer processor and the 225-MHz DP8512 video clock generator. The group is rounded out by the DP8515 family of video shift registers and a variety of standard dynamic random-access memory and video dynamic RAM controllers. Production pricing on the 8500 will be $95 in quantities of 10,000 or more.

What makes the partition building-block approach possible is the chip-level architecture of the DP8500, Reak says. One 100,000-mil² chip (see fig. 1) contains a general-purpose microcoded processor divided into two units, as well as a programmable video refresh generator, vector generator, bit-block transfer controller, and rectangle clipper.

The 8500's processor is divided into two blocks. Driven by a common microcoded instruction set, two arithmetic logic units—one each for addressing and data—operate concurrently.

The address processor consists of a 28-bit ALU with an instruction set and bank of sixteen 28-bit address registers. The data processor, on the other hand, is a 16-bit ALU with a relatively rich instruction set optimized for graphics applications and a bank of sixteen 16-bit registers. Other registers have dedicated functions in support of graphics or video refresh operations. In addition, certain graphics operations, notably bit-block transfers, line drawing, and clipping are implemented on chip with dedicated circuitry.

A single stream of instructions, fetched from external memory, serves both processors via mi-



1. DUAL PROCESSORS. The DP8500 graphics chip employs two processors, one for addressing and one for data, driven by a common microcoded instruction set and operate concurrently.

crocode control. The instructions include the register-to-register functions of both processors, and the load/store instructions for data transfers between the chip's registers and its memory. Additional instructions make use of both processors as well as other on-chip resources.

As a result of its dual ALU architecture, the 8500 can be adapted to a wide variety of system architectures without sacrificing performance, says Reak. In a work-station application, he says, it might execute a communications protocol with another processor upstream in the graphics pipeline, awaiting arrival of a display list to be executed. Upon receipt, the 8500 can either directly execute or interpret the display list, rasterizing graphics primitives into the display buffer. Upon executing the final display-list instruction, the processor signals completion, ending the exchange of protocols with the upstream processor and allowing the process to continue.

Alternatively, says Reak, in a stand-alone application such as a computer terminal, the 8500 enters a control program, servicing peripherals and executing a command interpreter. In this application, it would be responsible for the keyboard, mouse, and UART service, at the same time executing a graphics language interpreter, responding to host commands by maintaining the graphics environment, and drawing into the display buffer.

Unlike competitive integrated graphics processors, the 8500 is not limited to one type of graphics frame-buffer architecture. "It can be used not only in either of the two major approaches, pixel and plane, but also in a system that mixes the two," Reak says.

In a pixel-based architecture, frame-buffer data is handled one pixel at a time. For multiple planes, typical in color applications with one plane per color, the address to the frame buffer generates a data word composed of pixels at the same location across multiple planes. These applications often require 16 to 32 memory planes.

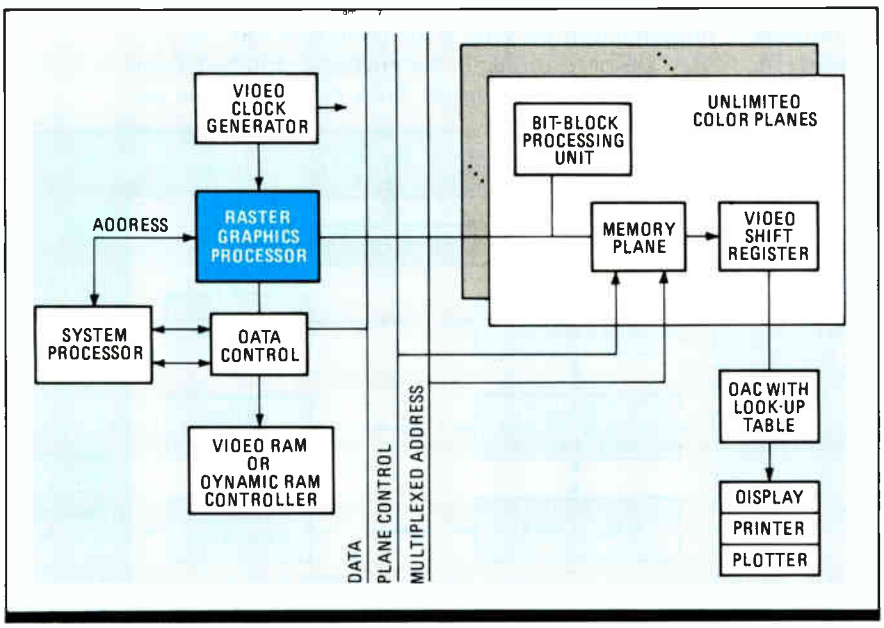
In a plane architecture, the frame buffer is manipulated a word at a time within each plane; each word is usually 16 bits long. To change 1 bit, the other 15 must be carried along. Also, a barrel shifter circuit is required if image placement and movement accuracy is needed down to the actual pixel level. Engineering and business applications often use plane architecture, because they require much data manipulation and image movement.

Many other graphics processors cannot work in pixel and plane architectures on the same chip. "In most cases, this has restricted the performance and applicability of these devices across the spectrum of graphics applications," Reak says. Because they are designed to support only up to 8 planes of memory, conventional graphics adapters require additional processors to accomplish transition to more planes, increasing system cost and degrading performance.

Most other graphics processing architectures have the main controller intimately involved with both frame buffer addressing and data manipulation. "This approach severely affects performance, especially as the number of planes increases," Reak says. National's solution is to separate the graphics processing function into two different chips with the 8500 processor performing all of the address and timing functions associated with the graphics frame buffer while maintaining the classical address and data interface with the system's host central processing unit. The actual data manipulation associated with each memory plane is assigned to a separate slave processor, the DP8510, responsible for masking, barrel shift operations, and bit-block boundary operations.

In a typical multiplane color graphics system (fig. 2), a control bus separate from the graphics processor passes all control and setup information to the slave manipulators in parallel with the control information via the data bus. Once this initial information is set up, and the graphics function is being implemented, the graphics processor is no longer involved in graphics manipulation. The slave processors can be configured via the control and data bus for exact destination, left and right asking, bit-block operations, and the barrel shift. When plane-to-plane transfers are required, one slave processor acts as the source and any combination of slave processors the destination. □

For more information, circle 481 on the reader service card.



2. PLANE AND FANCY. National uses the DP8500 raster processor and the DP8510 slave processor, responsible for masking, barrel shift operations, and bit-block boundary operations.

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OVERSEAS MARKET REPORT

WORLDS APART: JAPAN SET FOR BRISK 13% GAIN AS GROWTH SLIPS SLIGHTLY FOR EUROPE'S BIG FOUR

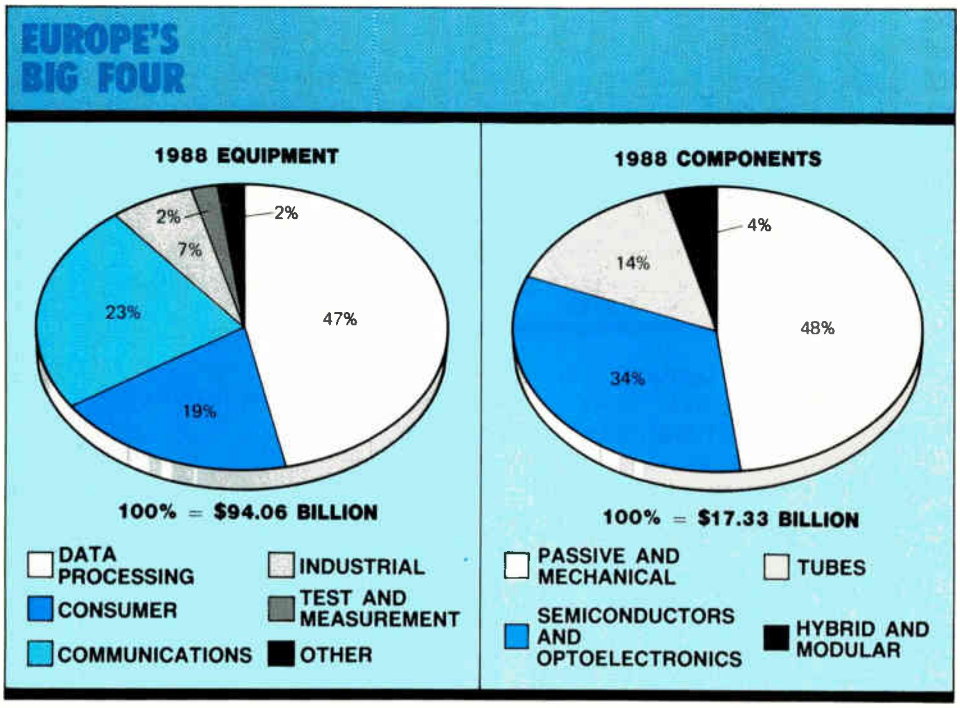
The Land of the Rising Sun will outshine the other major electronics markets around the world this year. *Electronics'* consensus forecast spots the growth of equipment sales in Japan at 13%, two percentage points better than the rise in sight in the U. S. and more than double the growth rate for the top four markets in Western Europe—West Germany, the United Kingdom, France, and Italy. And although Japanese markets for semiconductors and components won't match the 12% growth in store for the U. S., they remain the world's largest at $45.5 billion, some $5 billion more than in the U. S.

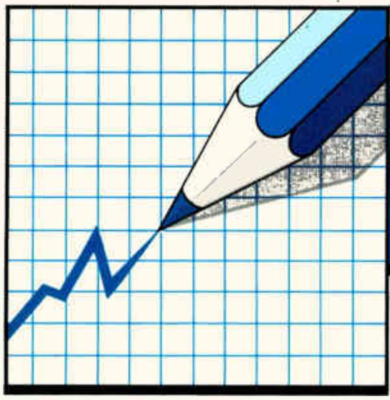
Largely because the Japanese market will do so well this year, the top five overseas equipment markets for the first time will top those of the U. S. All told, Japan and the West European quartet will rack up total consumption of $222 billion, a hefty $52 billion more than the U. S. mark [*Electronics*, Jan. 7, 1988, p. 63]. Credit the slide in the standing of the U. S. in large part to the weak dollar, which magnifies the value of the overseas markets, where sales are figured in local currencies (see "How exchange rates distort forecasts," next page).

Japan's markets loom as large as Mount Fuji compared to national markets of European countries, even though their currencies have largely held their own against the yen. Japan is forecast for hardware markets of $110.6 billion (plus an additional $17.7 billion for software), while all four European nations come in for a total of $94 billion in hardware. Because equipment makers in Japan export so heavily, the difference gets even greater in components: $45.5 billion for Japan; $17.3 billion for Western Europe. (The market figures throughout this forecast are for domestic consumption only, including imports).

In the year ahead, equipment suppliers in Japan should mark much the same growth they did last year: slipping a percentage point to 13%. All the same, competition figures to stiffen as the native producers scramble to recoup lost exports at home while U. S. producers try to leverage favorable exchange rates to break into the Japanese market.

As throughout the industrialized world, data-processing hardware will drive Japan's equipment markets. Mainframes still account for more than half of computer-system sales in Japan and they'll fuel a 15% rise that will carry the sector to $58.7 billion. Consumer electronics, the No. 2 sector, won't come anywhere close: sales will ease up only 6% to $26.5 billion and that is mainly because home computers and new-wave video equipment like camcorders will run strong while color TV stays flat. As last year, communications equipment is in for a lift from the push toward integrated digital services networks, enough to match the 1987 rise of 8% and take the sector to $13.8 billion. In industrial electronics, robot installations are on the rise as manufacturers react to the strong yen by automating their factories, and semiconductor production equipment fig-





JAPAN

WITH COMPUTERS AND SOFTWARE LEADING THE WAY, EQUIPMENT MARKETS WILL RISE 13%

Japanese equipment and software markets are poised for a year of good growth, with sales rising 13% to $128.3 billion overall. The 1988 increase will virtually match last year's 14% growth rate to $113.4 billion—no mean feat as Japanese equipment makers are forced to turn inward to replace lost export markets, pursued by U. S. manufacturers attempting to take advantage of the more favorable exchange rate. (Last year, the *Electronics* survey used an exchange rate of 163 yen to $1; this year, the rate is 125 yen. So comparing dollar totals in this year's tables with those published last year can be misleading.)

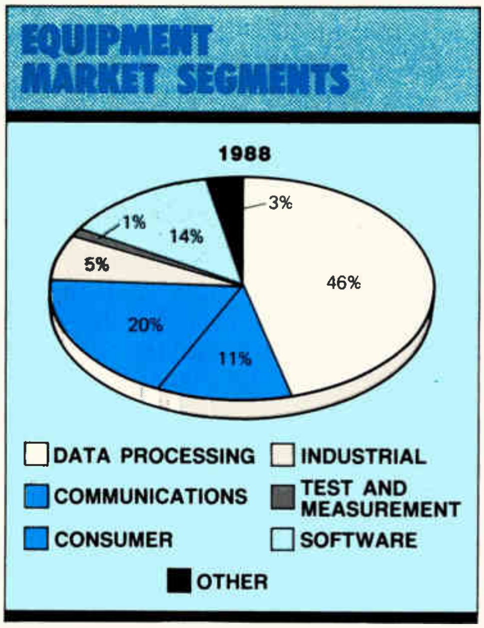
Growth is being driven by the data-processing and software sectors, which together account for about two-thirds of the total equipment markets. These are also the areas where U. S. manufacturers have the greatest hopes of market penetration. That's because Japan continues to use U. S. operating systems and software—a trend that means rapid growth in Unix-based work stations and widespread interest in IBM Corp.'s PC AT compatibles, for example. However, there's growing interest in the convenience of Japanese-language input and that, too, is fueling sales of work stations, personal computers, and kanji word processors.

A good year following a so-so year is the story for industrial equipment. Growth will be strong in semiconductor-production equipment, as companies tool up after emerging from a slump and increased production of 1-Mbit random-access memories spurs equipment sales. Also, robot sales will climb as manufacturers seek to deal with the higher priced yen by increasing efficiency.

For makers of test-and-measurement equipment, the spur is accelerated activity in 1-Mbit DRAMs and other advanced semiconductors, as well as the start of the phone systems' integrated services digital networks this year. The ISDN startup and government pressure for increased investment to fan domestic demand are also driving Nippon Telegraph & Telephone Corp.'s purchases of digital switches and transmission facilities, while users are expected to buy new communications equipment.

The market with the slowest growth is consumer electronics, which is now down to about 20% of the total equipment market and falling after holding steady at 28% for the preceding two years. Growth will be a languid 6% this year, to $26.5 billion, following a 4% hike in 1987.

In the fast-paced data-processing sector, computer makers should see a robust year: the *Electronics* survey estimates that overall consumption will rise 15% to $58.8 billion. In mainframes, *Electronics* forecasts a 16% increase to $14.9 billion—about the same growth rate as last year. But there is a bit of a slump at the top end of the range, says Takehiko Inoue, general manager of NEC Corp.'s EDP Product Planning Division, who adds that he expects lower growth than last year's 15%—perhaps 10% to 13%. One of the reasons for the slowdown is reduced purchases for manufacturing, especially by exporters. Most affected is IBM Japan, because about half of its business is in large computers, and about 40% of that is to manufacturing industries—the largest ratios for any Japanese computer firm.



For supercomputers—a small market in Japan compared with mainframes—*Electronics* sees an 18% increase to $373 million. U. S. makers should pick up 20% to 30% of that business.

The fastest-growing equipment sales are in a still small market segment—minsupercomputers, which should soar by 122% this year to $80 million. In 1986, the market was just $18 million, and last year it reached $36 million. Seven U. S. companies—Alliant, Convex, Elxsi, Floating Point Systems, Gould, Multiflow, and Scientific Computer Systems—sell minisupercomputers in Japan; no Japanese manufacturer does. In Japan, minicomputers and superminicomputers are mainly

	1986	1987 (millions of dollars)	1988
Data processing and office equipment, total	**42,977**	**51,172**	**58,748**
Data processing systems, total	19,832	22,870	26,723
Personal computers	2,794	3,104	3,534
Technical work stations	1,160	1,867	2,758
Office computers	2,960	3,091	3,287
Minicomputers	1,072	1,108	1,182
Superminicomputers	494	574	663
Mainframe computers	11,107	12,775	14,846
Minisupercomputers	18	36	80
Supercomputers	227	315	373
Data input peripherals	224	296	336
Optical character readers	136	176	208
Other data-input peripherals	88	120	128
Data output peripherals, total	4,284	5,854	6,613
Displays	935	1,317	1,464
Plotters	152	212	242
Printers, impact-type	2,017	2,449	2,583
Printers, nonimpact-type	823	1,500	1,906
Other data-output peripherals	357	376	418
Data storage subsystems, total	8,228	10,318	12,086
Flexible disks	1,478	1,754	2,074
Hard disks	4,541	6,262	7,614
Magnetic tapes	1,975	2,018	2,014
Optical disk systems	74	124	224
Other data-storage subsystems	160	160	160
Data terminals, total	4,899	5,634	6,480
CRT	1,993	2,293	2,637
Other (teleprinters, remote job entry, etc.)	2,906	3,341	3,843
Electronic office equipment, total	5,510	6,200	6,510
Calculators (nonconsumer)	533	510	502
Copying equipment	1,038	1,114	1,158
Facsimile transmission systems	1,711	1,916	2,136
Kanji word processors	1,424	1,572	1,869
Billing and accounting equipment	804	1,088	845
Power supplies (noncaptive), total	**2,011**	**2,309**	**2,506**
Bench and lab	73	83	89
Industrial (heavy duty)	172	176	184
OEM and modular, total	1,766	2,050	2,233
Linear	59	65	68
Switching	1,707	1,985	2,165

	1986	1987 (millions of dollars)	1988
Test and measuring instruments, total	**1,289**	**1,353**	**1,505**
Amplifiers, lab	9	9	9
Analog voltmeters, ammeters and multimeters	18	17	17
Automatic test equipment, total	457	493	551
Component testers	27	27	28
IC testers	377	409	462
PC-board testers	53	57	61
Calibrators and standards, active and passive	18	19	19
Counters, time and frequency	21	23	21
Digital multimeters	50	58	60
Logic analyzers	38	38	43
Microprocessor development systems	121	130	161
Microwave test and measuring instruments	25	26	27
Oscillators	15	15	16
Oscilloscopes (including accessories)	127	141	152
Power meters (below microwave frequencies)	168	168	172
Recorders (including chart and X-Y types)	99	91	126
Signal generators (pulse, sweep, and function)	62	63	64
Analog	19	20	20
Synthesized	43	43	44
Spectrum analyzers	61	62	67
Software, total	**11,240**	**14,200**	**17,712**
Microcomputer software, total	1,440	2,000	2,560
Systems software	320	400	480
Applications software	1,120	1,600	2,080
Minicomputer software, total	2,400	2,880	3,360
Systems software	800	880	960
Applications software	1,600	2,000	2,400
Mainframe software, total	7,400	9,320	11,792
Systems software	1,400	1,720	2,152
Applications software	6,000	7,600	9,640
EQUIPMENT, TOTAL	**99,515**	**113,441**	**128,272**

All figures in current U.S. dollars.
The figures in this table, based on a survey made by Electronics in October and November 1987, estimate the noncaptive consumption of equipment, valued at factory prices for domestic products and landed cost for imported products.
Exchange rate: 125 yen to $1.

be robot systems, up 12% to $2.2 billion after a 9% boost in 1987.

In test and measurement, 1988 is a year of high hopes because of the anticipated increase in semiconductor sales, especially 1-Mbit dynamic random-access memories. After last year's forecast of a 9% increase went unrealized—sales rose only 5% to $1.4 billion—the *Electronics* survey indicates an 11% jump to $1.5 billion.

Communications equipment appears poised for an 8% rise to $13.8 billion, about the same growth rate as last year, as manufacturers prepare to announce ISDN terminals and facsimile equipment. ISDN also provided a boost last year, as NTT accelerated its purchases of digital exchanges, both for the start of ISDN in March and because the government wanted to stimulate demand.

In consumer electronics, the *Electronics* survey indicates that 1988 will see a rise of just 6% to $26.5 billion after a 4% rise in 1987 to $25.1 billion. Just as last year's figure was helped by an 18% jump in sales of home video equipment, such as video-cassette recorders and camcorders, this year's will be hurt by a cooling market. Home video equipment sales will be up only 3% to $5.9 billion. But with total TV sales rising just 4% to $5.5 billion, projection TV will be a big winner, albeit starting from a narrow base. Sales will rise 42% to $68 million. At the other end of the size spectrum, perhaps 1 million pocket TVs were sold in 1987 at an average price of $240, and both size and picture quality are creeping upward. Sales should climb to 1.3 million in 1988.

Sales of video disk players, especially the VHD capacitive-pickup types, were down almost 2% in 1987 but optical types should perk up this year and lead the way to an 11% increase, to $392 million. Out front will be CD-V—CD with video—a new category of video players that has hit the market. Last year something like 100,000 CD-V players were sold, and Kiyohara Sasaki, deputy manager of Toshiba Corp.'s Consumer Products Planning Office, forecasts that there will be 400,000 this year at an average retail of $950.

In audio, makers of digital audio tape find that most Japanese are apparently concentrating on the compact disk. Estimates are that perhaps 20,000 DAT units were sold last year at an average selling price of $1,600, and that 50,000 will be sold this year.

stations for computer-aided design and engineering: they should rise 15% to $288 million, atop a 14% increase last year. "When the economy sours, people more readily invest in computers to streamline operations," argues Rössner of Unisys.

The slowdown that characterized West Germany's communications equipment markets in 1986 continued into 1987, and in 1988 the situation may get worse. The *Electronics* survey pegs last year's market at $5.5 billion, up 7% over 1986, and projects only a 2% rise to $5.6 billion this year. Some forecasters come in at a higher growth figure for 1988, however, around 5%.

Several factors underlie the lull. One is that communications is still in the analog-to-digital transition period. Although there's much talk about integrated services digital networks, there's been little action so far in terms of installations. To be sure, some ISDN public switches are in place, but installations on a large scale won't get under way until the early 1990s.

Also, the slow growth in the computer market is pulling communications down, says Manfred Beinder, chief economist at Stuttgart-based Standard Elektrik Lorenz AG, a subsidiary of the French communications group Alcatel NV. "With data processing and communications coupled the way they are, one follows the other either up or down," he says.

WEST GERMANY EQUIPMENT

	(millions of dollars) 1986	1987	1988
Data processing and office equipment, total	**15,272**	**16,660**	**17,883**
Computer systems	9,047	10,071	10,919
Personal computers (under $5,000)	938	1,063	1,188
Microcomputers ($5,000 to $20,000)	863	979	1,025
Minicomputers ($20,000 to $100,000)	1,751	1,863	2,022
Superminicomputers ($100,000 to $400,000)	1,004	1,119	1,225
Mainframe computers ($400,000 to $5 million)	4,471	4,999	5,419
Supercomputers (over $1 million, with integral vector processor)	20	48	40
Data-input peripherals	425	459	494
Data-output peripherals	1,238	1,338	1,444
Data-storage subsystems	1,938	2,125	2,313
Data terminals	1,400	1,514	1,628
Electronic office equipment, total	1,224	1,153	1,085
Copiers	693	711	708
Electronic typewriters	381	354	315
Word-processing systems	150	88	62
Test and measuring instruments, total	**573**	**594**	**623**
Amplifiers, lab	9	9	9
Analog voltmeters, ammeters, and multimeters	14	13	12
Automatic test equipment, total	159	181	208
Discrete-component testers	4	5	6
IC testers	55	63	72
Pc-board testers	100	113	130
Calibrators and standards, active and passive	4	4	4
Counters, time and frequency	13	13	13
Digital multimeters (including accessories)	41	41	42
Logic analyzers	28	28	29
Microprocessor development systems	63	59	56
Microwave test and measuring instruments	41	43	45
Oscillators	8	8	8
Oscilloscopes	100	100	100
Recorders and plotters	41	41	42
Signal generators, total	21	21	21
Analog	11	10	9
Synthesized	10	11	12
Spectrum analyzers	31	33	34
Industrial electronic equipment, total	**2,649**	**2,598**	**2,649**
Inspection systems	48	47	46
Machine-tool controls (including numerical)	248	228	203
Motor controls	275	291	266
Process-control equipment (including computers, loggers, consoles)	1,563	1,494	1,531
Programmable controllers	406	400	453
Semiconductor production equipment	109	138	150
Power supplies (noncaptive), total	**254**	**272**	**296**
Bench and lab	22	23	23
Industrial (heavy duty)	25	18	13
OEM and modular, total	207	231	260
Linear	63	50	47
Switching	144	181	213

	(millions of dollars) 1986	1987	1988
CAD/CAE equipment, total	**219**	**250**	**288**
Consumer electronics, total	**6,272**	**6,561**	**6,761**
Audio equipment, total	1,948	2,107	2,188
Car audio	450	481	494
Compact disk players	273	389	487
Phonographs and radio-phonographs	68	61	51
Radios (including table, clock, and portable)	49	48	46
Radio/recorder combinations	268	269	263
Stereo equipment, total	444	451	454
Components (including tuners and turntables)	319	313	306
Consoles and compact systems	125	138	148
Tape recorders and players	396	408	393
Home video equipment, total	1,163	1,253	1,335
Camcorders and cameras	128	206	269
Cassette players and recorders	1,035	1,047	1,066
Television receivers, total	1,773	1,831	1,860
Color	1,723	1,784	1,813
Monochrome	50	47	47
Other consumer electronic products, total	1,388	1,370	1,378
Calculators (personal and professional)	90	78	77
Electronic musical instruments	86	88	88
Electronic watches and clocks	376	388	403
Home computers (under $1,000)	611	497	441
Microwave ovens	225	319	369
Communications equipment, total	**5,123**	**5,484**	**5,586**
Data communications equipment	197	201	206
Facsimile terminals	120	188	231
Fiber-optic communications systems	63	141	250
Intercom systems	50	53	50
Navigation aids, except radar	38	47	52
Paging systems, public and private	47	50	53
Radar (air, land, and marine)	256	272	292
Radio, total	582	677	786
Broadcast equipment	102	120	131
Land mobile	208	245	386
Microwave	209	218	206
Satellite earth stations	63	94	63
Telecommunications equipment, total	3,570	3,635	3,427
Customer premise equipment	338	325	294
Telephone and data-switching, private (PABX)	904	935	984
Telephone and data-switching, public	844	969	938
Transmission and carrier equipment	1,484	1,406	1,211
Television equipment, total	200	220	239
Broadcast (studio) equipment	75	70	74
CCTV (educational, industrial, and medical)	125	150	165
EQUIPMENT, TOTAL	**30,362**	**32,419**	**34,086**

All figures in U.S. dollars.
The figures in this table, based on a survey made by Electronics in October and November 1987, estimate noncaptive consumption of equipment, valued at factory prices for domestic products and landed cost for imported products.
Exchange rate: 1.60 marks to $1.

WEST GERMANY COMPONENTS

	1986	1987 (millions of dollars)	1988
Semiconductors, total	**2,161**	**2,005**	**2,094**
Discrete, total	528	483	493
Diodes, total	198	184	183
Microwave (above 1GHz)	10	9	10
Rectifiers and rectifier assemblies	108	100	104
Signal (less than 100 mA)	32	29	27
Varactor	11	10	11
Zener	37	36	31
Thyristors	98	93	96
Transistors, total	232	206	214
Bipolar, total	207	182	185
Power (1W or more)	107	94	96
Small-signal	100	88	89
Field effect	19	19	23
RF and microwave power (including GaAs)	6	5	6
Integrated circuits, total	1,633	1,522	1,601
Custom and semicustom, total	250	231	263
Custom (compiled, standard cell, hand-crafted)	125	109	129
Gate arrays	75	78	81
Programmable logic devices	50	44	53
Linear ICs, total	432	394	419
Communications (codecs, SLICs, etc.)	106	97	101
Consumer-product ICs	181	165	178
Interface (buffers, decoders, drivers, etc.)	54	51	55
Op amps (monolithic only)	56	50	52
Voltage references and regulators	33	29	31
Timers	2	2	2
Memories, total	262	288	307
Application-specific	6	6	7
Random access memory, total	162	185	194
Dynamic RAM	116	132	139
Static RAM	46	53	55
Read-only memory	94	97	106
Microprocessors and microcomputers	289	283	306
Standard logic families, total	400	326	306
Bipolar	256	213	200
CMOS	144	113	106
Hybrid and modular components, total	**159**	**163**	**166**

	1986	1987 (millions of dollars)	1988
Passive and mechanical, total	**3,529**	**3,513**	**3,577**
Capacitors, total	572	560	600
Fixed	555	544	584
Variable	17	16	16
Connectors, plugs, and sockets	906	875	875
Filters, networks, and delay lines	74	73	73
Loudspeakers (OEM)	138	141	142
Printed circuits and interconnection systems	813	837	845
Quartz crystals	69	71	72
Relays (for communications and electronics)	230	231	233
Resistors, total	236	237	234
Fixed	131	131	128
Potentiometers and trimmers	105	106	106
Switches and keyboards	225	219	222
Transformers, chokes, and coils	266	269	281
Tubes, total	**752**	**773**	**801**
Cathode-ray (except TV)	41	44	47
Image-sensing (including vidicon and orthicon)	49	51	52
Light-sensing (including photomultipliers)	11	12	13
Power tubes (including klystrons, magnetrons and traveling wave)	91	94	96
TV picture tubes, total	560	572	593
Color	550	563	585
Monochrome	10	9	8
Optoelectronic devices, total	**136**	**132**	**139**
Discrete light-emitting diodes	30	28	29
Imaging arrays (CCD, diode, transistor)	n/a	n/a	n/a
Laser diodes	2	3	3
Optically coupled isolators	27	25	27
Photoconductive cells (light-dependent resistors)	21	22	23
Photodiodes and phototransistors	23	21	23
Photovoltaic (solar) cells	5	5	5
Readouts (LCD, LED, fluorescent character displays)	28	28	29
COMPONENTS, TOTAL	**6,737**	**6,586**	**6,777**

All figures in current U.S. dollars. The figures in this table, based on a survey made by Electronics in October and November 1987, estimate noncaptive consumption of components, valued at factory prices for domestic products and landed cost for imported products. **Exchange rate: 1.60 marks to $1.**

including memories, will firm up a bit. ICs will keep replacing discretes, except for optoelectronic devices. As a result, the *Electronics* forecast for discretes is growth of only 2% to $493 million. Optoelectronic devices will move up 5% to $139 million.

In chips, the lustiest growth will come in application-specific integrated circuits. Peter Olfs, spokesman for technical activities at Siemens, sees worldwide sales of nonstandard ICs, including ASICs, rising by as much as 17% annually during the next few years; that compares with his forecast of 11% for standard ICs. ASIC growth in West Germany, he feels, will keep pace with that elsewhere in the world. Olfs' estimates are essentially in line with the *Electronics* forecast, which spots the market for custom and semicustom circuits, including ASICs, at $263 million. That's a rise of 14% over the $231 million market for 1987, a year that saw custom circuits decline by 8%.

ASICs, of course, replace standard logic packages in most instances, an impact that is reflected in the market. Despite the general turnaround for ICs, sales of standard logic will drop to $306 million, according to the survey. They were $400 million two years ago. The rise of ASICs, though, has not checked sales of microprocessors and microcomputers: they are forecast to bounce back 8% to $306 million after last year's 2% decline.

Though near-term growth prospects aren't that bright, Hein and other market analysts are optimistic about the future simply because, they say, equipment markets are destined to expand. "Long-term, the overall trend in IC sales is a 12% to 13% annual rise," says Hein.

As for passive components, they continue to plod along, hovering at a level around $3.5 billion and growing less than 2% a year. Despite the lackluster prospects, "We are not pushing the alarm button," says Klaus Wolf, managing director of the Electrical and Electronics Industry Association. Wolf notes that sagging prices caused the market drop last year; unit sales of parts increased. He expects prices will firm up a bit this year and put passives back on an upward trend.

Tubes will mark a modest advance: a gain of 4% to $801 million. Credit most of that rise to the demand for flat, square-corner picture tubes—more expensive than conventional picture tubes—by TV makers.

own with a 6.5% rise to $3.1 billion.

"Three years ago, people were saying mainframes were dead," says Mike O'Riordan, director of UK marketing for Unisys Ltd. "But they grew about 50% last year [for Unisys], and we should see growth of around 19% in 1988." Deregulation of financial houses, he explains, is forcing both small savings banks and large commercial banks to become more competitive by putting terminals into all their branches. That, and heavy activity in airline reservation systems, has been a salient factor in the strength of mainframes, he explains.

O'Riordan's optimism is echoed in a recent survey conducted by the Confederation of British Industries. The CBI says that 48% of the companies it polled in the computer sector reported that order levels were higher than the average for 1987. Moreover, 83% reported fuller export order books, and 62% said that the value of orders in hand was higher. Nevertheless, trade statistics released in mid-December indicate that for the first half of 1987, the balance of trade for the sector was in deficit by $613 million. Mark that up to the success of foreign brands by companies that don't produce hardware in the UK.

Communications has always represented a steady market in Britain, and it will continue its measured advance this year. The survey shows shows a 6.5%

UNITED KINGDOM EQUIPMENT

(millions of dollars)	1986	1987	1988
Data processing and office equipment, total	**9,421**	**9,907**	**10,460**
Computer systems, total	5,799	6,217	6,680
Personal computers (under $5,000)	1,018	1,079	1,138
Microcomputers ($5,000 to $20,000)	648	759	820
Minicomputers ($20,000 to $100,000)	797	851	944
Superminicomputers ($100,000 to $400,000)	574	592	657
Mainframe computers ($400,000 to $5 million)	2,738	2,901	3,090
Supercomputers (over $1 million, with integral vector processor)	24	35	31
Data-input peripherals	157	167	178
Data-output peripherals	648	666	703
Data-storage subsystems	1,203	1,258	1,314
Data terminals	740	777	786
Electronic office equipment, total	874	822	799
Copiers	535	535	546
Electronic typewriters	213	204	194
Word-processing systems	126	83	59
Test and measuring instruments, total	**382**	**373**	**384**
Amplifiers, lab	2	2	2
Analog voltmeters, ammeters, and multimeters	15	15	14
Automatic test equipment, total	78	78	81
Discrete-component testers	4	4	4
IC testers	28	30	31
Pc-board testers	46	44	46
Calibrators and standards, active and passive	4	4	4
Counters, time and frequency	28	26	26
Digital multimeters (including accessories)	24	22	24
Logic analyzers	13	13	15
Microprocessor development systems	35	35	37
Microwave test and measuring instruments	20	19	20
Oscillators	5	5	5
Oscilloscopes	52	54	56
Recorders and plotters	39	39	41
Signal generators, total	43	37	33
Analog	22	17	13
Synthesized	21	20	20
Spectrum analyzers	24	24	26
Industrial electronic equipment, total	**1,105**	**1,185**	**1,300**
Inspection systems	7	8	8
Machine-tool controls (including numerical)	44	46	50
Motor controls	194	205	215
Process-control equipment (including computers, loggers, consoles)	723	770	836
Programmable controllers	100	115	148
Semiconductor production equipment	37	41	43
Power supplies (noncaptive), total	**133**	**134**	**139**
Bench and lab	15	13	15
Industrial (heavy duty)	31	31	33
OEM and modular, total	87	90	91
Linear	35	31	28
Switching	52	59	63

(millions of dollars)	1986	1987	1988
CAD/CAE equipment, total	**122**	**204**	**294**
Consumer electronics, total	**4,633**	**4,695**	**4,790**
Audio equipment, total	1,276	1,338	1,398
Car audio	189	200	211
Compact disk players	148	200	250
Phonographs and radio-phonographs	191	185	185
Radios (including table, clock, and portable)	65	67	63
Radio/recorder combinations	194	198	202
Stereo equipment, total	315	309	302
Components (including tuners and turntables)	191	189	185
Consoles and compact systems	124	120	117
Tape recorders and players	174	179	185
Home video equipment, total	844	910	968
Camcorders and cameras	67	87	104
Cassette players and recorders	777	823	864
Television receivers, total	1,138	1,117	1,135
Color	1,101	1,082	1,104
Monochrome	37	35	31
Other consumer electronic products, total	1,375	1,330	1,289
Calculators (personal and professional)	68	68	68
Electronic musical instruments	85	87	89
Electronic watches and clocks	241	259	263
Home computers (under $1,000)	500	431	379
Microwave ovens	481	485	490
Communications equipment, total	**5,512**	**5,885**	**6,269**
Data communications equipment	148	176	196
Facsimile terminals	176	192	211
Fiber-optic communications systems	33	46	60
Intercom systems	24	26	28
Navigation aids, except radar	507	520	535
Paging systems, public and private	56	57	59
Radar (air, land, and marine)	1,049	1,073	1,104
Radio, total	832	942	1,036
Broadcast equipment	102	109	109
Land mobile	648	744	833
Microwave systems	56	59	61
Satellite earth stations	26	30	33
Telecommunications equipment, total	2,553	2,710	2,894
Customer premise equipment	370	392	413
Telephone and data-switching, private (PABX)	389	389	379
Telephone and data-switching, public	1,230	1,326	1,443
Transmission and carrier equipment	564	603	659
Television equipment, total	134	143	146
Broadcast (studio) equipment	93	100	102
CCTV (educational, industrial, and medical)	41	43	44
EQUIPMENT, TOTAL	**21,308**	**22,383**	**23,636**

All figures in current U.S. dollars.
The figures in this table, based on a survey made by Electronics in October and November, 1987, estimate noncaptive consumption of equipment, valued at factory prices for domestic products and landed cost for imported products.
Exchange rate: $1.85 to 1 pound.

automate Italy's voting booths. Another would computerize the national lottery with thousands of point-of-sale terminals, and a third would automate all Italian deed-registry offices.

In the communications sector, as well, government action will mean the difference between so-so markets and solid ones. The survey forecasts a gain of 7% to $3.7 billion, slightly off last year's 8% rise. But the market could take a strong upward bound after 1988. If a proposed 20% increase in the current 10-year telecommunications plan goes through, switching-equipment makers will see their orders rise from this year's 1.3 million lines to 2.3 million lines a year. "Thirty percent of Italian households now have phones; the goal is to reach the same level as the UK—38%," says Claudio Pilati, a vice president at Italtel SpA, Milan, the leading Italian telecommunications producer. "It's practically all digital," he adds.

Tuning in on the consumer electronics sector, the survey foresees a market of $3.1 billion, up 6% over 1987. Saturation has set into the market mainstay, medium-size color-TV sets, and overall no gain is in sight. But "portables and sets with big, square screens should do well," says Mario Zappini, an official of the electronics trade association ANIE in Milan. Video-cassette recorders are still running strong, and sales of camcorders and compact-disk players will burgeon.

ITALY EQUIPMENT

	(millions of dollars) 1986	1987	1988
Data processing and office equipment, total	**4,740**	**5,374**	**5,741**
Computer systems, total	2,889	3,286	3,601
Personal computers (under $5,000)	672	806	921
Microcomputers ($5,000 to $20,000)	258	289	318
Minicomputers ($20,000 to $100,000)	542	633	704
Superminicomputers ($100,000 to $400,000)	284	325	358
Mainframe computers ($400,000 to $5 million)	1,125	1,215	1,292
Supercomputers (over $1 million, with integral vector processor)	8	18	8
Data-input peripherals	61	67	73
Data-output peripherals	300	336	379
Data-storage subsystems	635	719	796
Data terminals	259	290	304
Electronic office equipment, total	596	676	588
Copiers	413	495	421
Electronic typewriters	154	164	154
Word-processing systems	29	17	13
Test and measuring instruments, total	**210**	**232**	**248**
Amplifiers, lab	2	2	2
Analog voltmeters, ammeters, and multimeters	7	7	6
Automatic test equipment, total	46	52	58
Discrete-component testers	2	2	2
IC testers	18	20	23
Pc-board testers	26	30	33
Calibrators and standards, active and passive	n/a	n/a	n/a
Counters, time and frequency	5	5	5
Digital multimeters (including accessories)	11	12	12
Logic analyzers	7	8	8
Microprocessor development systems	21	23	27
Microwave test and measuring instruments	28	32	35
Oscillators	2	2	2
Oscilloscopes	27	27	26
Recorders and plotters	21	23	25
Signal generators, total	15	17	17
Analog	8	9	9
Synthesized	7	8	8
Spectrum analyzers	18	22	25
Industrial electronic equipment, total	**1,224**	**1,356**	**1,481**
Inspection systems	17	18	20
Machine-tool controls (including numerical)	104	116	128
Motor controls	113	132	144
Process-control equipment (including computers, loggers, consoles)	917	1,004	1,094
Programmable controllers	57	66	72
Semiconductor production equipment	16	20	23
Power supplies (noncaptive), total	**65**	**71**	**76**
Bench and lab	5	5	5
Industrial (heavy duty)	18	20	22
OEM and modular, total	42	46	49
Linear	15	16	16
Switching	27	30	33

	(millions of dollars) 1986	1987	1988
CAD/CAE equipment, total	**221**	**288**	**373**
Consumer electronics, total	**2,718**	**2,877**	**3,053**
Audio equipment, total	655	701	755
Car audio	138	142	142
Compact disk players	29	39	51
Phonographs and radio-phonographs	31	29	28
Radios (including table, clock, and portable)	54	54	54
Radio/recorder combinations	104	108	114
Stereo equipment, total	188	211	241
Components (including tuners and turntables)	121	128	134
Consoles and compact systems	67	83	107
Tape recorders and players	111	118	125
Home video equipment, total	289	412	534
Camcorders and cameras	43	54	96
Cassette players and recorders	246	358	338
Television receivers, total	1,052	1,052	1,047
Color	1,000	1,004	1,004
Monochrome	52	48	43
Other consumer electronic products, total	722	712	717
Calculators (personal and professional)	92	83	82
Electronic musical instruments	46	44	44
Electronic watches and clocks	271	267	273
Home computers (under $1,000)	270	265	258
Microwave ovens	43	53	60
Communications equipment, total	**3,218**	**3,472**	**3,723**
Data communications equipment	86	98	115
Facsimile terminals	42	61	69
Fiber-optic communications systems	n/a	n/a	n/a
Intercom systems	35	36	33
Navigation aids, except radar	149	163	179
Paging systems, public and private	6	4	4
Radar (air, land, and marine)	248	263	289
Radio, total	201	225	246
Broadcast equipment	18	21	25
Land mobile (mobile and base stations)	104	116	128
Microwave	79	88	93
Satellite earth stations	n/a	n/a	n/a
Telecommunications equipment, total	2,395	2,563	2,727
Customer premise equipment'	550	595	643
Telephone and data-switching, private (PABX)	262	288	302
Telephone and data-switching, public	1,291	1,372	1,457
Transmission and carrier equipment	292	308	325
Television equipment, total	56	59	61
Broadcast (studio) equipment	27	28	29
CCTV (educational, industrial, and medical)	29	31	32
EQUIPMENT, TOTAL	**12,396**	**13,670**	**14,695**

All figures in current U.S. dollars.
The figures in this table, based on a survey made by Electronics in October and November 1987, estimate noncaptive consumption of equipment, valued at factory prices for domestic products and landed cost for imported products.
Exchange rate: 1,200 lire to $1.

BERLIN

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for all types of wirewrap products. Such as transformers, electric motors, generators, rectifiers, transmitters and LF + HF coils.

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Economic Development

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MILITARY/AEROSPACE NEWSLETTER

GaAs WAFER SUPPLIES COULD BE TIGHT IF DEMAND FOR CHIPS TAKES OFF

Suppliers of gallium arsenide wafers are struggling as demand for GaAs chips lags—and that could cause problems for the Defense Department's plans to boost GaAs chip output. "Right now, the [wafer] industry's dead," says Karl Lifshitz, president of GFI Advanced Technologies, a New York supplier of purified gallium. "There are a couple of people going under." But Mimic, the $500 million Pentagon program to boost yields for microwave and millimeter-wave integrated circuits, could ignite the GaAs market; some insiders predict that individual defense programs could require up to 200,000 chips a month [*Electronics*, Nov. 26, 1987, p. 122]. That's just 33% less than the 300,000 GaAs chips the entire U. S. industry produced in 1987, says one wafer supplier. But there's a downside to a sudden boost in demand. "If the government wanted 1 million devices this year, no one could supply them," he says. "There wouldn't be enough material." □

THE ARMY LOOKS AT SILICON SOLUTIONS FOR HIGH-DENSITY RAD-HARD SRAMs

The Army Space Defense Command in Huntsville, Ala., wants high-density, radiation-hardened memory chips, and it's looking at three competing silicon technologies to get them. It's funding programs to develop 64- and 256-Kbit static random-access memories in bulk silicon, silicon-on-insulator, and silicon-on-sapphire technologies. The parts are needed for the satellites and missile interceptors that will be key to the Strategic Defense Initiative. A parallel effort in gallium arsenide is being handled by the Defense Advanced Research Projects Agency [*Electronics*, Jan. 7, 1987, p. 162]. Seven companies are battling it out in the silicon program. Honeywell and IBM are pursuing bulk silicon, Texas Instruments and Harris are studying silicon-on-insulator, and GM/Hughes Electronics, GE/RCA, and Westinghouse Electric are looking at silicon-on-sapphire. Each is pursuing either 64- or 256-Kbit densities, and TI is developing 64-Kbit "elements," using 1-μm lines, that it hopes eventually to combine on a single chip to create a 256-Kbit part. □

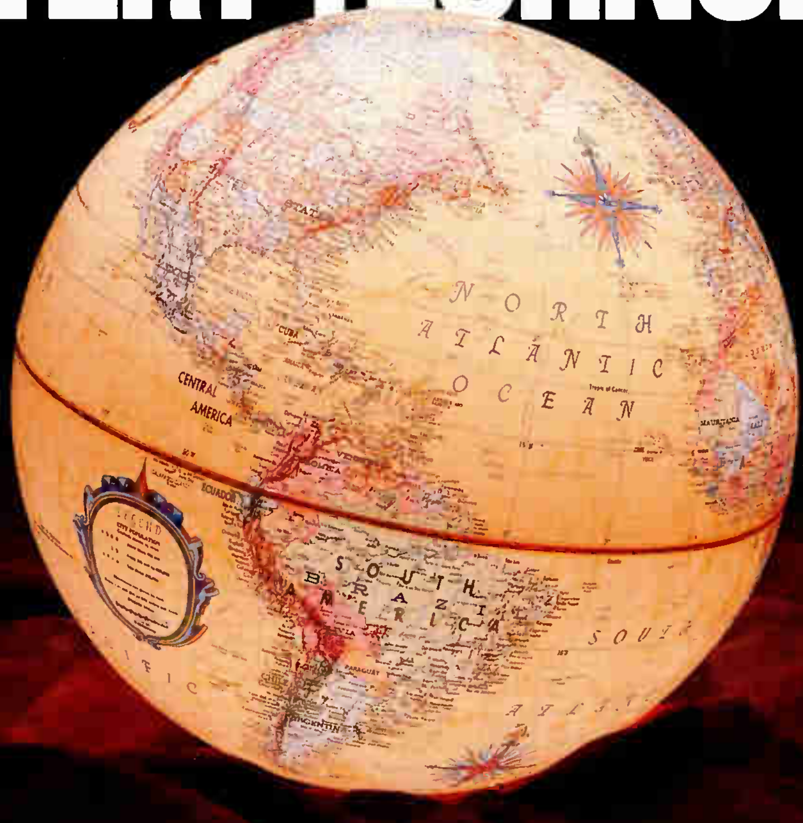
SDI RAILGUNS COULD ALSO LAUNCH SMALL SPACE PROBES

Scientists at the Jet Propulsion Laboratory in Pasadena, Calif., are proposing a novel scheme that would use railgun technology developed for the Strategic Defense Initiative to launch small scientific space probes. The plan is of interest because of a rising backlog of experiments caused by delays in NASA's Space Shuttle program. Advances in microelectronics have reduced the weight of the contents of conventional space probes from hundreds of pounds to less than 3 lbs. A 2.2-lb. spacecraft launched by an orbiting railgun would achieve an exit velocity of about 6 miles/s, scientists say, allowing it to travel the 750 million miles between Earth and Saturn in just two years. □

UNISYS MAKES THE TOKEN RING FAIL-SAFE FOR U. S. WARSHIPS

Unisys Corp. has developed an adapter for the Navy's shipboard token-ring local-area network that can reconfigure the network if vital links are broken. Called SafeNet I, for Survivable Adaptable Fiber Optic Network, it adds a second, counter-rotating ring to the primary token-passing ring. If the primary ring is broken, the secondary link takes over; if both are damaged, SafeNet I software will reconfigure the warship's net, pulling pieces of the rings together to maintain vital links. Unisys demonstrated the embedded redundant token ring, which uses special adapaters based on Texas Instruments Inc.'s TMS380 token-ring chips, last week in San Diego. A second-generation version, SafeNet II, will eventually add compatibility with the fiber distributed data interface standard. □

THE NEW POWER IN RECHARGEABLE BATTERY TECHNOLOGY.



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Circle 84 on reader service card

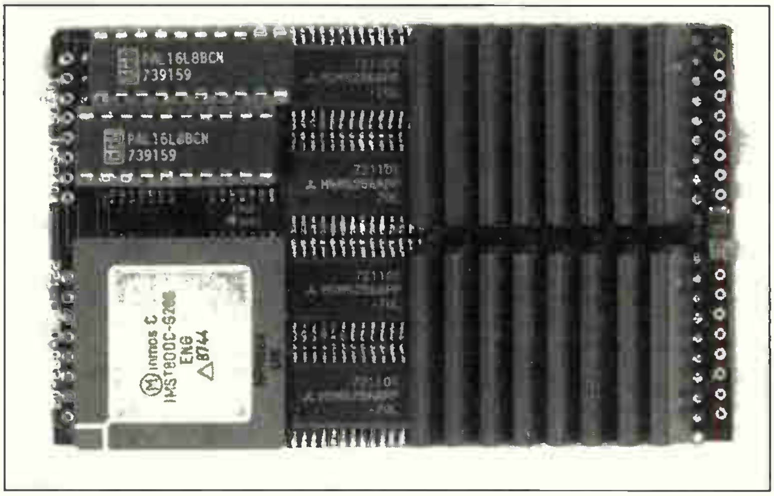
NEW PRODUCTS

CREDIT-CARD SIZE TRANSPUTER MODULES CAN TURN A PC INTO A SUPERMINI

INMOS LINE SNAPS TOGETHER INTO MORE THAN 100 CONFIGURATIONS

Building powerful multiprocessor computer systems that rival superminicomputer performance is becoming almost as easy as snapping together Lego building-block toys, with Inmos International plc's modular line of transputer-based boards.

The Bristol, UK, company's modules—as small as a credit card—boast microprocessors that deliver performance up to 4 million whetstones and memory capacities ranging up to 8 Mbytes. By stacking them together in mix-and-match fashion, designers can quickly fabricate a high-performance system that plugs into popular platforms such as Sun Microsystems Inc. work stations or IBM Corp. Personal Computers and compatibles.



MINI. Shown actual size, the B404 transputer module packs 128 Kbytes of fast SRAM, 2 Mbytes of DRAM, and an IMS T800 floating point transputer processor.

100 FLAVORS. "With this approach we can meet requests for up to 100 different board designs with only a few basic bare motherboards and a few module boards," says David Bye, field applications engineer for Inmos Corp.

The building blocks are well suited for imaging, graphics, industrial control, robotics, and military systems as turbo chargers for technical work stations, and other multiprocessor systems requiring tens to hundreds of processors.

Initially, Inmos is offering five modules and two motherboards. The two motherboards are the IMSB008, which is compatible with IBM's PC XT, and the IMSB012, which conforms to the double-extended Eurocard format.

The motherboards, which can be cascaded together to configure very powerful systems, have two roles. First, they provide an interface between the modular transputer array and the host computer. The other function is to create soft-wired transputer networks using the four communications links on each processor and the on-board link switches to dynamically wire the processors into a specific configuration—matrix, pipeline, or tree structures, for example.

The B008 contains 10 slots for the module boards. The B012 has 16 slots. An IMS T212A-G20S transputer is used as a control processor on both boards. One IMS C004 link switch is used on the B008 and two on the B0012.

The first five module boards are IMSB401, B402, B403, B404, and B405. The B401 is the smallest size available. It packs a T414B-G20S or T800C-G20S transputer and 32 Kbytes of static random-access memory and measures 3.66 in. by 1.05 in. The B402 has 8 Kbytes of SRAM and one T212A-G20S transputer and is the same size as the B401.

At 3.66 in. by 4.35 in., the B403 sports 1 Mbyte of dynamic RAM and either a T414B or T800C transputer. The B404 and B405 both come with T800C transputers and have 2 and 8 Mbytes of DRAM, respectively. The B404 is 3.66 in. by 2.15 in. The B405 measures 3.66 in. by 8.75 in.

All the modules have standard 16-pin dual-in-line edge plug and socket connectors with extra wide 3.5-in. pitch.

Available now, the modules range in price from $584 for the B402 module to $7,471 for the 8-Mbyte B405. The PC-compatible B008 motherboard costs $1,226 and the Eurocard-compatible B0012 costs $1,750. – *Tom Manuel*

Inmos Corp., 1110 Bayfield Dr., P. O. Box 16000, Colorado Springs, Colo. 80935. Phone (303) 630-4000 [Circle 340]

POWER SUPPLY REGULATES VOLTAGE 5 TIMES BETTER

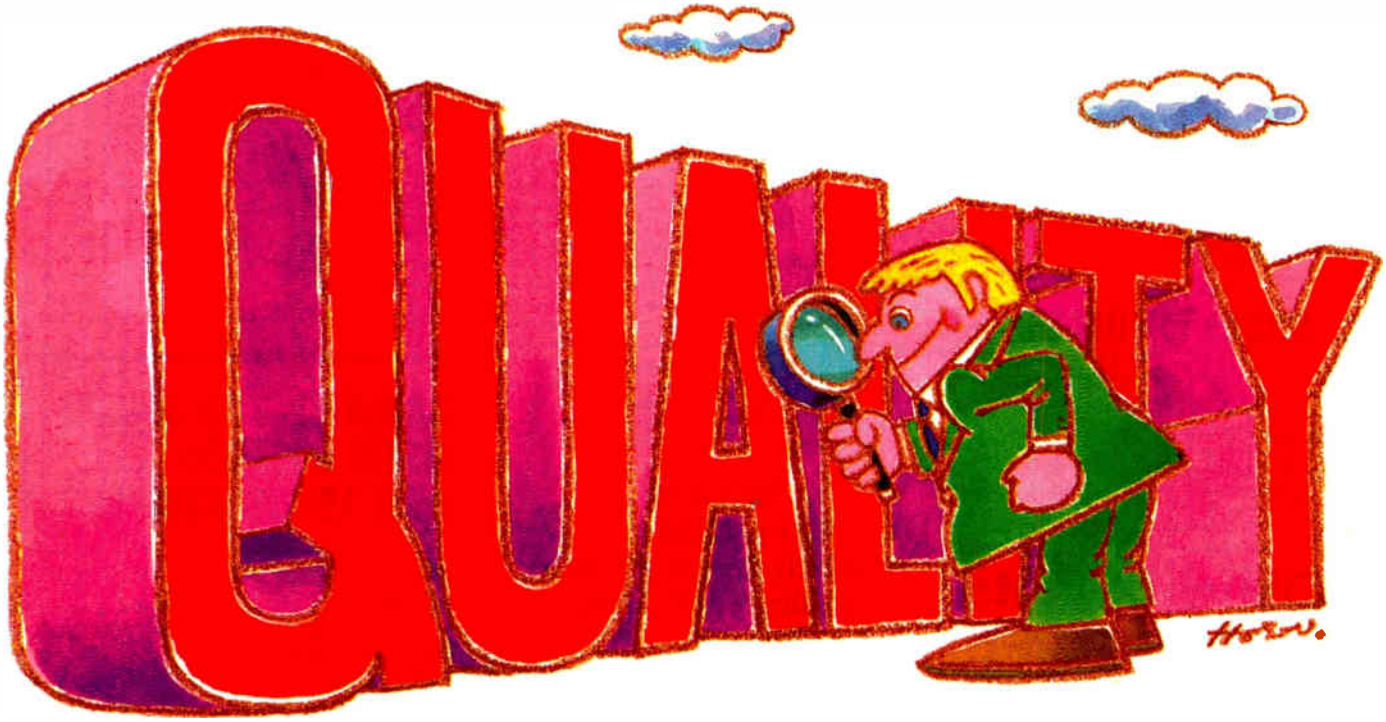
The current-sharing technique used by Computer Products Inc. in its new series of redundant power supplies guarantees 0.2% output voltage regulation during a single-point failure—compared to 1% regulation for major competitors.

The higher precision means designers get more reliability and enhanced data integrity for a wide variety of equipment that must be kept on line. Unlike techniques that depend on master/slave interactions to maintain current flow during failures, the Pompano Beach, Fla., company's method keeps each output power source independent. This forced current sharing is achieved in the 250- to 600- W Switching Power Supply Series by a closed-loop circuit controlled by a high-gain amplifier that disconnects the failed output.

Up to seven outputs, all with the same power rating and all tied to the same computer power bus, are available, says Rex Vacca, Computer Products product manager.

The series targets applications in which high reliability and minimum sys-

More than just a word...



If one word could describe the corporate philosophy of Graphtec, that word would be quality. From the preliminary design through to final delivery, we know that the key to success is in making equipment that works, perfectly. At every stage, components are rigorously tested, performance is carefully scrutinized and any parts less than perfect are rejected. Why do we go to the trouble? Quite simply, because our reputation is on the line with every product you buy.

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Circle 87 on reader service card

speed grades of 70, 80, 100, and 120 ns. Both versions are available in 16-pin plastic dual in-line packages and surface-mountable 18-pin plastic leaded chip carriers. Vitelic is also offering the chips in a 16-pin ZIP, which doubles the chips's packing density.

In 100-piece quantities, the 70-ns parts sells for $7.87 each. The 100-ns parts cost $5.66 each. The low-power versions cost $8.78 for 70-ns speeds and $6.24 each for 100-ns parts. Pricing is for 100-piece orders. – *J. Robert Lineback*

Vitelic Corp., 3910 N. First St., San Jose, Calif. 95134.
Phone (408) 433-6000 [Circle 360]

SARATOGA'S SRAM USES BICMOS FOR 15-NS SPEED

Saratoga Semiconductor Corp. has introduced biCMOS technology to the world of application-oriented static random-access memories with a 16-Kbit cache-tag RAM that boasts a top address-to-compare access speed of 15 ns.

Saratoga's SSL4180, a 22-pin, 4-K-by-4-bit tag RAM, and SSL4181, a similar part that has open-drain-match outputs in place of the 4180's totem pole outputs, are at least 5 ns faster than competing all-CMOS 4-K-by-4-bit parts, says Dan Scovel, product marketing engineer.

Saratoga's biCMOS, called Sabic-II for Self-Aligned Bipolar CMOS, is a 1.5-μm technology, which is used to integrate a 16-K array and 4-bit comparator. The tag RAM's die measures 145 by 158 mils. The Cupertino, Calif., firm will also use the same process to introduce a second 16-Kbit tag RAM, organized as 2-K-by-9-bit, by midyear.

Samples of the 4-K-by-4-bit cache-tag parts, with address-to-compare times of 15, 20, 25, and 35 ns, will be available this month. The biCMOS design also offers data-to-compare access times of 12.5, 15, or 20 ns.

The 4180 and 4181 are TTL-compatible with +5-V power supply. They feature a flash-clear function and can be used together to expand word widths. The maximum power dissipation for the memory parts is expected to be 560 mW.

In 1,000-piece orders, the 15-ns tag RAMs cost $31.50 each in 22-pin plastic dual in-line packages. In similar quantities, the 20-ns speed grade costs $27.50 each, 25-ns chips $24.50, and 35-ns tags $21.50. Deliveries of volume shipments start in April. – *J. Robert Lineback*

Saratoga Semiconductor Corp., 10500 Ridgeview Ct., Cupertino, Calif. 95014.
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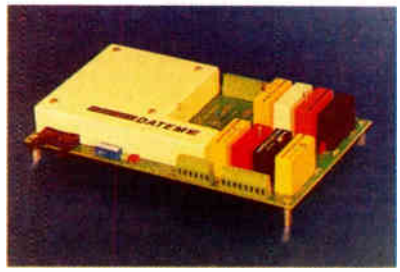

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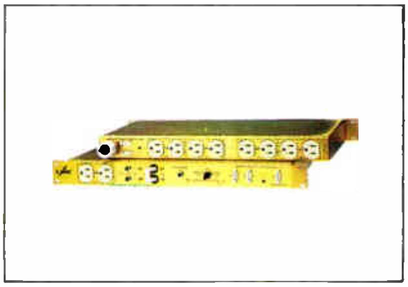

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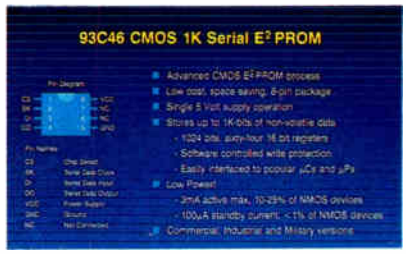

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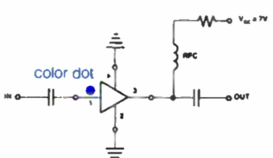

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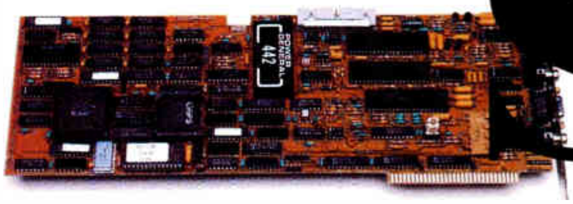

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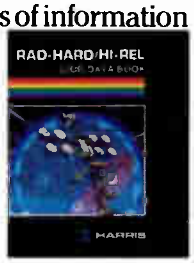

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In another move designed to strengthen *Electronics'* position as the most authoritative voice in the industry, we're adding strength to our Silicon Valley coverage. Rob Lineback, one of the hardest working and most respected journalists covering electronics, is moving from Dallas to San Mateo. And he relishes the excitement of the new challenge.

LINEBACK: The Texan moves to the Silicon Valley.

"The constant state of bubbling enthusiasm in the commotion of Silicon Valley is exciting," says the Dallas native. "So even though I'm leaving my roots and well-traveled paths around Texas and Colorado with a little sadness, I expect to feel right at home in California."

Also, Rob says, the magazine's pioneering treatment of the industry as one in which national boundaries are fading for both business and technology has its parallel in the U. S. "The long-held regional stereotypes are crumbling in this country the same way they are on a global level," he says. "Engineers and managers seem to be moving across regional boundaries more frequently and with more ease today. West Coast companies continue to lure ambitious professionals away from the security of the nation's heartland, just as the promise of lower costs and new talent in the Southwest has been stealing away divisions from Silicon Valley."

The 34-year-old Lineback has a background uniquely suited to his job. Though he has a journalism degree from North Texas State University, it would be safe to say that the semiconductor business is in his blood. His father was one of the early product engineers in Texas Instruments Inc.'s semiconductor division. When Rob was four, his father taught him all the components in a Regency pocket transistor radio. "I was brought up on stories of the days when TI's chip operations were housed in a former Dallas bowling alley, when my father's engineering team once used Coca-Cola as an etching agent for germanium transistor slices and a hair-styling jell to help seal packages."

Now, as Rob views the industry, techniques may be different but the emotions are the same. "Engineers might have more formal product-development methods than they had in that old bowling alley, and they also have all those computer-based tools. But they are still faced with exciting times as the pace of change quickens," he says.

And Rob has recorded more than his share of changes in the seven years he has been a member of our staff. "When I started, there was no Compaq Computer Corp. in Houston. Today's successful venture capitalist, L. J. Sevin, was still chairman of Mostek Corp. in Carrollton, Texas, and Mostek was still in the money and in the 16-Kbit dynamic RAM market."

Executive editor Art Erikson, who runs the magazine's worldwide news operations, sums it up best when he says, "In Rob Lineback, we have a newsman who is bright, knowledgeable, and totally professional. Bringing those attributes to the Silicon Valley, Rob will make the *Electronics* package that much more valuable."

January 7, 1988 Volume 61, Number 1
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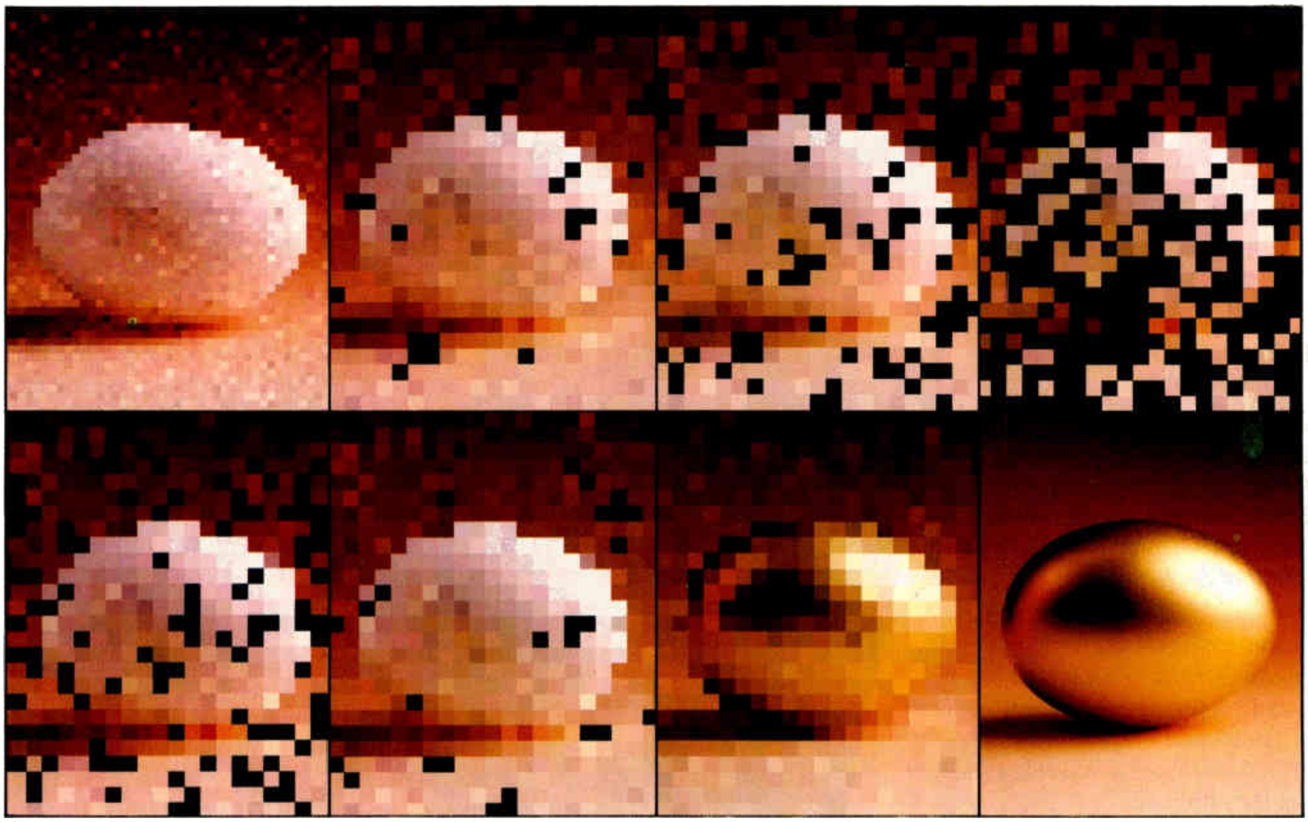

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ELECTRONICS NEWSLETTER

IBM LAUNCHES A MAJOR SUPERCOMPUTING INITIATIVE IN EUROPE

While IBM Corp. was making headlines by promising to develop a next-generation supercomputer with Steve Chen (see story, p. 31), Big Blue was busy on other fronts as well. IBM announced that it will spend $40 million over the next two years to advance supercomputing in Europe. IBM's investment will be used in part to set up supercomputing centers in Europe similar to those in the U. S. created by the National Science Foundation in 1985. The five European centers it is planning will be based at major universities or research institutions, and will be supported by IBM, the institutions, and national governments. IBM will also supply over 25 other European educational and research institutions with advanced processors or vector facilities. The first European center will be at the Centre National Universitaire Sud de Calcul in Montpellier, France, and is slated to begin operating this month. ☐

PRIME-COMPUTERVISION MERGER WOULD MAKE A NEW NO. 2 IN CAD

Prime Computer Inc. is trying to vault over Intergraph Corp. to become the world's second-largest supplier of computer-aided-design equipment with its unsolicited $400 million offer for Computervision Corp. Only IBM Corp. would have a larger market share. Cash-rich Prime, of Natick, Mass., made the offer last week. The deal would give Prime an in-house source for the work stations it buys from Sun Microsystems and then sells, with software, as a low-end system, says Charles Foundyller, president of market researcher Daratech Inc., Cambridge, Mass. Computervision also uses Sun platforms, but manufactures them itself under license. The merger would also give Prime access to Computervision's widely used Medusa software and to low-end work-station expertise it doesn't now have. Computervision had sales of $494 million in 1986, but has experienced slow growth and slim profits in recent years. Foundyller says the company would benefit from the financial stability of Prime, which earned $47 million on sales of $860 million in 1986. Computervision has until Jan. 16 to decide on the offer. Its initial reaction was noncommital. ☐

FCC PROMOTES RADIOPHONES FOR RURAL AREAS

The Federal Communications Commission is establishing a radio-telephone standard designed to help bring phone service to the nearly 1 million rural U. S. homes and businesses that right now have no service at all. Operating in the 150-, 450-, and 800-MHz bands—which are already included in the public land-mobile-service band—the new Basic Exchange Telecommunications Radio Service sets aside 94 channels for such radio-telephone hookups. The FCC announcement, made in December, is a big boost for at least one company, International Mobile Machines Corp. [*Electronics*, March 31, 1986, p. 21]. The Philadelphia-based company has been using its Ultraphone system experimentally in conjunction with a number of local telephone companies, including Mountain Bell, for the past two years. ☐

NOW APPLE'S MACINTOSH CAN TALK TO A PLOTTER

Apple Computer Inc.'s fight to gain acceptance for its Macintosh personal computer from engineers and scientists is getting a lift. One problem the Mac has faced is that, until now, it could not be used with most engineering plotters. But IOtech Inc. of Cleveland, Ohio, has developed a $495 interface card that lets the Mac talk to any plotter equipped with an IEEE 488 or HP-IB/GPIB interface. Combined with MacPlot software, a $395 desktop utility that converts the Macintosh screen to the HPGL or compatible plotter graphics language, the board lets programs such as MacPaint run directly on plotters. ☐

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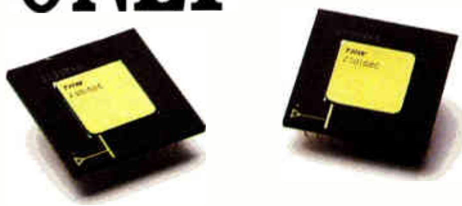

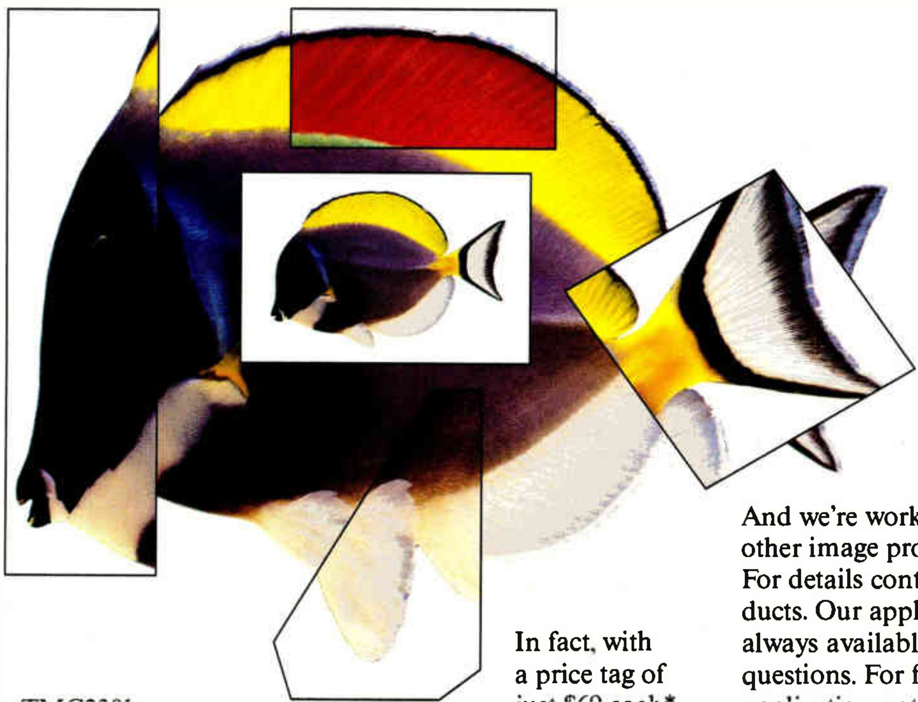

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PRODUCTS NEWSLETTER

IDT'S 4-KBIT FIFOs RUN 29% FASTER THAN ITS EARLIER PARTS

Integrated Device Technology Inc. is beating its own 35-ns speed record in 512-by-9-bit first-in, first-out memories with a new CMOS process that hits 25 ns—29% faster than the previous parts. The Santa Clara, Calif., company uses its CMOS-III double-polysilicon, single-metal technology to reduce the effective gate lengths in its IDT7201 FIFO from 0.9 to 0.8 μm (the drawn gate lengths remain at 1.2 μm). The result is lower capacitance and what IDT managers call the industry's fastest parallel in-out 512-by-9-bit FIFO. The speed increase lets the chip handle faster processors, mass-storage peripherals, laser printers, and local-area networks. Available now, samples of the parts, in 100-piece quantities, cost $42.50 each in 600-mil-wide plastic dual in-line packages and $60 each in 300-mil ceramic DIPs. □

ULTRATHIN CRYSTAL OPENS DOOR TO MORE PRECISE SMART-CARD CLOCKS

Smart-card technology is taking a big step forward with a 26-mil-thick quartz crystal from the Micro Crystal Division of ETA Industries Inc.—just one-fourth the thickness of the thinnest crystal resonators now available. By dipping below the 30-mil maximum thickness allowed in smart-card design, the GX-1 clears the way to implement crystal-controlled clocks on the cards, says the New York company. This clock will provide better accuracy than the other smart-card alternative, which is a patented technique to boot. The 0.33-by-0.155-by-0.026-in. GX-1 is produced in Switzerland using a photolithographic process and protected by a glass envelope. It comes in two frequency ranges: 10 kHz to 2 MHz and 8 to 30 MHz. It has contact pads for surface mounting, withstands 270° C for 30 seconds, and is available on tape or reel. Pricing hasn't been set by the Swiss parent company, SMH SA, but the GX-1 is expected to cost under $1 each in 100,000-unit quantities. □

MICRO DESIGN TARGETS SCSI COMPUTERS WITH ITS 65-MS WORM OPTICAL DRIVE

By doubling the speed of its write-once, read-many optical disk drive and then integrating a Small Computer Systems Interface, Micro Design International Inc. is putting 800 Mbytes of high-speed memory in the hands of personal computer users. The LaserBank 800 achieves its 65-ms access time—equivalent to midrange hard-disk speeds—mostly by replacing an 8-bit host adapter with a 16-bit adapter. Proprietary software means users of IBM Corp. Personal Computers and compatibles can install the SCSI interface simply by plugging a SCSI card in a PC and connecting it to the LaserBank 800 with a standard 50-pin cable. MS-DOS compatiblity means users can continue to use their favorite applications programs such as Lotus 1-2-3, dBASE III, and AutoCad without modification. Available now, the Winter Park, Fla., company's drive costs $9,995. □

COMPUTER DYNAMICS DELIVERS A LOW-COST STDBUS NETWORK

Computer Dynamics Inc.'s marriage of Intel Corp.'s Bitbus industrial communications bus with the popular STDbus industrial-controller bus lets a process engineer control up to 250 devices from a terminal in his office for only $300 per node. Previously, engineers had to collect data from each STDbus node manually or have sophisticated networking software written to do the job. The Greer, S. C., company's STD-BitBoss interface board is compatible with any STDbus microprocessor, and since Bitbus implements IBM Corp.'s SDLC serial communications protocols, error-correction and handshaking are accomplished transparently. The system can handle up to 62.5 Kbits/s over 13.2 km of twisted-pair wire. Available now, STD-BitBoss boards cost $300 each in 100-unit purchases. □

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Electronics

THE IBM-CHEN DEAL COULD MAKE SUPERCOMPUTERS KING OF THE MOUNTAIN

BIG BLUE IS BETTING THAT SUPERCOMPUTING IS THE HOT MARKET OF THE 1990s

WHITE PLAINS, N.Y.

There is no longer any question that the supercomputer market is shaping up as one of the most important for computer makers in the 1990s. But if any doubt remained, it was erased by IBM Corp. late last month.

Three days before Christmas, IBM announced plans to forge an alliance with Steve Chen—the 43-year-old former superstar designer for Cray Research Inc.—to develop a supercomputer 100 times faster than anything available today. IBM will provide funding for Chen's three-month-old company, Supercomputer Systems Inc., and will give Chen access to its high-end technology. In return, IBM gets the right to market the machine, along with Supercomputer Systems, when it is ready for commercial introduction in the early 1990s.

For Chen, the deal provides a financial base that assures the viability of his Eau Claire, Wis., company. "Now we can concentrate on doing design work, and we won't have to worry every year about going out and trying to find money," he says.

UNPRECEDENTED. The IBM move is unprecedented for the world's largest computer maker. It has formed outside alliances in the past, but never before has it signed up with an outsider for the development of an entire high-end system. And IBM even broke its own rules by talking publicly about a future commercial product.

But though the nature of the deal may be surprising, an IBM thrust in high-end supercomputers was not unexpected. "IBM has been interested in this market for a while. They've been doing research projects, and it was inevitable that they were going to enter it, because both the technology and the markets are converging," says Stephen P. Cohen, a vice president with Gartner Securities Group in Stamford, Conn. Indeed, the U.S. supercomputer market alone is projected to total $902 million this year, and some estimates say it will surpass $2 billion by the early 1990s. That's a business that IBM can't afford to ignore.

Because the Chen machine is not expected to emerge until the next decade, it is generally not seen as a near-term threat for Cray, the Minneapolis-based leader in the supercomputer market, or for the other major vendors—ETA Systems Inc., the St. Paul, Minn., subsidiary of Control Data Corp., and Japan's Fujitsu, Hitachi, and NEC. But if IBM continues to talk publicly about the machine between now and its 1990s introduction date, "they may in fact be able to occupy the mindspace of some of the people involved in procurements," says Gary Smaby, a technology analyst at Piper, Jaffray & Hopwood Inc. in Minneapolis.

CHEN: "Now we won't have to worry every year about going out and finding money."

Neither IBM nor Chen is saying how much money IBM will put into the project. The details of the preliminary agreement are still to be negotiated.

But Smaby guesses that IBM funding will initially come to more than $20 million over two years. That's much less than the estimated $100 million cost of the 64-processor MP machine Chen was working on until Cray canceled the project last summer [*Electronics*, Sept. 17, 1987, p. 21]. But for IBM officials, even $100 million would be "pocket change," Smaby points out. "And yet they get a potentially very high return on their investment, relative to the kind of investments they make internally for development projects."

In return, the partnership will provide Chen's company access to a vast wealth of IBM technology, including advanced semiconductors, packaging, software, and peripherals, as well as leading-edge design technology. "As far as I know, we'll have free access to all that's necessary," says Chen. "And if IBM doesn't have what we need to fulfill our requirements, we'll talk to them about a joint effort to develop it."

Chen says the IBM connection will not alter the overall architectural design of the system he is planning. "But the building blocks will be different now, since we'll be using IBM's technology and not somebody else's," he allows.

Despite a minority IBM investment, Chen is determined to keep his company an independent entity. "We want to make sure that we don't get trapped into the typical merger, where the little company becomes part of a big company, where we lose our creativity," he says. Indeed, the IBM link "doesn't mean we won't involve other partners," says Chen. In particular, he is interested in participation in the development effort by potential major customers. IBM, however, will have the right to veto any potential new partners.

IBM ACTIVITY. Even with the Chen linkup, few observers expect IBM to sit still until the next decade in supercomputers. "There's no doubt in my mind that we will see some follow-on offerings in the IBM vector-facility line," says Jeffrey Canin, senior technology analyst with Hambrecht & Quist Inc. in San Francisco. "If nothing else, we'll see support for the vector facility both on higher-performance machines, and perhaps even on lower-scale systems such as the 43XX and the 9370 class."

In addition, some industry observers believe the Chen partnership could in fact help hasten the appearance of high-end commercial supercomputer systems under development at IBM. "In a sense, this creates some competition between the internal groups and the renegade group on the outside in Wisconsin," Smaby says. *–Wesley R. Iversen*

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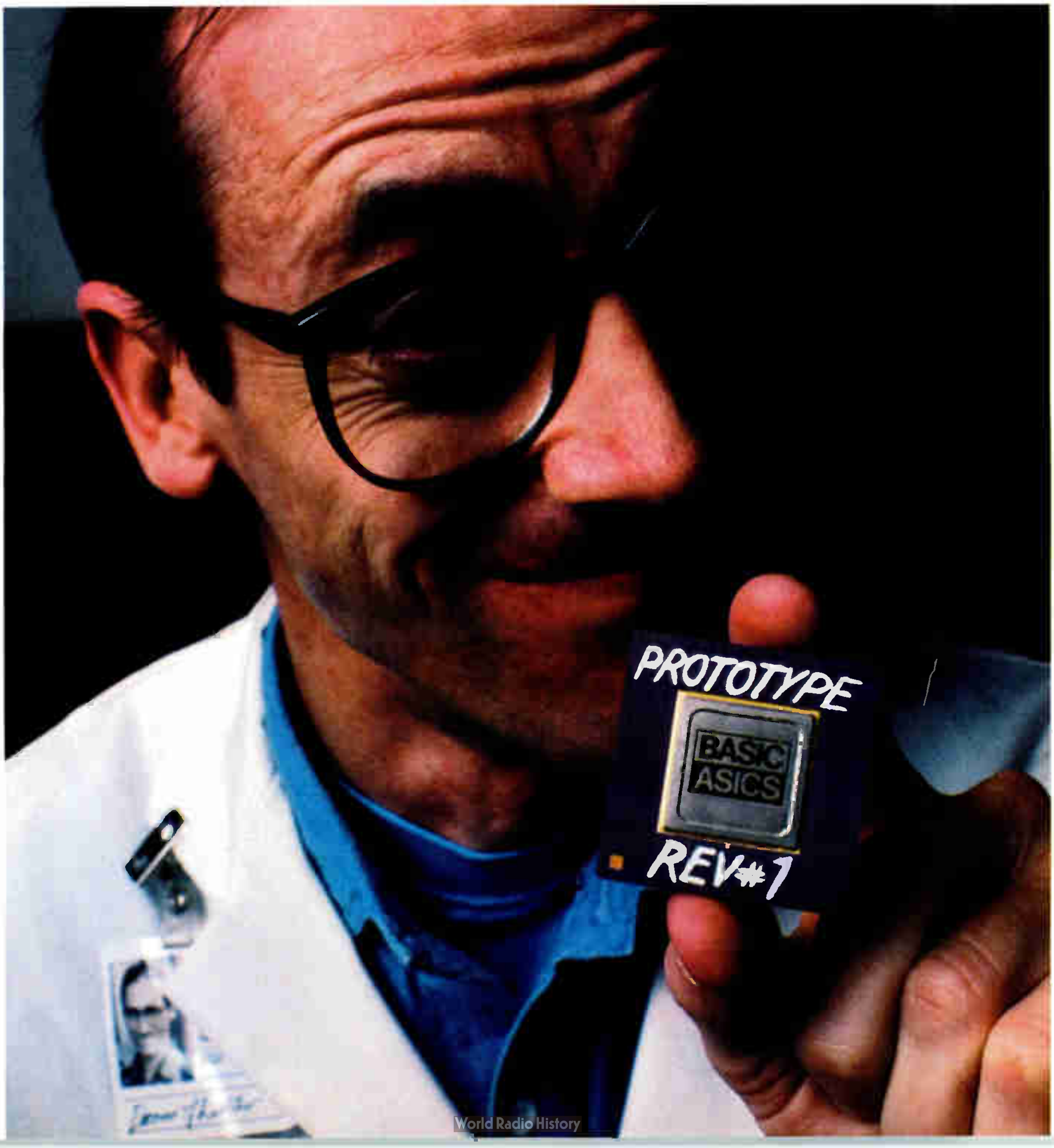

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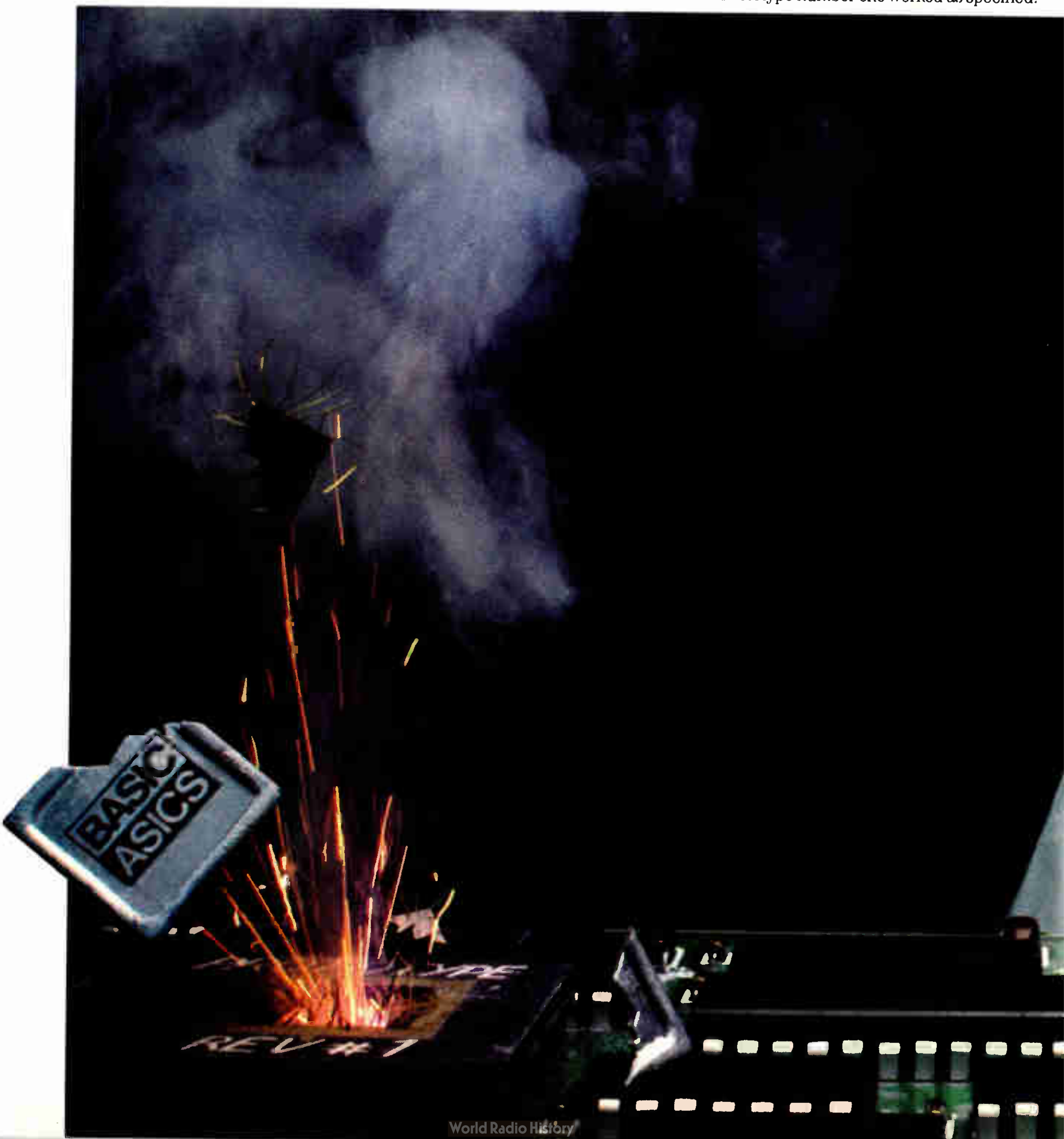

You see, we've been refining our design tools for the past fifteen years. And because they verify your input to worst case specs, as well as scrutinize every detail from spike analysis to bus contention, all the guesswork is eliminated. Our simulations are closely correlated to silicon (with a 99% hit rate). Plus, all prototypes and wafers are tested exactly like production units. So you know what you'll get. Before you get it.

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Once you've accepted a prototype from Fujitsu, you can put all your production worries aside. Our design system drives devices to match the production process. That's guaranteed by 100% AC testing at frequency, in addition to the standard DC and functional testing. What's more, all wafer fabrication, assembly and testing are done in-house. All this means that you can count on production units that work uniformly.

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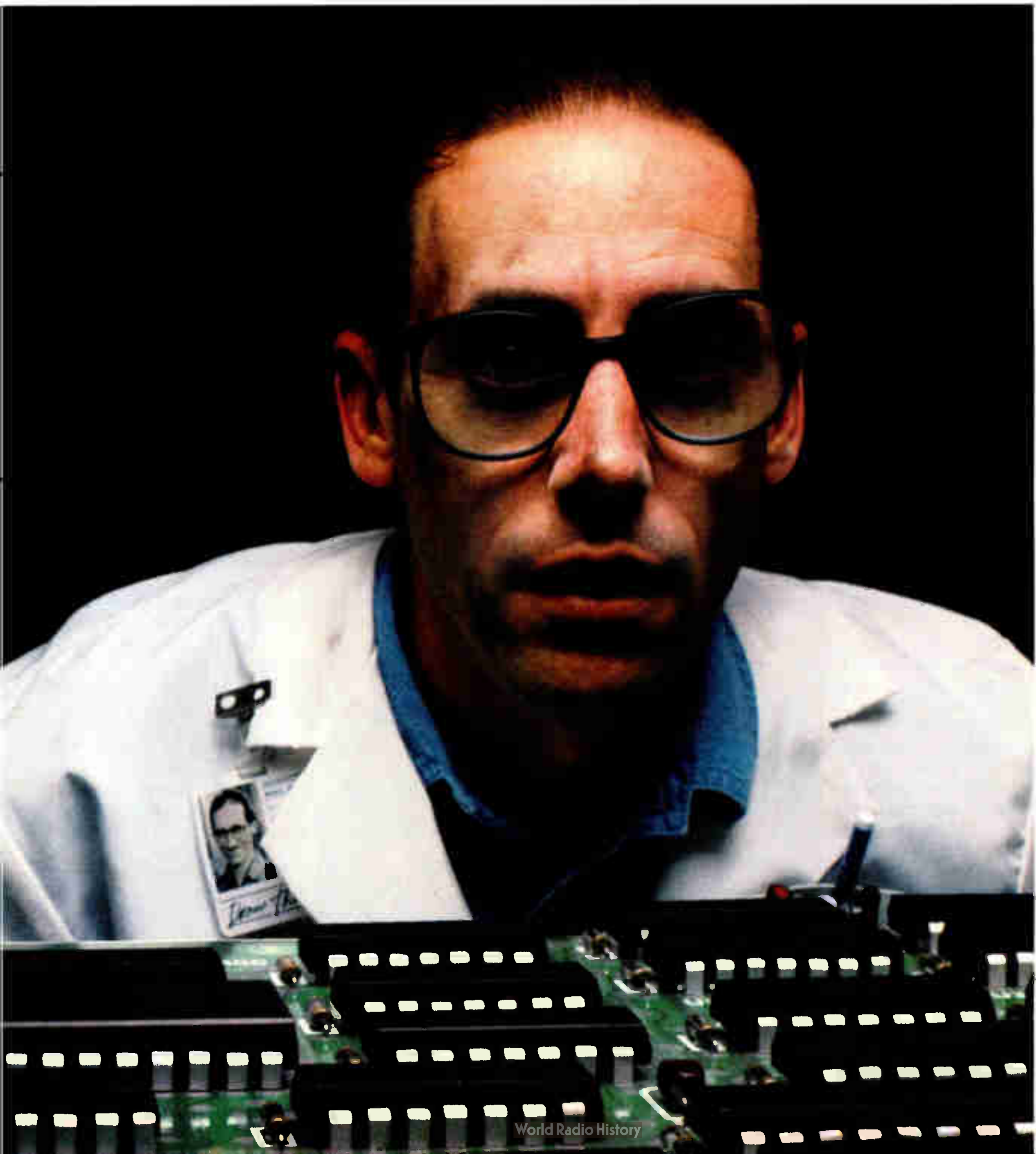

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30-1	7	LP	Elliptical	1Hz — 99Khz
30-2	7	LP	Elliptical	0.1Hz — 9.9kHz
30-3	7	LP	Elliptical	0.01Hz — 990Hz
31-1	7	HP	Elliptical	1Hz — 99kHz
31-2	7	HP	Elliptical	0.1Hz — 9.9kHz
31-3	7	HP	Elliptical	0.01Hz — 990Hz

Here's an entire filter system you can configure exactly to your needs—Krohn-Hite's Multichannel Filter System. Plug-in filter modules give flexibility—bandwidths, slopes, and expandability to 16 channels. Up to 60dB of input plus output gain is standard with each module. Bessel and Butterworth types coming soon. Choose the configuration that fits your application best. And don't pay for more than necessary.

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With this structure, a bipolar transistor's good properties can be exploited even at 1,000 V without much tradeoff, Zlabinger says. While maintaining the characteristics for a typical bipolar transistor, the Siret has a short current fall time during switchoff—about 50 ns for inductive loads. And Sirets can be combined into modules that handle high currents. For example, with four transistors in parallel, a module can tackle 50 A.

Besides motor controls, applications are in switched-mode power supplies, horizontal deflection circuits, and high-voltage generators for monitors. In all of these, the high switching frequency of Siemens' new part will help make power transformers smaller. *–John Gosch*

IMAGE PROCESSING

UNPLUGGING A BOTTLENECK IN COLOR PROCESSING

MARLBORO, MASS.

A pair of CMOS gate arrays cracks a bottleneck in the computer processing of color images by doing in real time what now takes 8 to 10 minutes. The chips, from Data Translation Inc. of Marlboro, Mass., convert standard red, green, and blue (RGB) signals into more quickly processed values of hue, saturation, and intensity (HSI). The two arrays are being used first on a $2,995 color frame-grabber board for personal computers but could find their way into a host of color image-processing products.

Typical color image processing, such as performing convolutions or histograms on the combined RGB levels to determine the dominant color or to detect object edges, requires substantially more time than it takes to work with HSI levels. That's because the RGB signals must be manipulated simultaneously.

And heretofore, as many as five minutes might be required for a personal computer to make the RGB-to-HSI conversion to facilitate that processing, says John Molinari, product marketing manager for imaging products at Data Translation. Another five minutes would be consumed in reconverting to RGB for display. The Data Translation chip pair does these conversions in real time—1/30th of a second.

MANY JOBS. The chips form the brain of the company's new DT2871 color frame grabber, a board that captures, processes, and displays color images from video sources on the fly using IBM AT and compatible PCs. The frame grabber can handle applications ranging from animation and film coloring to medical imag-

WORLD BEATER.

AMD's 32-bit chip uses an enhanced RISC design to run at a sustained performance level of 17 mips; it can hit a peak execution rate of 25 mips.

AMD Develops The Fastest, Most Powerful 32-bit CPU.

"In the high-stakes race to produce ever-faster microprocessors, AMD is about to blow past the rest of the field with the first microprocessor ever designed by the company. Using an enhanced RISC design, the Am29000 stakes a claim to the title of the world's fastest 32-bit μp. The company regards the new microprocessor as its most significant product in a decade.

AMD thinks its μp can be a formidable contender against the swelling ranks of RISC-based chips. The company believes the chip can outrun a whole host of similar products: the popular RISC chip set from MIPS Computer Systems; the Clipper 32-bit μp from Fairchild; and upcoming releases reportedly on the way from DEC and IBM..."

Excerpted from an exclusive article in the March 19, 1987 issue.

McGraw-Hill **Electronics**

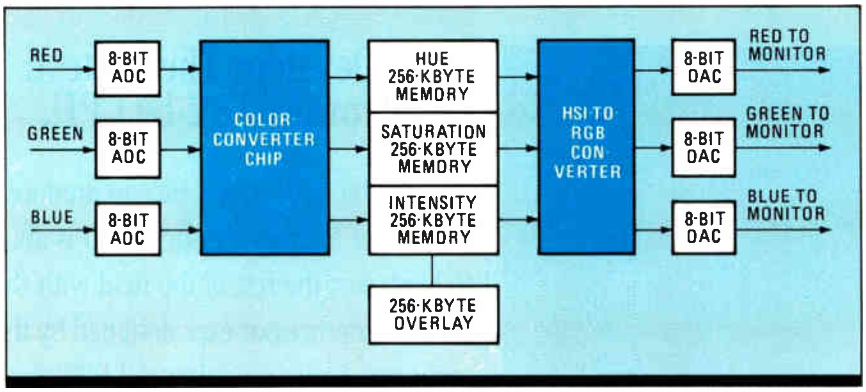
THE LEADER IN NEW TECHNOLOGY COVERAGE

ing and machine-vision inspection.

The two chips make obsolete "the need to do [intermediate] black-and-white image processing of color signals," says Molinari. "They open a whole new way to handle true color information in a meaningful way." Data Translation has no plans to sell the chips separately, but the company might license others to manufacture them.

Industry experts say the development bears watching. "There's nothing like this in the chip or board world," says Will Strauss, president of Forward Concepts Co., a Tempe, Ariz., market research and consulting firm. "They've come up with a fast algorithm that allows them to do something that can't be done with present hardware." Richard D. Schwarz, first vice president at Shearson Lehman Bros. Inc. in New York, says, "Because HSI signals lend themselves to digital processing, this development has potential significance of a high order."

The designs are based on the fact that unlike RGB signals, HSI levels can be individually processed. For example, filtering by using a convolution algorithm on the intensity value can enhance edges or remove white noise from the color image. Similarly, the hue value alone can be used to generate a histogram to graph the frequency and distribution of colors.



COLOR TRAIL. Color inputs are converted to HSI levels before going to a frame buffer memory with one buffer per signal. Then they are reconverted to RGB and fed to a DAC for display.

Suzanne Genz, design engineer for the two arrays—called simply Chip 1 and Chip 2—says they implement well-known algorithms that convert signals from the RGB color cube to the HSI triangle model. Chip 1 takes three inputs, one for each color, from three analog-to-digital converters and converts them to HSI levels, then sends them to a frame buffer memory that consists of one buffer for each signal.

The digitized signals can then be routed off the frame-grabber board for more intensive processing, such as convolutions, histograms, edge processing, or compression of the HSI levels by a frame processor or array processor. Or they can go directly to Chip 2, which reconverts them to RGB signals, then feeds them to one of three 8-bit digital-to-analog converters for display.

LSI Logic Corp. of Milpitas, Calif., is fabricating the two chips in its 2-μm, two-layer-metal 7000 series CMOS process. After going through three redesigns to get down to 8,700 gates, first silicon on Chip 1 is expected soon. First silicon has already been delivered for the less complex 6,500-gate Chip 2. Both operate at 15 MHz in order to meet the minimum 10 MHz required of the color frame-grabber board for real-time, 30-frames/s operation.

Molinari says these chips form the basis for "major new work in color image processing. RGB space is sufficient for graphics, but not for color image processing. We're offering another color space." *–Larry Curran*

COMPANIES

PLESSEY FACES A TOUGH JOB IN ITS CHIP BUSINESS

LONDON

Where will Britain's Plessey Co. strike in 1988? Now that it has added Ferranti plc's semiconductor business and is mounting an assault on world markets for application-specific integrated circuits, Plessey still has about $415 million left in its acquisitions war chest. And after a dazzling series of joint ventures and acquisitions in 1987, which changed the face of England's semiconductor industry, Plessey Chairman Sir John Clark promises "significant growth" this year. But first Plessey must integrate its own IC operations with Ferranti's.

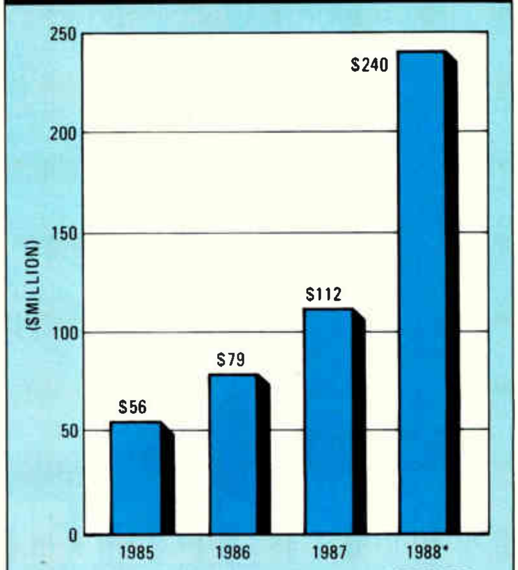
The $70 million Ferranti deal [*Electronics*, Dec. 17, 1987, p. 152] topped off the hectic activity. It was preceded by:

- A joint venture with Racal Electronics plc, called Orbitel, to market digital cellular telephone systems and equipment;
- An agreement with GTE Telenet to make and market data-communications equipment;
- The merger of Plessey's telecommunications division with that of England's General Electric Co., in a 50-50 joint venture to create the world's eighth-largest maker of telecom equipment; and
- The acquisition of Sippican Corp. of Marion, Mass., which doubled Plessey's sales of defense electronics in the U. S.

But indications are that Plessey may not be done wheeling and dealing. The rumor mills have been grinding away and in the last month, the company's name has been linked with two of the remaining three British semiconductor manufacturers, Inmos Ltd. and Marconi Electronic Devices Ltd. Both say they have had discussions, although Plessey is maintaining that it is not interested in either company. And Inmos's parent, Thorn-EMI, now says it has no plans to sell its chip-making subsidiary. (See p. 52)

So while plotting his next move, Sir John has been planning to widen the

ADDING FERRANTI DOUBLES PLESSEY CHIP SALES



*PROJECTED
(WORLDWIDE SALES FOR FISCAL YEARS ENDING MARCH 31)
SOURCE: PLESSEY SEMICONDUCTOR LTD

vistas of Plessey Semiconductors Ltd. With the addition of Ferranti, the new combine will have projected sales in fiscal 1988, which ends March 31, of $240 million, more than twice Plessey's 1987 total of $112 million (Ferranti's 1987 sales alone reached $96 million).

The big market is ASICs. "This is a market [that] is growing by 50% a year, and which will account for nearly 70% of the worldwide semiconductor market by the mid-1990s," Sir John says. With Ferranti, Plessey becomes the largest ASIC specialist in Europe, "at least twice the size of Thomson-SGS in ASICs" says Vivian Butler, managing director of Plessey Engineering and Components Division. "Now," says Butler, "we rank with the major international ASIC companies such as LSI Logic and Fujitsu, and just behind Motorola in the world league."

TOP FIVE. Plessey is now in the top five, agrees market analyst Bill McClean, manager of market research at Integrated Circuit Engineering Corp. in Scottsdale, Ariz. However, he is less bullish than Butler about immediate prospects. McClean says, "Ferranti has been strong in bipolar, which has been coming under price pressure from CMOS. So it's difficult to see where Ferranti gives Plessey a leg up on anyone else. Of course, a lot depends on what Plessey does with it."

The takeover has enabled Plessey to add global targets. Doug Dunn, managing director of Plessey Semiconductors Ltd. and leader of the new combined operation, says the addition of Ferranti's design centers and marketing offices in Europe, North America, and the Far East double his sales and marketing capability. "We expect sales of $65 million to $70 million in the U. S. A. in 1988," after 1987 sales by Plessey alone of $25 million, he says, by combining the efforts of Plessey's design and marketing center at Irvine, Calif., and Ferranti's in Scotts Valley, Calif., and New York. He has also gained centers in Munich and Hong Kong.

The two operations dovetail neatly in terms of ASIC technology, says Dunn. Ferranti has concentrated on the high-density bipolar collector-diffusion isolation (CDI) process that it licensed from AT&T Bell Laboratories in the early 1970s. Plessey, on the other hand, has developed high-density low-power CMOS as well as ultrafast bipolar technologies.

His major problem area is likely to be with Ferranti's discrete semiconductor operation. Making a range of small-signal transistors and power MOS FETs, the Discrete Components Group suffered a 12% drop in sales in 1987, and turned in a "substantial trading loss." Dunn remains noncommittal, saying only that he plans to continue marketing discrete devices.

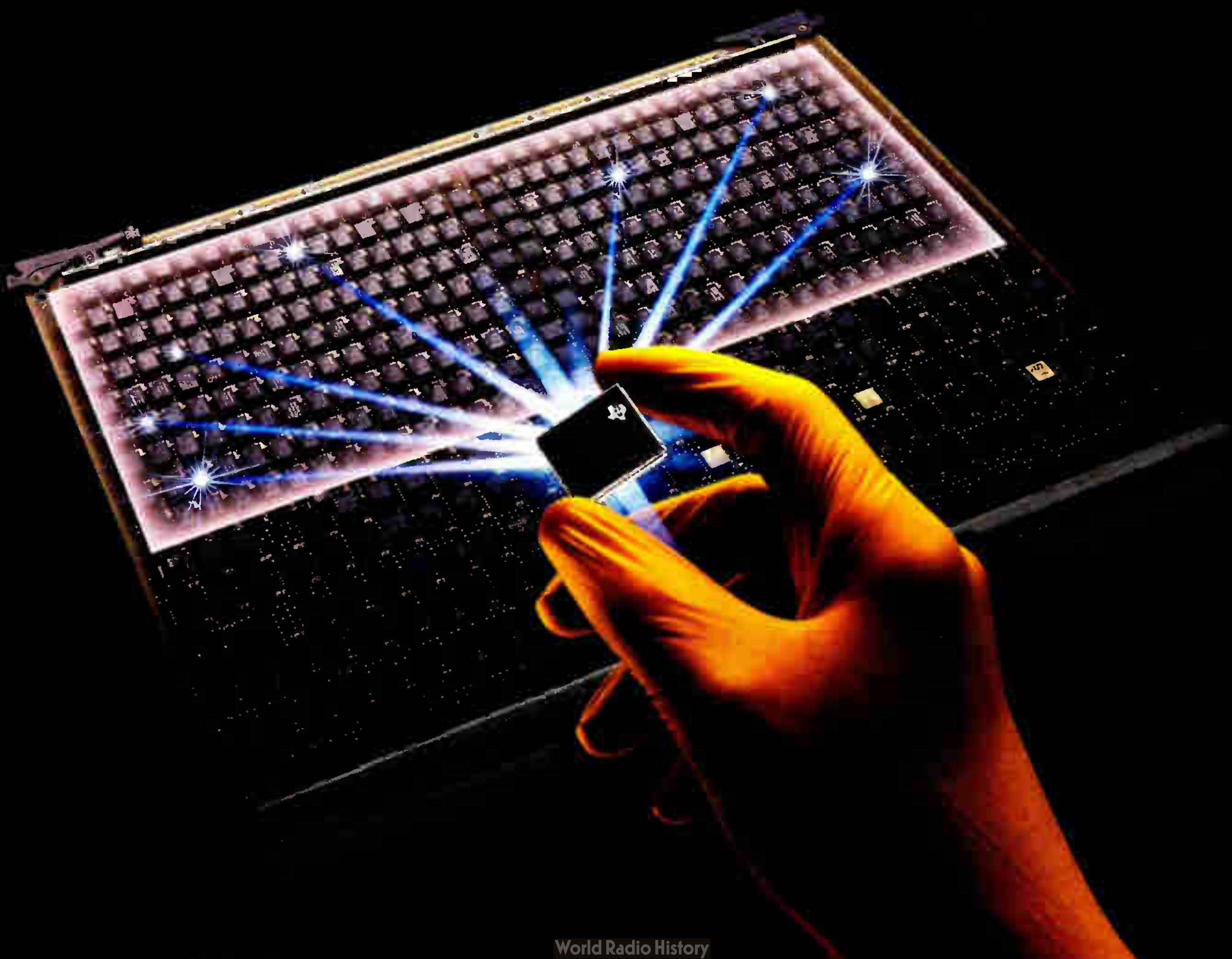
Circle 45 on reader service card →

TEXAS INSTRUMENTS REPORTS ON

MEMORY MANAGEMENT

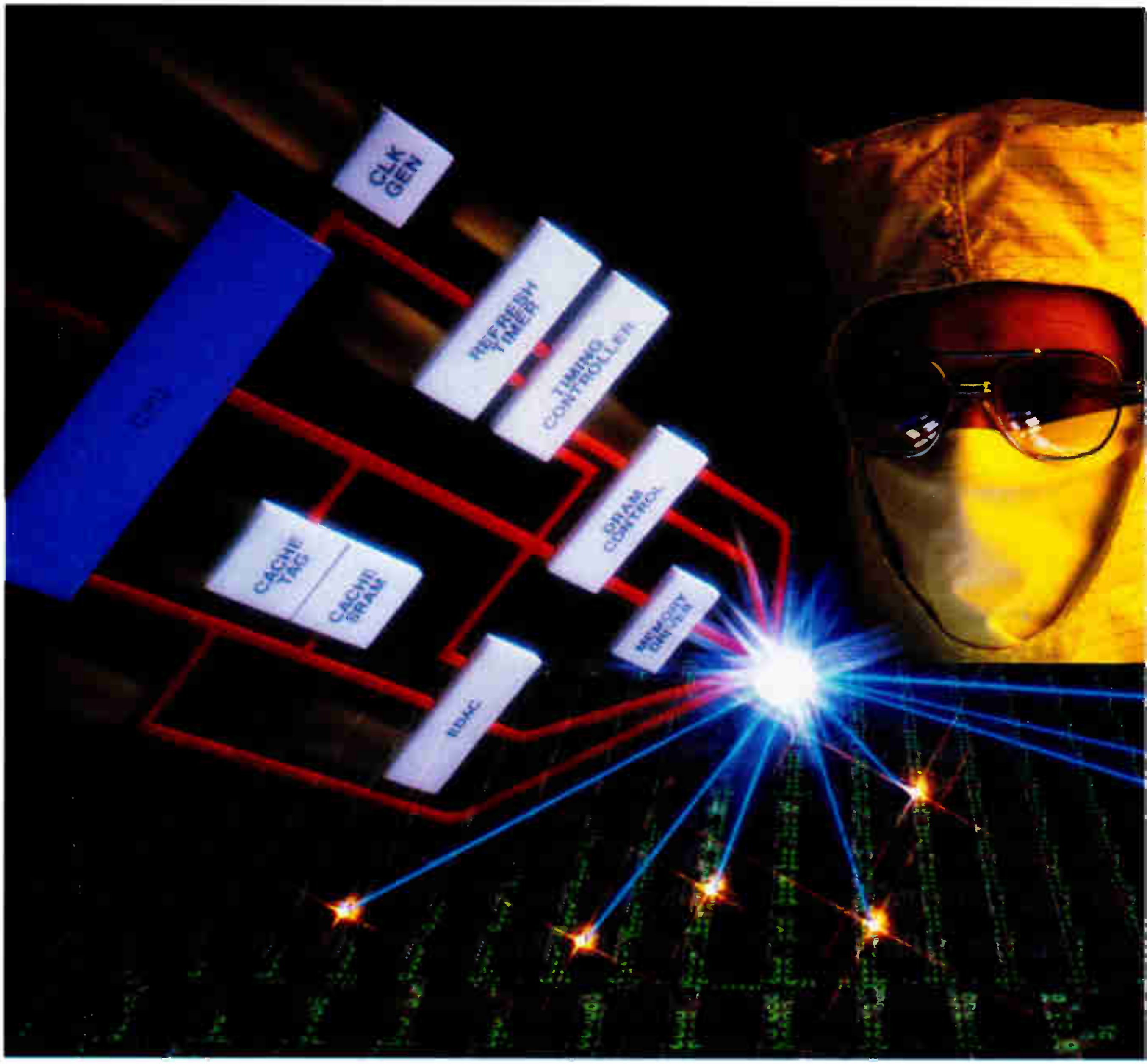
IN THE ERA OF

MegaChip TECHNOLOGIES



Memory management in the Era of MegaChip Technologies:

Memory-management ICs from you bring memory arrays up to



Memory systems are a prime area for significant improvements in overall system throughput. Read how TI's memory-management ICs can get you in and out of memory faster no matter which processor you choose.

You can now solve a problem whose solution has eluded design engineers for years: How to catch memory speeds up to CPU speeds. The solution lies with TI's advanced memory-management circuits, and you can use them with whichever processor best suits your application.

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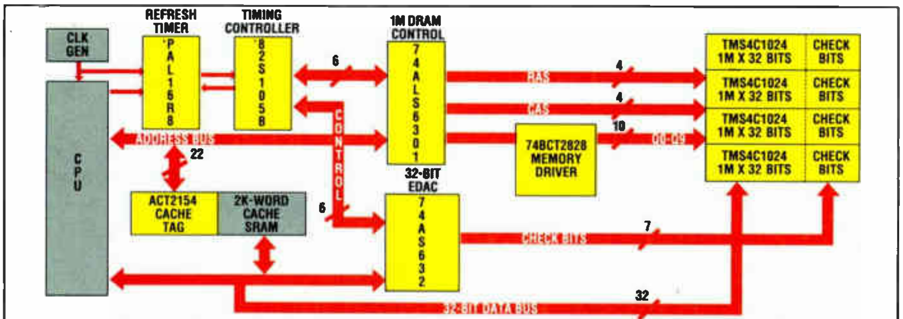
In addition, your component count is cut because these are single-chip VLSI circuits. Your design time and effort are shorter and easier because of TI's comprehensive Memory Management Design Kit *(see page 4)*.

TI addresses your major memory-design concerns

To immediately improve memory-access time, use both main and cache memories, as shown in the block diagram. This approach can produce up to a 3X increase in system performance.

Frequently accessed data and instructions are stored in a few high-speed static random-access memories and "tagged" by a TI industry-standard cache controller (SN74ACT2151/4). These CMOS controllers are the fastest available and can support deep cache architectures of 16K or even 32K.



High-speed memories can be designed with less effort and implemented more cost-effectively by using TI's family of universal memory-management ICs. These devices, all of which are contained in TI's Memory Management Design Kit, will work with and enhance almost any high-speed processor.

This scheme is cost-effective because slower, less expensive dynamic random-access memories (DRAMs) can be used for main memory.

When you must assure system integrity, use of an error-detection-and-correction (EDAC) circuit can improve system reliability 500-fold. Since this approach is necessary with memory arrays larger than half a million bits, TI offers its leadership 32-bit EDAC.

The SN74AS632 detects dual-bit errors and detects and corrects single-bit errors while avoiding processor wait states. It is the fastest EDAC available: 25 ns for error detect, 32 ns for correct.

Interfacing between processor and main memory gets tougher as speeds increase. But TI has the SN74ALS6301 DRAM timing controller. It can handle any DRAM up to 1 Mbit and incorporates only the essential functions on chip to improve flexibility and speed and to allow for custom timing routines. This controller supports nibble- and page-mode access and scrubbing-mode refresh to increase memory output.

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>
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▶ *Turn page for more information.*

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  - —SN74AS632 32-bit EDAC
  - —SN74ALS6301 16K to 1 Mbit DRAM Controller
  - —SN74BCT2828 10-bit Buffer/Driver with series-damping resistor
  - —TIBPAL16R8-10 and TIB82S105B High-speed Programmable-logic Devices for user-defined timing control
  - —TMS4464 256K DRAM
- *Memory Management Applications Handbook* containing applications reports and briefs that supply valuable insights into memory-management system design.
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TEXAS INSTRUMENTS

Computer-aided design is vital to Plessey's strategy for the next decade, since quick design turnaround and low cost are what make an ASIC supplier competitive. So Dunn's prime concern now is to merge what might appear to be duplicated CAD efforts. Mostly, Ferranti has concentrated its CAD development in Scotts Valley, with Ferranti Interdesign. Dunn and his team have spent some time there to determine just how quickly they can add Ferranti CDI cells to the Plessey Megacell system, and whether Plessey cells can be added to the Ferranti software.

Technical Director William Gosling says that that in ASICs, the objective is to reduce design costs to around 37¢ per gate from a current industry average of some $3.70. Gosling says that a new design package called Shade (structured hardware development environment) is pricing out at 75¢ in the laboratory.

Cost-reduction pressure is mounting as process technologies improve. Plessey will offer 1.5 μm CMOS and bipolar processes during 1988, moving to 1 μm in 1989. By 1992, Gosling expects 0.6 μm technologies to be in production. The implication, he says, is that gate densities will increase rapidly. The average ASIC today has fewer than 10,000 gates. But in the next few years, as designers become more competent and demanding, this will increase to 150,000 and possibly 250,000 by the early 1990s. Cost per gate then becomes critical.

> **To succeed in ASICs, Plessey must find a way to merge overlapping CAD efforts**

The testing of such complex devices also becomes progressively more difficult and costly. It now accounts for around 30% of the cost of a 10,000-gate chip, a proportion that is rising exponentially with complexity. Plessey's answer to the testing problems is Shade 2, which automatically compiles a self-testing capability onto the ASIC chip.

Whether the two operations can be successfully merged without casualties remains to be seen, however. The danger is that in attempting to blend the processes and CAD software philosophies, development may be slowed down to the point where Plessey loses its advantages in the marketplace. The new operation also finds itself with what may be an embarrassment of processing capacity. Plessey's new plant near Plymouth in the far west of England, commissioned only a year ago, is still less than 50% utilized. Add to this Ferranti's two wafer fabs in Manchester and Plessey's bipolar plant in Swindon, and it may just be too much. *–Peter Fletcher*

INTERNATIONAL NEWSLETTER

THE JAPANESE WILL FIRE UP 1-MBIT DRAM PRODUCTION . . .

Japan's Ministry of International Trade and Industry says Japanese production of 1-Mbit dynamic random-access memories will jump 46% in the first quarter of 1988, to 30.8 million units, and then another 41% to 43.5 million in the second quarter. And when MITI forecasts, Japanese chip makers listen: although by law the ministry is not permitted to control production, the manufacturers fall in line with the "forecasts," which are calculated to satisfy the requirements of the U. S.-Japanese antidumping agreement. The proportion of Japanese 1-Mbit DRAM production that will be exported will not change from the fourth quarter of 1987 to 1988's first quarter, holding steady at about 63.5%, but it will rise slightly in the second quarter to 65.1%. MITI predicts that demand will rise in concert with production, keeping prices steady at about $16 each. Production of 256-Kbit DRAMs, meanwhile, will peak in 1988's first quarter, says MITI, falling off about 1.6% to 159.9 million units in the second quarter. ☐

. . . AND A GOOD YEAR IN JAPANESE EQUIPMENT PRODUCTION IS EXPECTED, TOO

The production of electronic equipment in Japan will rise 7% to $104 billion in 1988, despite unfavorable exchange rates, international trade friction, and increased offshore production, the Electronic Industries Association of Japan predicts. Sectors outside the consumer field will push this growth, says the association, and will post total growth of almost 10%, reaching a value of $72 billion. Computers and related equipment will be star performers: production will grow 14%, to $41.6 billion. Production of test and measurement equipment will grow 6.3% to $4 billion—coming off two declining years—thanks to an upward turn in capital investment for semiconductor and other device manufacturing. Consumer-equipment production, also off during the last two years, will gain 1.3%, to almost $32 billion, fueled by higher-quality video cassette recorders and color TVs. ☐

A STRONG DEUTSCHMARK HITS GERMAN MEDICAL-EQUIPMENT MAKERS HARD

Shifting rates of exchange are causing a slump in West Germany's medical electronics business. The sector has grown unabated for nearly a decade—hitting $2.64 billion in sales in 1986—but exports normally account for well over half of total sales, says the Electrical & Electronics Industry Association in Frankfurt. As the U. S. dollar fell and the deutschmark rose, exports plummeted more than 22% during the first six months of 1987, the association says, and total sales dropped 15.8%—to $1.07 billion—compared with the same period in 1986. The primary reason is the dollar's decline, but the deutschmark has climbed against other currencies, too, making all products exported from West Germany more expensive. ☐

SONY'S RECHARGEABLE LITHIUM CELL DELIVERS OVER TWICE THE ENERGY OF A NiCAD UNIT

A new rechargeable lithium battery cell capable of about 2.4 times the energy output of a high-capacity nickel cadmium cell has been developed by Sony Energytec. The ability to deliver higher energy in a cell of the same size is due in part to a higher operating voltage, 2.8 V compared with 1.2 V for NiCad. At the same time, weight has been reduced to 65% that of a NiCad cell the same size, thanks to the low weight of lithium. The subsidiary of Sony Corp. says that a manganese compound used as the anode provides excellent reversibility of the chemical reaction during charge and discharge. An organic-solvent electrolyte makes for a negligible self-discharge current and a shutdown of current flow at the end of a charge cycle. Sony will introduce the first products based on the new lithium technology next year. ☐

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PIC 7000-4	*TMS 7000 NL-4*	*PIC 7040-4*	*TMS 7040 NL-4*
PIC 7000I-4	*TMS 7000 NA-4*	*PIC 7040I-4*	*TMS 7040 NA-4*
PIC 7001-2	*TMS 7001 NL-2*	*PIC 7041-2*	*TMS 7041 NL-2*
PIC 7001I-2	*TMS 7001 NA-2*	*PIC 7041I-2*	*TMS 7041 NA-2*
PIC 7001-4	*TMS 7001 NL-4*	*PIC 7041-4*	*TMS 7041 NL-4*
PIC 7001I-4	*TMS 7001 NA-4*	*PIC 7041I-4*	*TMS 7041 NA-4*
PIC 7020-2	*TMS 7020 NL-2*		
PIC 7020I-2	*TMS 7020 NA-2*		
PIC 7020-4	*TMS 7020 NL-4*		
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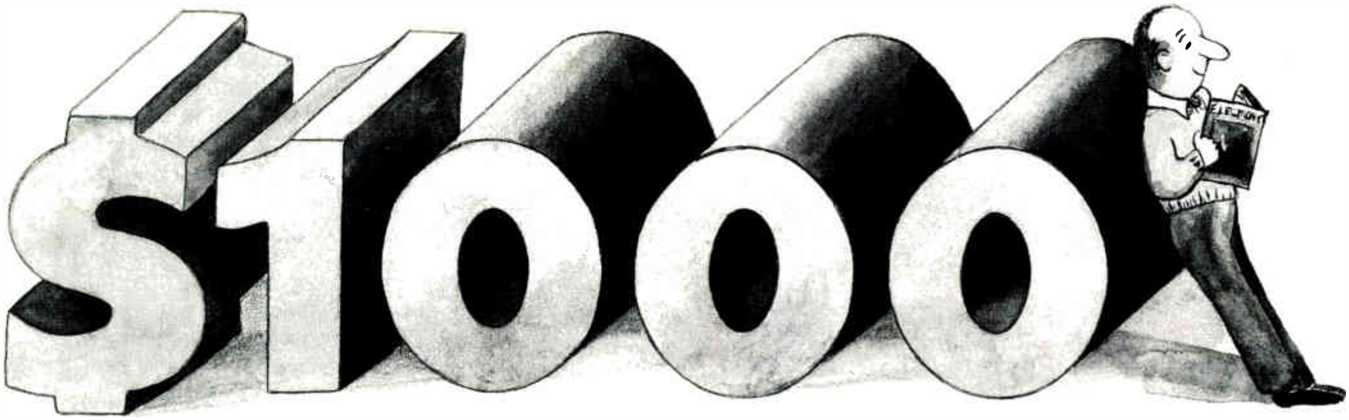

Details and complete contest rules appear in this issue.

It's easy to enter, and fun to win! Simply select the 10 ads in this January 7, 1988 issue of *Electronics* that you think will be best-read by your peers. List your selections on the entry card bound in this issue, or a reasonable facsimile. Whoever comes closest to selecting the 10 winning ads collects $1,000 cash!

Electronics

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All advertising and marketing personnel in companies and agencies are invited to participate along with our readers by checking the box marked "Advertiser Contest" on the entry blank bound in this issue. Whoever comes closest to picking the 10 winning ads in this special advertiser's contest will receive an award acknowledging their skill in evaluating advertising, plus a free ad for their company—and $1,000 cash!

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Reader Contest Rules

1. After you have examined this issue of *Electronics,* pick the ten ads that you think will be best remembered by your peers and enter your selections on the entry blank bound in this issue or on a 3" x 5" index card. Your entry should include: 1) the name of the advertiser; 2) the advertiser's Reader Service Number; and 3) the page number the advertisement appears on. Ads placed by *Electronics* or McGraw-Hill, Inc. should not be considered in this contest.

2. Check the box on the entry blank marked "Reader Contest." No more than one entry may be submitted by any one individual. All entries must be postmarked no later than midnight, February 26, 1988.

3. The winner of the $1,000 cash prize will be determined by POSTCOM, (conducted by Signet Research, Inc.), *Electronics'* method of measuring readership. The winner will be notified by mail.

4. No purchase necessary. Contest void where prohibited or restricted by law. Liability for any taxes on the $1,000 cash prize is the sole responsibility of the winner. Employees of McGraw-Hill, Inc., its advertising agencies, and their families are not eligible to participate.

5. In case of a tie, the earliest postmark will determine the winner. Decisions by the judges will be final.

Advertiser Contest Rules

1. All advertising and marketing personnel in companies and agencies (other than McGraw-Hill, Inc. and its advertising agencies) are invited to participate in a separate contest for advertisers. All rules for the Reader Contest will similarly apply for this contest, with one exception: the box on the entry blank marked "Advertiser Contest" must be checked.

2. Examine this issue of *Electronics* with extra care. Choose the ten ads that you think readers of *Electronics* will best remember and enter your selections on the entry blanks bound in this issue or on a 3" x 5" index card. No more than one entry may be submitted by any one individual.

3. All entries must be postmarked no later than midnight, February 26, 1988. Each individual's qualifying entry will be matched against the winning ads as determined in the Reader Contest. Whichever individual in this Special Advertiser Contest comes closest to picking the 10 winning ads will receive $1,000 cash, and a plaque acknowledging their skill in evaluating advertising. The winner will be notified by mail.

4. This special Advertisers Contest is open to all advertising and marketing personnel in companies and agencies (other than McGraw-Hill, Inc. and its advertising agencies), whether or not their companies or agencies have an advertisement in the January 7, 1988 contest issue.

5. No purchase necessary. Contest void where prohibited or restricted by law. Liability for any taxes on the $1,000 cash prize is the sole responsibility of the winner. Employees of McGraw-Hill, Inc., its advertising agencies, and their families are not eligible to participate.

6. In case of a tie, the earliest postmark will determine the winner. Decisions by the judges will be final.

Winning Advertisers Earn Free Ad Reruns

The ten winning advertisers will receive a free rerun of their winning ads in *Electronics* and a plaque commemorating their achievement.

All reruns will be made from existing plates or negatives. If the advertisement qualifying for a free rerun is an insert, the winner may run up to a four-color, two-page spread on R.O.P. stock from existing plates or negatives. McGraw-Hill, Inc. reserves the right to schedule reruns at its discretion.

INTERNATIONAL WEEK

VICTOR SETS UP EUROPEAN PLANT

Victor Company of Japan Ltd., Tokyo, will start up its second TV plant outside Japan in the UK, following one in the U. S. The new plant at East Kilbride, Scotland, will assemble 20,000 units of 14- and 20-in. color TVs a month, beginning next April, for both the UK and European markets. JVC also hopes to start assembling 25- and 28-inch color TVs, compact-disk players, and displays for office-automation equipment at the new plant within the next four years.

JAPAN TO START ION R&D CENTER

Japan's Ministry of International Trade and Industry plans to establish an ion engineering center in 1990. The new facility will be used for research and development of various new technologies, including fabrication of fine-pattern VLSI devices, superconductive devices, new thin-film materials, and genetic engineering using ion beams. MITI says that the facility will be available for use by domestic and foreign firms and R&D facilities that do not have sufficient funds to buy their own R&D gear.

FRANCE SETS THREE TELECOM SATELLITES

France's national Telecom 2 program calls for three satellites to be launched by 1991, and Matra Espace and Alcatel Espace have just been tapped to build the new birds. Matra's prime responsibility will be to build the Telecom 2 platforms; Alcatel will be responsible for the payloads. The new satellites will handle both civilian and military telecommunications, as well as data transmission and TV broadcasts. They will link France with other European countries and with its overseas departments, such as those in the French West Indies. Alcatel says the Telecom 2 satellites will carry a payload three times heavier and 3½ times more powerful than the Telecom 1 satellites they will replace. They will be based on the Eurostar platform, which Matra developed with British Aerospace. A Eurostar-class satellite has a useful life of at least 10 years, payloads of more than 500 kg and more than 4 kW of available power.

FIRST VAN SERVICE DEBUTS IN JAPAN

NEC Corp. opened Japan's first international value-added network service, which links the company's network in that country with the worldwide teleprocessing operation of General Electric Information Services Co., (Geisco) which has its headquarters in Rockville, Md. The first offering on the VAN service will be Geisco's electronic mailbox service, Quick-Comm. The cost of using Quick-Comm is said to be 40% less than sending messages through International Telex. The new service can be accessed from nearly 200 locations in Japan, 650 in the U. S., and 80 others around the world. Geisco says the two companies will add functions and capabilities to the existing VAN services—but no date has been set.

SONY TO SELL UNIX STATION ABROAD

Sony is setting up in-house ventures abroad to handle its low-price NEWS Unix Workstation *[Electronics*, Nov. 12, 1987, p. 166] in overseas markets in the same manner as it set up an in-house venture in Japan to develop, build, and sell the work station. The company will establish Sony Microsystems Company in Palo Alto, Calif., and Sony Microsystems Europe in Cologne, West Germany. The work station will be built in Sony's San Diego consumer electronics plant.

S. KOREA, HONG KONG, ACCUSED OF DUMPING

The Brussels-based European Community commission has started antidumping procedures against South Korea and Hong Kong, which are allegedly selling video cassettes at below-market prices in the 12 EC countries. The commission is reacting to complaints by European video cassette manufacturers who charge that cassettes imported from the two Asian exporters have risen 440% between 1983 and 1986, primarily as a result of their undercutting European prices by 20% to 36%.

PHILIPS TO SELL PABX TO CHINA

Philips of the Netherlands has carved a niche for itself in China's private branch exchange market by signing licensing agreements with two Chinese factories for the production of its Sopho-S PABX. In addition to the contracts with the two factories—Zhen Hua and Chande, both administered by China's Electronics Industry Ministry—the Dutch company expects to sign a similar agreement with a third factory in late January.

ESPRIT II GETS EC APPROVAL

European Community research ministers have given the go-ahead for the second phase of Europe's ambitious Esprit program, which promotes joint research in information technology. Esprit II's budget, covering the five years to the end of 1992, comes to about $1.2 billion. It will fund research work at some 500 firms throughout the 12-nation EC.

TAIWAN TO BUILD SECOND WAFER FAB

Taiwan Semiconductor Manufacturing Co. is getting set to build near Hsinchu its second manufacturing facility, at an estimated cost of $220 million. Scheduled for completion by the end of 1980, the plant will handle fabrication of chips from reticle generation to final test. It will ultimately have a capacity of 30,000 6-in. CMOS wafers a month, initially in a 1.2-µm process. Later, part of the plant will be converted for 8-in. wafers and all of its facilities upgraded for submicron feature sizes. The company's existing plant produces 6-in. wafers with 1.5-, 2-, and 3-µm features.

NOKIA ACQUIRES SEL ELECTRONICS

The Finnish Nokia Corp. acquired the West German Standard Elektrik Lorenz AG's consumer electronics division and part of its component division on Jan. 1, 1988. Net sales by SEL's electronics division will reach 1.6 billion DM this year, bringing the Nokia Group's electronics net sales to over 10 billion Finnish marks, or 60% of its total sales. After the deal, Nokia's consumer electronics operations, which include color TV sets and monitors, will reach nearly 7.5 billion Finnish marks. This will make it the world's ninth largest color TV manufacturer.

ERICSSON SPLITS UP COMPONENT UNIT

The Finnish group Finvest will acquire the capacitor operations of Rifa AB, the L. M. Ericsson components-producing subsidiary. The unit had 1,000 employees. Ericsson, however, has retained Rifa's microelectronics and power-supplies-equipment operations, as well as its sales organization, but under a new name. Ericsson will also retain a minority interest in the new capacitor company, which takes over manufacturing operations in Sweden and France. A marketing unit in Stockholm is also included in the deal.

INTERNATIONAL PRODUCTS

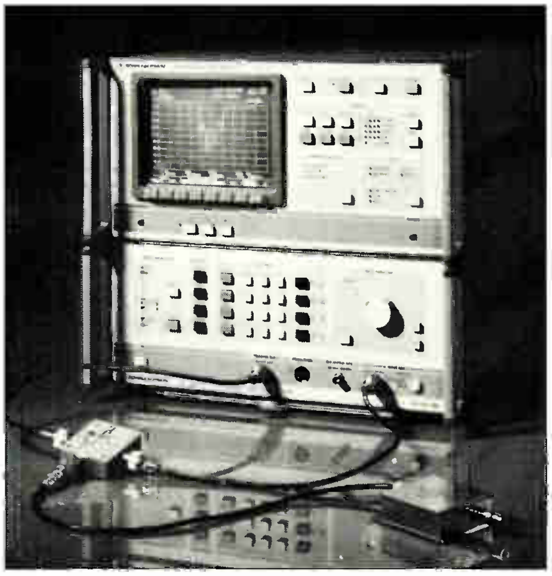
TWO-IN-ONE RF TESTER COMBINES SPECTRUM AND NETWORK ANALYZERS

ROHDE & SCHWARZ ACHIEVES 2-GHz, LOW-NOISE PERFORMANCE IN A SINGLE BOX

By integrating a spectrum analyzer and network analyzer into a single unit, Rohde & Schwarz's FSAS radio-frequency tester combines a high degree of measurement flexibility with top-notch specifications. The FSAS handles frequencies from 100 Hz to 2 GHz, and its –150-dBm noise performance as a spectrum analyzer is 10 dB better than competing instruments.

The instrument can measure the level and frequency of all commonly encountered signals—anything from single-frequency sine waves to broadband pulse signals. In addition, the FSAS also performs selective scalar network analysis for the absolute measurement of transmission and reflection parameters and for voltage and power.

Moreover, all the instrument's functions can be controlled remotely using the IEEE-488 interface, which allows the unit to be integrated into large-scale measurement systems.



UNIVERSAL. The FSAS handles almost any signal—from single-frequency sine waves to broadband pulses.

TIGHTER INTEGRATION. Although competitors offer roughly similar systems, their products are either discrete instruments or modular units coupled together. The FSAS's higher integration results in a one-third to one-half space savings compared to competing combinations. But more important, says Wolfgang Cohrs, co-developer of the FSAS at the Munich, West Germany, company, is that the integrated setup provides tighter coupling between the two instrument sections, with the transmitted and received frequency always in synchronism.

The 110,000 DM price of the FSAS is not less than that of competing systems, says the company. But for what they have to pay, users get more performance, it maintains.

Applications include checks for leakage from coaxial cables and in addition measuring their attenuation, shielding, and voltage standing-wave ratio. Antenna parameters can be measured selectively, too.

As spectrum analyzer, the unit boasts broad dynamic range and high precision, says Cohrs. Its intermodulation-free dynamic range is greater than 100 dB, and its single-sideband phase noise is typically –114 dBc at a 1-kHz offset from the carrier.

Precise level and frequency measurements are achieved by a level calibration routine. A short calibration can be triggered for highly accurate measurements. Level correction is carried out at the specified resolution bandwidth with the internal level calibration source at 100 MHz. A compensation circuit almost completely eliminates the frequency-dependent level error.

Thanks to the high accuracy and broad dynamic range of a built-in tracking generator, the FSAS can measure the characteristics of components such as crystal and notch filters as well as bandstops of steep edges and narrow bandwidths.

For special applications, the output signal of the FSAS can be amplitude modulated (with signals from 10 Hz to 20 kHz) or level controlled with an external detector. The output level can be set in 0.1-dB steps from –5 to –100 dBm. The instrument's frequency response is flat to within 0.6 dB, a value Rohde & Schwarz claims is better than that of most other spectrum analyzers.

Key specifications for the network analyzer section are high gain—greater than 130 dB—and high attenuation, which is better than 120 dB. Of note too is the high amplitude resolution, which checks in at 0.01 dB. The inherent frequency response is less than 0.8 dB. "These values match the best of competing network analyzers," Cohrs says.

The FSAS operates on the principle of search frequency analysis. An internal oscillator frequency is varied using an analysis filter with matched resolution bandwidth. Spectral components of the signal being tested that fall in the filter's passband stimulate the filter and produce an output.

The frequency range to be analyzed is defined by any combination of the start, center, and stop frequencies as well as the span. Resolution bandwidth, video bandwidth, and sweep time are selected depending on the displayed frequency range. The analysis is displayed on a color monitor, with the frequency in the x-direction and the associated amplitudes in the y-direction.

Operation of the instrument can be characterized in two words: simple and convenient. Examples range from the clear front panel layout to the temperature-controlled fans, which reduce noise to a minimum.

SINGLE SPINWHEEL. Simple operation is achieved by having just one spinwheel on the clearly constructed front panel—only one function is assigned to each key—and a color monitor with eight soft keys in the frame. The soft-key functions depend on the operation menu that is selected.

Parameters are entered on a numeric keyboard and can be varied using two-step keys or the spinwheel. The 9-in. color monitor output is divided into trace and text information.

The FSAS monitor displays test traces, graticule, and soft-key labeling as well as the background in different, user-selectable colors. The color shades are infinitely variable to suit the operator. Using different colors for each of the four traces that the instrument can display makes the FSAS easy to work with and the interpretation of its results simpler.

As for documentation facilities, the screen content, regardless of whether it is a trace or status display, can be put out as hard copy with an ordinary printer, a graphics printer, or an IEEE-bus plotter.

The FSAS will become available toward the end of this month. Delivery time takes from two to three months.

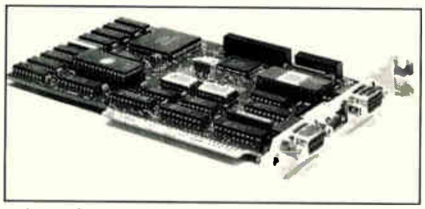
– John Gosch

Rohde & Schwarz, P.O.Box 801469, D-8000 Munich, West Germany.
Phone 49-89-41292625 [Circle 500]

GRAPHICS CARD HANDLES IBM's VGA STANDARD

ATI Technologies Inc.'s VIP (for VGA Improved Performance) graphics board supports IBM Corp.'s new Video Graphics Adapter standard as well as being downwardly compatible with the Enhanced Graphics Adapter, Color Graphics Adapter, and Hercules standards.

The card offers up to 800-by-560-pixel resolution on multisync monitors—twice the resolution of EGA—and up to 256



colors from a 256,000-color palette in its analog monitor modes.

Based on a proprietary ATI-developed graphics chip, the VIP supports the VGA standard on analog monitors and EGA graphics on all IBM-compatible digital monitors, automatically sensing and switching to accommodate the monitor being used.

The card includes both 9- and 15-pin connectors for use with digital and analog monitors, respectively. Available now, it costs $449 in single-unit quantities. Volume discounts are available.

ATI Technologies Inc., 3761 Victoria Park Ave., Scarborough, Ontario, Canada M1W 3S2.
Phone (416) 756-0711 [Circle 702]

£24 ENCRYPTOR STOPS SOFTWARE PIRATES

An encrypting device from Data Encryption Systems Ltd. attaches to the RS-232-C serial port of any personal computer to provide, for only £24, a means of preventing software pirating.

The Deskey is programmed with an algorithm that responds with a unique encrypted code to a message sent by the software program being protected. If the software does not receive the response it expects, it refuses to boot up.

Although the disk containing the software may be copied, it will only work when used with a specific Deskey. The product is available now.

Data Encryption Systems Ltd., West Buckland, Wellington, Somerset TA21 9LE, UK.
Phone 44-823-474-561 [Circle 703]

EEPROM HAS CELL SIZE HALF THAT OF OTHERS'

A 256-Kbit electrically erasable programmable read-only memory from Toshiba Corp. can be erased in 1 second—1,200 times faster than an ultra-violet EPROM—yet it rivals the UV-EPROM in simplicity and size.

Unlike other EEPROMs that use two transistors per cell, the TMM 28257P needs just one, which reduces cell size to about half that of conventional EEPROMs. The size of the 256-Kbit chip is 5.69 by 5.78 mm.

Toshiba designers achieved the breakthrough with an additional fabrication layer called an erase gate that is activated by a 21-V supply.

The device comes in three access speeds: 200 ns, 250 ns, and 300 ns. Scheduled for January availability in 28-pin plastic dual in-line packages, the 28257P will cost 8,000 yen each.

Toshiba Corp., Shibaura, Minato-ku, Tokyo 105, Japan.
Phone 81-3-457-2104 [Circle 701]

HALL-EFFECT SENSOR YIELDS ANALOG SIGNALS

A Hall-effect integrated circuit from Siemens AG breaks new ground for the technology by translating physical parameters into analog—not digital—signals. The TLW4910K generates a voltage proportional to the flux density of a magnet mounted on the moving part. Until now, Hall circuits could only make a digital, "yes/no"-type of decision when the distance between the device and the magnet was above or below a certain value.

The TLE4910K functions as a sensor in professional applications to measure acceleration, pressure, torsion, and distance. The null point can be adjusted so that the circuit can recognize and evaluate both magnetic polarities (north and south poles).

A thermal sensor on the chip ensures that heat does not adversely influence measurements.

Available from stock, the TLE4910K costs 2.72 DM each in 1,000-unit lots.

Siemens AG, P. O. Box 103, D-8000 Munich 1, West Germany.
Phone: 49-89-2343613 [Circle 704]

POWER TRANSISTORS ARE CURRENT MISERS

SGS-Thomson's MTP3055A and 3055AP n-channel power transistors feature low drive current and low on-resistance for implementing energy-efficient designs.

Both are rated at 12-A drive current at 60 V and have on resistances as low as 0.15 Ω. Applications include series regulators DC/DC converters and motor drives for industrial control equipment.

The 3055A comes in a TO-220 industry-standard package and the 3055AP in an ISOWATTT220 package—SGS-Thomson's fully electrically isolated package with a dielectric strength of 2 kV DC.

Both transistors are available now. Price depends on importing country.

SGS-Thomson, Via C. Olivetti 2, 200451 Agrate Briaza, Italy.
Phone 39-39-65551 [Circle 705]

FIBER-OPTIC DEVICE KEEPS SIGNAL PURE

The 1300 Polarizer Module from Sifam Ltd. virtually eliminates unwanted wave polarizations in optical-fiber transmission systems by positioning a thin metal film near the fiber core. It offers extinction ratios over 45 dB.

The 1¼-by-1-by-1½-in. module targets fiber cable for 1,300-nm wavelengths, but the technology can be adopted for all types of single-mode optical fibers, including low- and high-birefringence fibers. It offers insertion losses of less

than 0.5 dB. The device operates on the principle of coupling the unwanted optical wave with a plasma wave propagated in a thin metallic film deposited on the fiber.

The device will be available in January. Its export price is $1,490.

Sifam Ltd., Woodland Road, Torquay, Devon TQ2 7AY, UK.
Phone 44-803-63822 [Circle 706]

MICROCONTROLLERS CUT POWER USE BY 90%

The microcontrollers 80C51BH and 80C31BH from Philips are CMOS versions consuming one-tenth the current of their n-MOS counterparts—just 16 mA at 12 MHz with a 5-V supply. The parts have nearly double the frequency range—from 1.2 to 16 MHz.

The devices target data-processing

and automotive applications and battery-powered communications equipment such as walkie-talkies and cordless telephones.

In full production at Philips, the devices result from an alternate-source agreement with Intel Corp. Both the 80C51BH and 80C31BH can be supplied in a 40-pin dual in-line package or as a 44-lead plastic-leaded chip carrier.

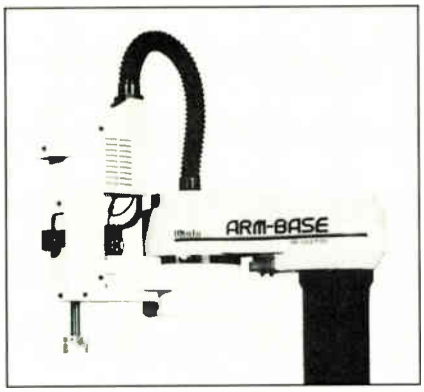
The 80C31BH is available from stock and will sell for around 6.40 DM apiece in up to 50,000-unit lots. The 80C51BH is available about 12 weeks after receipt of order and will sell for roughly 6.60 DM each also in up to 50,000-unit lots.

Philips Elcoma, P.O. Box 523, NL-5600 AM Eindhoven, the Netherlands.
Phone: 31-40-757189 [Circle 707]

ROBOT ARM HAS 8-MICRON ACCURACY

Hirata Industrial Machinery Co.'s Arm-Base AR-DD2700 robot arm for printed-circuit-board assembly boasts placement accuracy of ± 8 μm, a top speed of 6.8 m/s and a cycle time of less than 0.8 s for a 300-mm placement.

With the standard HAC-164 controller, the robot can handle point-to-point



or continuous-path control placements. Motion is controlled by a 16-bit microprocessor. Memory capacity is sufficient for 1,000 positions.

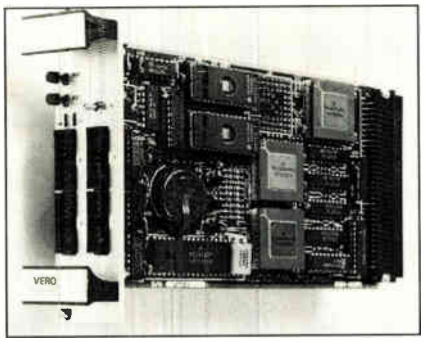
Rated payload is 1 kg. A self-diagnostic error-detection system can either display an error message on an optional display screen or transmit the message to external equipment.

The AR-DD2700 is available now. Price depends on importing country.

Hirata Industrial Machinery Co., 1061-1 Kusuno, Hokubu, Houtaku, Kumamoto 861-55, Japan.
Phone 81-96-245-1333 [Circle 708]

SOFTWARE SPEEDS MATH ON BOARD COMPUTER

The VME48024 series of single-board computers from BICC-VERO Electronics Ltd. features a Motorola 68000 processor, 68881 floating-point coprocessor, up to 256 Kbytes of erasable programmable



read-only memory, and 64 Kbytes of battery-backed static random-access memory.

A major enhancement of the new boards is a math software package. The new package wrings the best performance possible out of the math coprocessor for each application, particularly those that require full floating-point performance.

Available now, the boards cost about £1,002. The software package is available as an option for previous model boards for about £250.

BICC-VERO Electronics Ltd., Flanders Rd., Hedge End, Southampton SO3 3LG, UK.
Phone 44-703-266-300 [Circle 710]

VIDEO CARD DELIVERS 1,024 BY 800 PIXELS

The SYS68K/AGC-2 from Force Computer GmbH is a high-performance graphics controller on a single card. Its maximum resolution at 50 Hz is 1,160 by 870 pixels with 4 bits per pixel. At 60 Hz, a 1,024-by-800-pixel resolution may be displayed, also with 4 bits per pixel. The board displays 16 colors simultaneously.

Zoom, vertical, and horizontal smooth scroll, clipping, blinking, and conditional blinking are additional features. Also included in the design are facilities for a lightpen interface.

Available from stock, the SYS-68K/AGC-2 sells for 2,990 DM.

Force Computer GmbH, Daimlerstr. 9, D-8012 Ottobrunn, West Germany.
Phone: 49-89-600910 [Circle 711]

FACTORY SOFTWARE RUNS ON INTEL PROCESSORS

Kadak Products Ltd.'s AMX real-time, multitasking operating system targets industrial-automation and process-control applications using personal computers based on Intel Corp.'s 8086, 80186, and 80286 microprocessors.

AMX supports 100 applications tasks with as many as 1,024 interval timers and 4,096 envelopes for message-passing between tasks.

Its Resource Manager provides a simple mechanism for controlling access to disk files, input/output devices, database files, and even words in memory. Another facility, the Semaphore Manager, is a general-purpose counting semaphore that assigns priority queueing so that processor access is granted to the task bearing the priority in the queue.

Available now, the AMX software costs $2,195.

Kadak Products Ltd., 206-1847 W. Broadway, Vancouver, B. C., Canada V6J 1Y5.
Phone (604) 734-2796 [Circle 709]

WAVEFORM RECORDER HANDLES SIX CHANNELS

A waveform recorder from H-S Recorders Ltd. samples at a rate of 10,000 readings/s and can display up to six channels on thermal paper up to 100-mm wide—a 40% improvement over previous models.

The Model RS100M Flexicorder also offers the option to print text over the charted data. Text printing uses the full ASCII 96-character set and can print characters to be read either vertically or horizonally.

The solid-state thermal print head prints at a rate of 3,555 characters/s in the vertical mode and a rate of 1,592 characters/s in the horizontal mode. Paper transport speeds range from 10 mm/s to 100 mm/s.

Other features include built-in self-test and thermal, mechanical, and anti-static print-head protection. Fully compatible with IBM Corp. Personal Computers, the model RS100M can be controlled by software commands. It is available now. Price depends on importing country.

H-S Recorders Ltd., Portmanmoor Road Industrial Estate, Cardiff, CF2 2HS, UK.
Phone 44-222-485-885 [Circle 713]

VMEBUS MODULE ISOLATES 16 OUTPUT CHANNELS

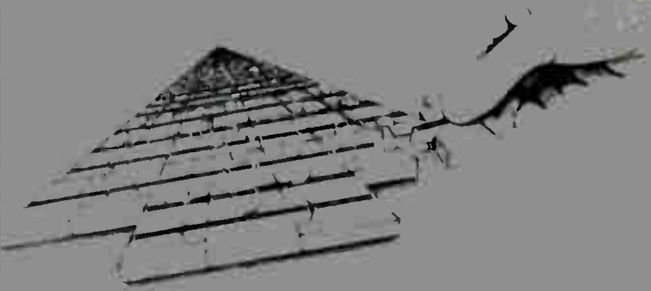
With the VDOUT module, PEP Modular Computers GmbH offers an easy-to-use output module that has 16 opto-isolated channels for VMEbus systems.

The module is designed for cost-effective solutions where a simple interface can be used to handle part of an application in industrial control.

The module's outputs are configured as two groups of eight, with a common ground line for each group. It runs at a drive voltage range up to 24 V dc and is being offered with an optional light-emitting-diode display that can show output line status. This gives users quick and easy monitoring and fault location.

Available from stock, the VDOUT sells for 750 DM.

PEP Modular Computers GmbH, P.O. Box 1652, D-8950 Kaufbeuren, West Germany.
Phone: 49-8341-81001 [Circle 714]



1988 U.S. MARKET REPORT

PUSHING FOR CONTINUED GROWTH IN 1988...

...BUT WALL STREET MAY BE SIGNALING A DIFFERENT DIRECTION

There are some strong signs that 1988 will be a year in the sun for the U. S. electronics industry, despite the dark clouds over Wall Street. The *Electronics* annual market survey forecasts an overall growth of almost 11% next year to more than $170 billion, driven by the momentum built up in a late surge in 1987 that boosted industry growth 12%.

Some significant portents support an optimistic outlook: the just-released 1987-1989 Data Resources/McGraw-Hill survey of preliminary plans for new plants and equipment shows that U. S. companies plan to boost 1988 investment outlays by 6.2% to a record $415.5 billion. It could be argued that these results are too optimistic because the survey was taken just prior to the Wall Street meltdown last October. Yet a U. S. Department of Commerce's Bureau of Economic Analysis survey, conducted in October and November, is even more bullish: it forecasts a 7.3% increase in spending for new plants and equipment in 1988. These expectations could spell good news for electronics suppliers, because a big part of that investment will be targeted at electronic automation and productivity-enhancing systems.

What's more, the nation's purchasing managers are projecting unbridled optimism in their latest semiannual economic forecast, which was put together after the market decline. Their forecast predicts 1988 will be better than 1987. The survey conducted by the National Association of Purchasing Management reported their member companies operating at the highest percentage of capacity since May 1979. Member responses indicate they expect the economy to continue to grow into the first quarter of 1988 and to accelerate in the second quarter spurred by increases in capital expenditures and expanding imports, with further growth in the second half at a somewhat slower rate.

Still, while there are few signs that electronics companies are pulling back as yet on their plans or expectations for 1988, many respondents to the *Electronics* survey expressed anxiety about the possible aftereffects of the October stock market debacle. Few expect a full scale recession to occur but many worry that post-crash blues could eventually put the brakes on their customer's capital spending. Worry about the continuing trade deficit is somewhat mitigated by the weakening dollar, which should help U. S companies gain market share; the other side of this coin is that key components—such as 1-Mbit dynamic random-access memories—may become even more expensive.

U.S. MARKET REPORT

DATA PROCESSING

GROWTH WILL HIT 11%, WITH HOT PRODUCTS LIKE SUPERCOMPUTERS REACHING 28% OR MORE

The U. S. computer market is a mixed bag this year. The newer, hotter segments—supercomputers, minisupercomputers, and high-end work stations—will sustain growth rates ranging from healthy to heady—a span of 28% to 60%. But mature products such as mainframes and superminicomputers will have to settle for growth of 6% and 11%—a far cry from their heydays in the late 1970s and early 1980s.

But since mainframes and minicomputers still represent the bulk of computer sales in the U. S., they have a big impact on total market figures. The upshot is an overall data-processing market tagged to grow 11% in 1988, to $83 billion, *Electronics* has found. That's a drop from last year's 15% and sales of $75 billion.

The big question is whether October's stock market crash will slow down capital spending—and therefore the computer industry. Not likely, say industry spokesmen and market analysts. Vendors have yet to see weakening sales, and researchers point out that computer spending is only a tiny portion of most capital budgets—7%, according to Sanford C. Bernstein & Co. And PaineWebber Inc.'s technology group reports that the computer industry represents such a modest portion of capital spending that it can grow even in a tight capital spending environment.

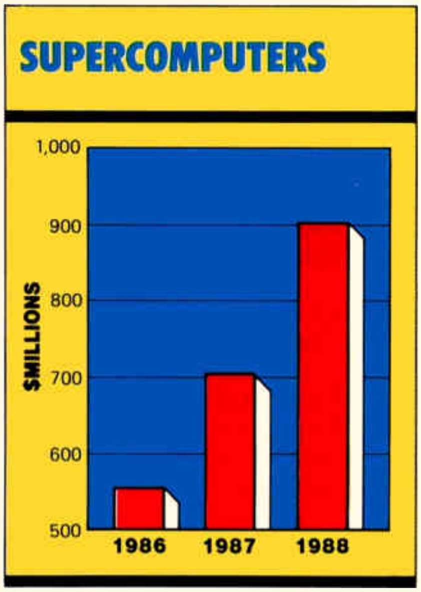
According to the Bernstein analysts, "Strong product-cycle years tend to show strong revenue growth, regardless of economic conditions." This view appears to be bolstered by developments in the 1988 market. Several segments of the computer industry are indeed in the midst of strong product cycles, including personal computers, high-end technical work stations, minsupercomputers, supercomputers, and hard-disk drives. And these are the very segments showing high growth rates in the *Electronics* forecast.

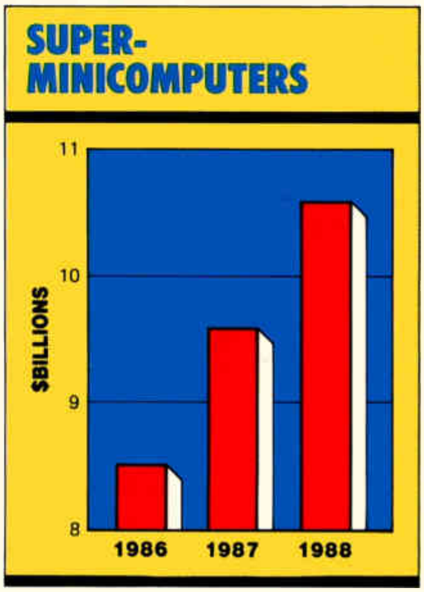
At the top rung of the market, it looks like another good year for supercomputers, with growth of 28% to $902 million expected on the heels of a 27% hike to $705 million in 1987. While the industry inputs last year resulted in a more optimistic prediction for 1987, 27% growth still was substantial. Optimistic U. S. supercomputer manufacturers tend to agree with the *Electronics* forecast. "Our feeling about the market is very bullish," says Marcelo A. Gumucio, vice president of marketing at Cray Research Inc. The Minneapolis company expects steady annual growth of about 25% worldwide for the next several years.

To highlight just how much supercomputing is catching on, Cray notes that last September it shipped its 200th system—just two and a half years after shipping its 100th system in the winter of 1985. The difference is that it took 13 years for Cray to ship those first 100.

Several powerful forces spur this growth. One cited by Cray is the increasing popularity of computer simulation, which for many applications requires the power of a supercomputer. Simulation is moving into the petroleum, automobile, aerospace, computational chemistry, and electronics industries. Scientists and engineers are simulating and analyzing physical systems from the very small, such as molecules, to the very large, such as galaxies.

Another factor is that "supercomputers are becoming a standard rather than an exception," Gumucio says. "For example, 19 universities now have





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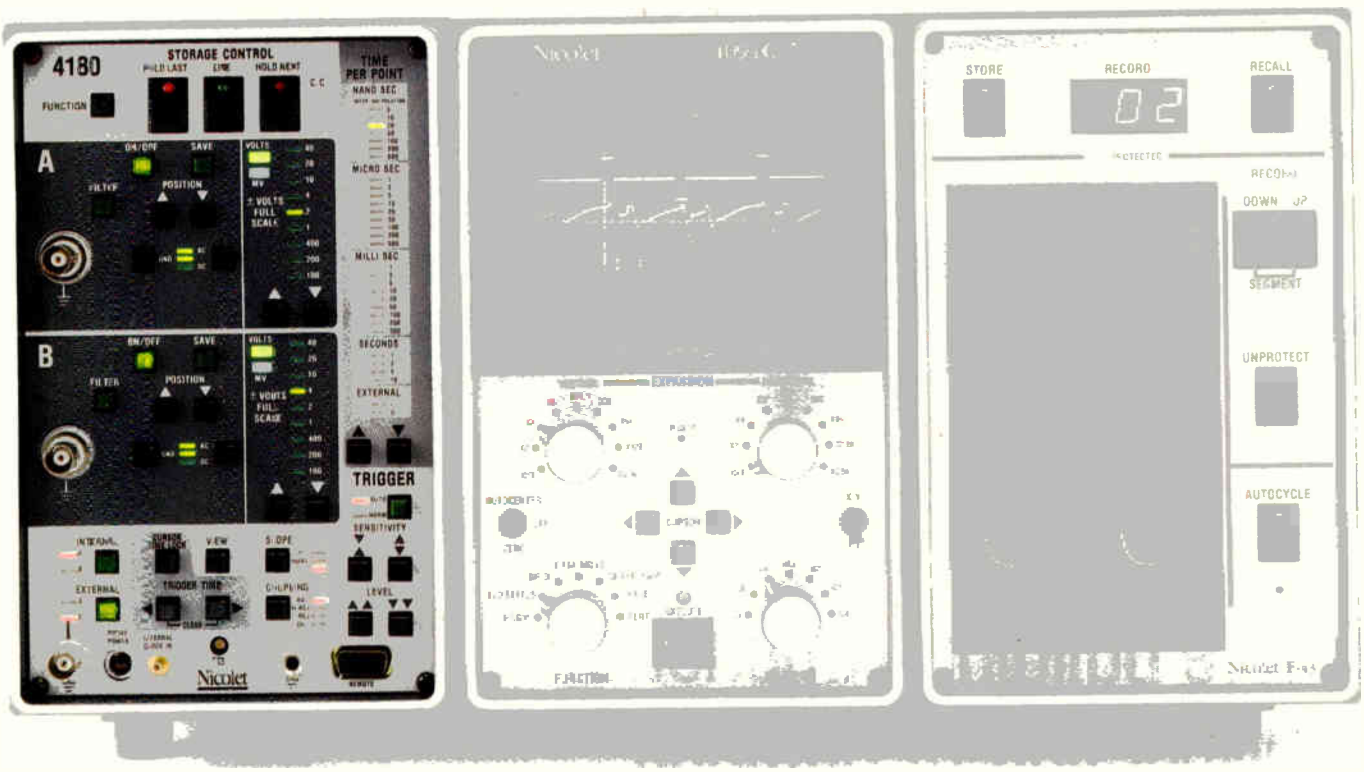

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processing systems now have an opportunity to displace conventional superminicomputers and mainframes when companies are faced with changing conditions. Encore Computer Corp., which sells such systems, sees them moving out of experimental research applications and into mainstream commercial, scientific, and engineering markets.

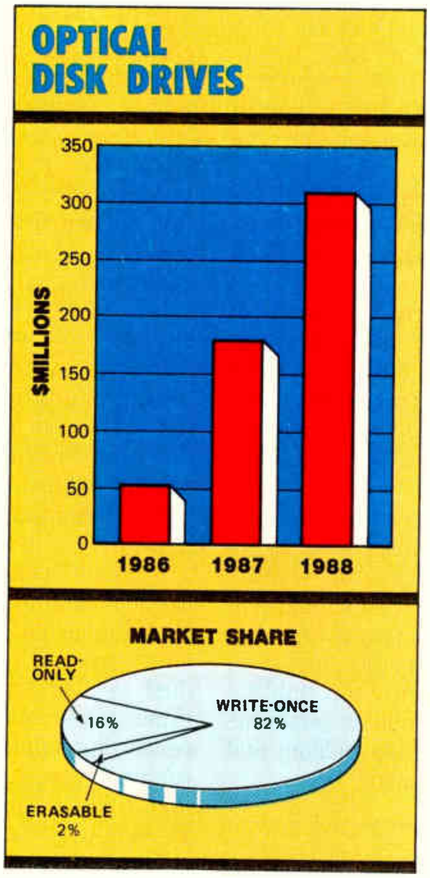
"We see four criteria that will be the major ones affecting buying decisions," says Frank Pinto, vice president of marketing at the Marlboro, Mass., company. No. 1 on the list is price/performance, he says, followed closely by connectivity. Also important are a standard Unix operating system and friendlier user interfaces, he says. The newer systems often meet all four of these criteria, while many of the older systems are weak or lacking in some of them. And that helps explain why the newer systems will have higher growth rates than the staid old mainframes and superminicomputers.

Another relative newcomer to the computer scene that's also a bright spot in the market is technical work stations. These products, which have been around in force for only about five years, will hit just under $3 billion in sales in 1988, *Electronics* has found. At $2.9 billion, that's 24% growth over last year's $2.3 billion—a healthy pace, although slower than 1987's 45%.

The pace in this market is fueled by two major influences. First, the companies employing millions of technical professionals are finding that work stations can contribute to improving productivity. A second factor is the same one driving the other high-growth segments of the industry: a mushrooming number of new product introductions.

Work station vendors are continually leapfrogging one another, boasting ever-higher computation and graphics performance. Several new offerings run in the range of 10 million instructions per second—all with top-notch graphics. A year ago, 4- to 5-mips was considered a high-end machine. By midyear, there may be offerings performing at 20 mips, with 50- and then 100-mips products not far behind.

This high end of the work-station market is growing at least twice as fast as work stations overall, says Roselie Buonauro, vice president of marketing at Silicon Graphics, Inc. in Mountain View, Calif. "We experienced very good growth last year and expect it to continue this year for our kind of high-performance, 3-d-graphics work station because of the growing acceptance in manufacturing companies of this product category," she says. Indeed, Dataquest Inc. estimates that the U. S. market for such high-end products with 3-d graphics will grow 60% in 1988, from about $200 million to around $350 million.



In another segment, 1987 was a good year for almost all players in the personal computer segment, who were hard hit in 1986. The *Electronics* survey pegs last year's growth at 25%, and forecasts a 16% gain to $17 billion this year. Egil Juliussen of Storeboard Inc. and the Computer Industry Almanac of Dallas considers the growth—which he believes may have been as high as 30%—phenomenal for such a large industry.

The very aggressive new product cycles launched by the major U. S. manufacturers last year—complete new product lines from IBM , Apple, Compaq, Tandy, and Zenith—have injected buyer excitement back into this segment. Apple's new open Macintosh family has garnered acceptance in the business market along with the IBM/Microsoft architecture. Products based on the 32-bit microprocessors, such as the Macintosh machines that use the Motorola 68020, and the IBM PS/2 and compatible machines that use the Intel 80386, are the vanguards of the industry. New operating software, such as OS/2, and new applications are on the way to take advantage of the new level of performance.

Another pleasant surprise of the 1987 market was the robust showing by hard-disk drives, and these products should see another good year in 1988. Sales of hard disks grew a healthy 38% to just over $4 billion, the *Electronics* report shows, outpacing a 25% forecast. This market is expected to leap ahead by another 30% in 1988, scoring $5.2 billion in sales.

Behind the booming market is the healthy growth of personal computers and work stations, plus the addition of superminicomputers, minisupercomputers, and supercomputers to work-station networks. Hard-core personal computer users are now making much fuller use of their machines, which takes plenty of mass-storage capacity and creates a big demand for 5¼- and 3½-in. drives. The growing use of technical work stations in big networks also increases the demand for hard-disk drives—primarily the 5¼- and 8-in. varieties. Many work-station users are extending their configurations by adding high-end microcomputers and some superminis as network file servers, to which large numbers of hard-disk drives are connected.

The shift toward the smaller drives that has been occurring over the last several years continues unabated as they keep improving in capacity, performance, and cost per megabyte. In 1988, for the first time the growth of total sales of 14-in. drives will

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COMMUNICATIONS

GROWTH SHOULD MOVE UP FROM 7% IN 1987 TO 9%; BIGGEST PUSH WILL BE DATA COMM'S 14% UPTICK

Coming off a lackluster 1987, the U. S. communications industry will rise in 1988. Some segments of this highly fragmented market, in fact, should enjoy a banner year. The *Electronics* market survey projects a 9% increase overall and sales topping $26.8 billion, compared with a 7% gain to $24.6 billion last year.

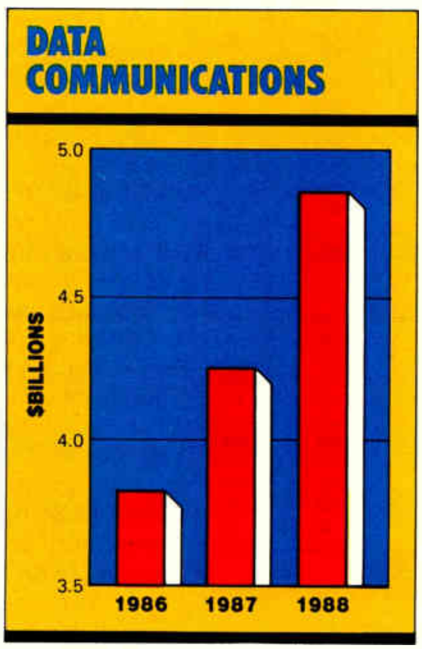
The most powerful driving force is the continuing confluence of communications and computers, with its inexorable march toward all-digital equipment. Within that fusion, the most prominent spending activity will be in networking, and this trend will push the data communications sector ahead 14% to $4.9 billion, outpacing last year's 11% gain. But the more mature market categories will lag behind. Telecommunications, for example, will grow only 7% to $7.6 billion—but still an improvement over the 4% rise this segment attained in 1987.

Electronics forecasts a 33% growth rate to $201 million for fiber-optic local-area networks; a 25% boost to $1 billion for multiplexers; and a 22% hike to $683 million for network controllers. Some industry analysts and corporate figures are more bullish, predicting up to 50% growth for some networking categories. The outstanding segments should include digital switches, T1 digital multiplexers, fiber-optic devices, and mixed-service equipment for combining voice, data, video, imaging, and other functions. T1 alone should show a 36% leap this year, to $550 million, according to Racal-Milgo Inc., a leading communications equipment supplier based in Sunrise, Fla.

Zia Hasan, marketing manager at Codenoll, a Yonkers, N. Y., LAN vendor, projects a 50% bound for LANs in general and fiber-optic LANs in particular. The only thing that has been holding back fiber LANs, he says, is not price but consumer ignorance. It is up to the LAN companies to teach prospective customers that fiber is less expensive than copper when installation costs are taken into account, he says. And the potential market is vast: "Of the 14 million personal computers at work on the North American continent, only 10% to 20% are connected [in networks]," says Hasan. The acceptance of networking standards will help, he adds, but the Fiber-optic Distributed Data Interface standard is still two years away.

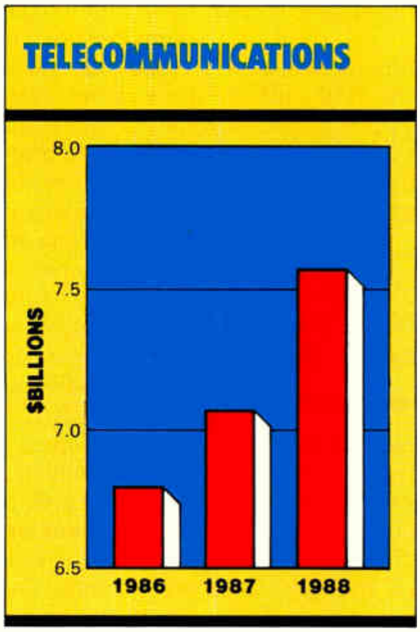
Fiber in the local loop is the next battleground, says Jim Watson, product manager for light-guide fiber and cable at AT&T Network Systems in Norcross, Ga. Long-haul fiber systems and trunks are already in the ground for the most part, he says, and it is the local user who must now be courted. Watson sees the military as one of the fastest-growing markets for fiber-optic communications systems, including avionic and shipboard replacement of copper cable, and rugged lightweight fiber cable in tactical situations, deployed by foot soldiers.

On the corporate networking scene, there is feverish activity in various sectors. Indeed, says Trudi Jackson, director of systems marketing for 3Com Corp. in Santa Clara, Calif., the "time is right" for networking. Jackson predicts a whopping 40% jump this year in local networks, leaping even beyond the bullish 27% compound annual rate forecast by such respected market researchers as Dataquest Inc. in San Jose, Calif., and International Data Corp. in Framingham, Mass. Jackson points to the aggressive networking stances of IBM, Digital Equipment, and Sun Microsystems in the work-station sector, and to the relentless computer-industry march to standards. She singles out the new Ethernet twisted-pair technology as one "that will have a tremendous growth rate" in 1988.



Now that the coast-to-coast deployment of fiber-optic transmission systems is all but complete, network managers will look to take advantage of their wide bandwidths and low error rates. The way to do that, it seems, is to go to a T1 digital carrier system, with its 24 channels and 1.544 Mbits/s data rate. Consequently, T1 multiplexers will represent a ers, coupled with market saturation and tumbling prices, will result in a 5% to 10% drop in sales, he says. But he believes that the leading suppliers—AT&T Co. and Northern Telecom—will sell a lot of software "into operating budgets"—that is, they will be upgrading their huge customer bases to improve the clients' service operations or profitability.

AT&T, the PBX leader, is attempting to keep that edge by rolling out value-added products such as the first PBX to work on the integrated services digital network. Others have jumped into ISDN too—including Fujitsu, IBM, and Northern Telecom—or are trying to offset the PBX slide with value-added products: automatic call distribution and voice messaging, and others.



The surge in ISDN products will help drive communication markets to new heights in the months ahead, as will technology advances, such as twisted-pair Ethernet capability and price/performance improvements in facsimile machines. Fax machines, in fact, should show outstanding growth as the price of desktop units continues to tumble toward $2,000. *Electronics* predicts a leap of 10% to $555 million on the heels of an identical rise last year. Small businesses are instrumental in the facsimile boom. They should be adding some 150,000 units in 1988, on top of the 200,000 machines already in place, says industry analyst CAP International Inc. of Marshfield, Mass. *Electronics* predicts a 21% jump to $230 million in the fastest-moving category, the speedy Group 3 machines.

Spending for radio equipment will be well ahead of 1987's languid 7%: growth should be 12% to $4.7 billion. Led by the land mobile sector, which will accelerate 22% to $1.8 billion, the star performers will be cellular telephones and microwave systems for short-haul operations. Such systems will mushroom in the major cities, where it is costly and difficult to run fiber optics. Long-haul microwave continues to sag, displaced by fiber-optic lines or satellite links.

U.S. MARKET REPORT

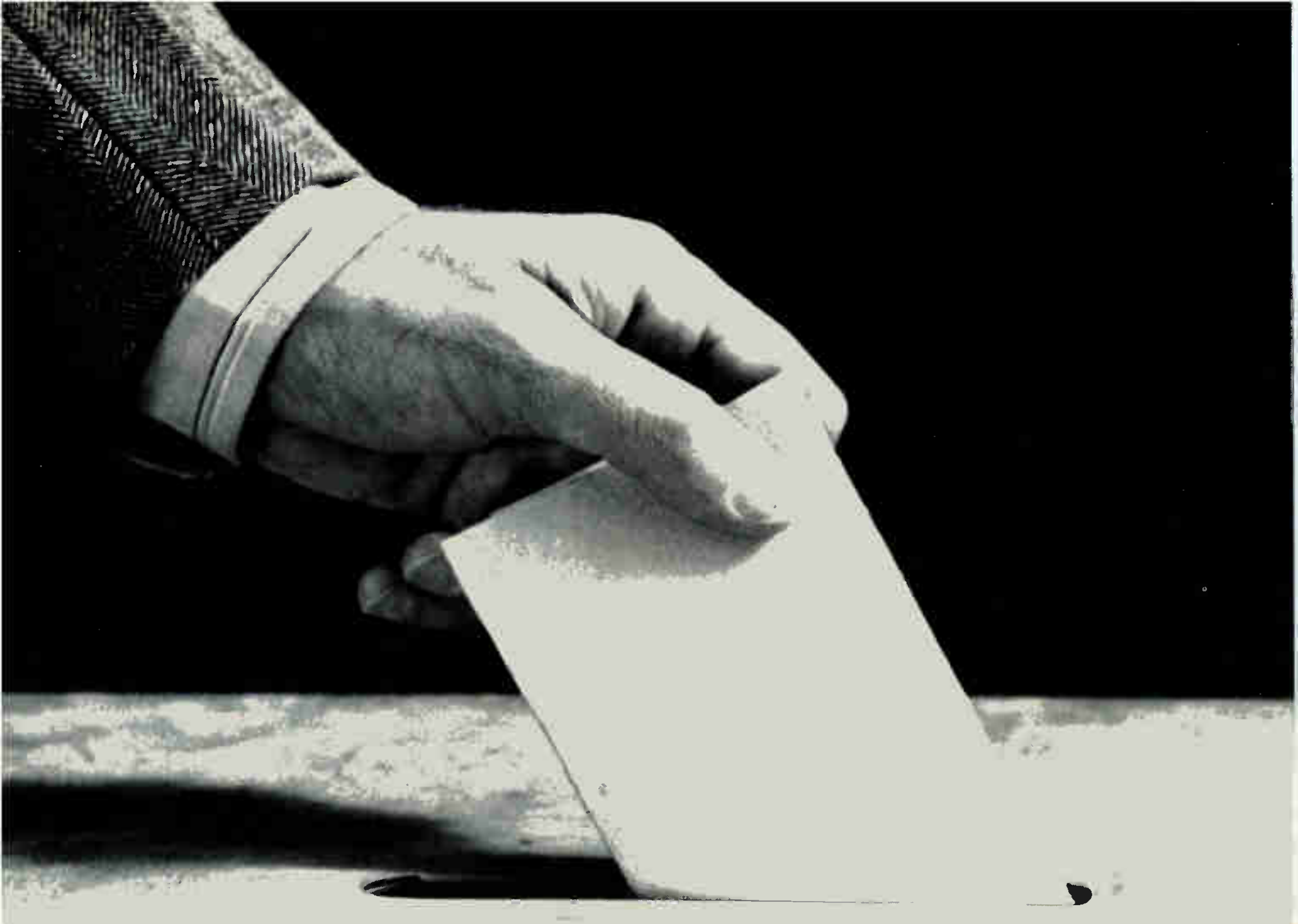
TEST & MEASUREMENT

SALES SHOULD CLIMB 10% TO $6.6 BILLION, UP A BIT FROM LAST YEAR'S BETTER-THAN-EXPECTED 9% GAIN

The rising popularity of high-speed microprocessors and application-specific integrated circuits is boosting demand for new test gear, sending a few segments of the 1988 test and measurement market skyrocketing on growth spirals of 20% or more. But those segments aren't enough to fuel major changes in the industry as a whole. The *Electronics* survey projects a moderate 10% growth rate and sales of $6.6 billion overall. That increase keeps pace with the 9% hike to $6 billion attained last year, which was better than the 6% expected.

Among the stellar performers in the high-end automatic-test-equipment market are combination in-circuit and functional board testers that sell for more than $500,000. *Electronics* expects consumption of these products to jump 26% in 1988 to $170 million in sales—a hefty rise, albeit lower than 1987's 35% hike to $135 million, largely because of competition from lower-priced gear just coming to market. However, chip testers are not keeping up with this brisk pace. These products, which are hounded by price competition, will experience a more modest 10% spurt to $856 million overall, a slight downturn from the 13% increase scored in 1987.

Among laboratory and bench instruments, digitizing oscilloscopes are a hot item and will likely remain so through 1990. *Electronics* expects this category to grow 25% to $488 million this year, on the heels of a 20% rise in 1987. Sales of logic analyzers should increase 24%, thanks largely to aggressive price cutting by Hewlett-Packard Co. that is expanding the market. HP analyzers now go for $4,000 or so, compared with a minimum of around $7,000 a year ago. Stand-alone in-circuit emulators should also see a fairly good year, rising 11% to $191 million, as developers increasingly write programs on work stations rather than on devel-



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Circle 81 on reader service card

Some of the credit for this meteoric growth must go to HP and its 1987 price cuts for the 32-channel HP1650 and 80-channel HP1651. Thanks to devising a logic-analyzer-on-a-chip design—one n-MOS chip contains most elements—the company was able to drop the price of the 32-channel instrument to $3,900 and the 80-channel model to $7,900—about $4,000 less than competing products. This year, other logic-analyzer manufacturers will strike back with price cuts of their own, along with performance hikes. "HP set a new price/performance point for logic analyzers, and we as competitors have to respond," says Kenneth Pine, senior vice president of Dolch American Instruments Inc. of San Jose, Calif.

The new price structure in effect expands the market for these instruments. "Our market analysis before we announced these products showed that typically five engineers shared a single logic analyzer," says Douglas Fryman, HP's program manager for logic analyzers. "With the new low cost, we believe that every engineer can now afford to have his own logic analyzer, just as he has his own oscilloscope."

Just as cost is affecting the market demand for logic analyzers, so too has lower cost improved the market acceptance for stand-alone in-circuit emulators. In addition, the increasing use of work stations and software development tools is boosting the need for emulators that can accept code from a variety of work stations and download it into the target hardware. In 1988, this instrument category will jump 11% to $191 million, up from $172 million.

Paired with the growth of emulators is a slippage for the tools they replace: microprocessor development systems. "Work stations are replacing dedicated microprocessor development systems like the familiar Intel 'blue box,' and general-purpose systems like the HP and Tektronix systems," says Richard Jensen, vice president of product development at Applied Microsystems Inc. of Redmond, Wash. This change is reflected in a negative growth rate of 4% for these products. Following an identical falloff last year, these systems should garner only $480 million.

Jensen says one factor in the rout is the declining cost of work stations, against which development systems cannot compete economically. Another is the work stations' Unix environment, which software designers find attractive. Then too, work stations offer the option of many programming languages, including C, that can speed program creation.

In the electronic counter market, one segment—universal counter-timers—is more than holding its own. These instruments enjoyed a 27% increase to $95 million in 1987, and they should make another 16% leap, to $110 million, this year. "The [universal] counter-timer market took off due to the improvement in ability to make time measurements with nanosecond accuracy," says Malcolm Levy, marketing manager at Racal Dana Instruments Inc. in Irvine, Calif. But Levy predicts price erosion slowing down growth in the overall counter-timer market, as the standard tools in this market drop from $10,000 or so into commodity-item range: $2,000 to $3,000. Taken as a group, counters should grow 11% to $191 million, compared with a heftier 16% rise last year.

When an older instrument becomes a commodity, there is usually a more sophisticated replacement in the wings commanding a much higher price. Typical of such a product is the Time Measurement Instrument from Wave Technologies Inc. of Edina, Minn., a very accurate timer. "TMI performs a simple timing measurement, but does so with a 100-ps resolution," says company president Dennis Leisz. Much of the demand for higher-performance counter-timers—more than 50% for Wave Technologies—is coming from the semiconductor test industry, which needs "the capability to test the increasing number of designs done in gallium arsenide, high-speed emitter-coupled logic, and TTL," says Leisz.

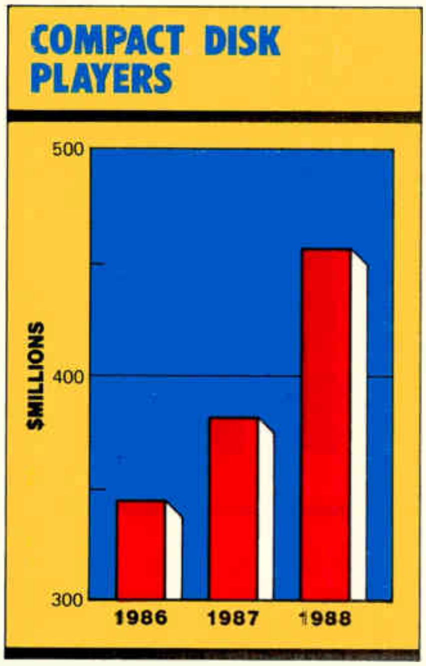
TEST & MEASUREMENT EQUIPMENT

	(millions of dollars) 1986	1987	1988
Automated test systems and equipment total	**1,527**	**1,686**	**1,852**
Active (discrete) component test systems	60	55	53
Automated field-service testers	50	55	60
IC testers, total	687	776	856
Benchtop testers	20	23	27
General-purpose systems	317	326	359
Specialized test systems (memory, etc.)	350	427	470
Interconnect and bare pc-board testers	165	185	203
Loaded pc-board testers, total	565	615	680
In-circuit	280	290	300
Functional	185	190	210
Combined	100	135	170
General test equipment, total	**3,973**	**4,333**	**4,770**
Amplifiers (laboratory)	68	71	74
Analog voltmeters, ammeters, and multimeters	28	30	31
Audio oscillators	28	31	33
Audio waveform analyzers & distortion meters	138	142	148
Calibrators and standards	160	169	174
Dedicated IEEE-488 bus controllers	100	105	111
Digital multimeters, total	181	194	205
3-1/2 digit and below	90	98	107
4-1/2 digit and above	91	96	98
Electronic counters, total	148	172	191
Frequency (500 MHz and below)	28	30	32
Microwave (above 500 MHz)	45	47	49
Universal	75	95	110
Frequency synthesizers	76	83	92
Function generators	68	72	79
Pulse generators	27	29	32
Signal generators, total	300	327	345
Rf (< 2GHz)	200	218	225
Microwave (> 2GHz)	100	109	120
Logic analyzers	258	298	370
Microprocessor development systems	520	500	480
Modulation analyzers	10	11	12
Noise-measuring equipment	13	14	15
Oscilloscopes, total	945	1,041	1,171
Analog	620	651	683
Digital	325	390	488
Panel meters	62	58	55
Personal-computer-based instruments	90	104	120
Recorders and plotters	382	407	450
Rf/microwave network analyzers	50	55	60
Rf/microwave power measuring equipment	31	31	32
Spectrum analyzers	315	353	395
Stand-alone in-circuit emulator	160	172	191
Temperature-measuring instruments	35	37	39
TEST AND MEASURING EQUIPMENT, TOTAL	**5,500**	**6,019**	**6,622**

All figures in current U.S. dollars

Electronics projects additional 56% growth this year to $840 million at the factory sales level.

Electronics projects the best growth this year among more traditional consumer categories to come in the audio segment, which will rise by 5% to $5.9 billion. Adding new excitement to the market is the expected emergence of a brand-new consumer category, digital audio tape, which should nab $20 million in sales. But the brightest star in the audio universe continues to be the compact disk. Aided by expected drops in CD software pricing, home-CD hardware sales are projected to rise by 20%, on top of last year's 10% gain, to hit $457 million. That, in turn, will mean good times for other stereo components, which CD owners are buying to upgrade their systems. The CD boom "has been very, very good for speakers. It's put a lot of emphasis back on the separates—the component area of the business," says Mark Finer, director of Communication Research Inc., a Pittsburgh consulting firm. Indeed, *Electronics* projects 18% growth in components this year to $1.5 billion.



The expected strength in CD player sales this year may be driven by declining prices for disks, rather than by falling hardware prices, many believe. For the first time since the CD made its U. S. debut in 1983, disk prices for new music releases could drop from the prevailing $12 or $15 to below $10 apiece—perhaps as low as $7—industry watchers say, due to disk-pressing overcapacity. An estimated 33% of music purchasers are under 20 years of age, and very few of them have gone CD, so a drop in disk pricing could be key in hardware sales. "The real opportunity for CD expansion, to keep the momentum going, is the younger consumer, the one who has not purchased CD up to this point primarily because of the price of the software," says Finer.

Like compact disks, digital audio tape offers vastly improved sound. DAT sales in the U. S. have been stymied by the copyright controversy surrounding the format, but that's likely to be resolved this year. And some observers believe that when DAT is finally loosed in the U. S., all the preceding publicity will mean higher consumer awareness—and sales outstripping even CD's early pace. About 35,000 CD players were sold in that format's first year. But in the first 12 months after DAT is introduced, "I'd say selling 50,000 to 75,000 units is going to be a piece of cake," says James Twerdahl, president of Marantz Co., Chatsworth, Calif. *Electronics* projects total sales of DAT hardware in 1988 to hit $20 million.

Meanwhile, on the video side, which last year accounted for 58% of the total consumer electronics market, 1988 growth will taper off slightly. *Electronics* projects 3% growth in the sector to $13.4 billion, on the heels of 4% growth last year. The market will be anchored by the venerable color television receiver, despite estimates that some 94% of U. S. households already own one. *Electronics* projects 2% growth in color TV sales this year to $6.4 billion, against a 5% hike last year. Key to TV's long life is the widespread adoption of stereo TV broadcasting, the move toward larger screen sizes, and new, advanced features.

Camcorders will continue to be a bright spot in video. *Electronics* projects 18% growth to $1.8 billion in 1988, following a 23% jump last year. The category continues to be dominated by ½-in. models, where the introduction of smaller units based on the compact VHS format seems to be taking some steam out of the competing 8-mm format.

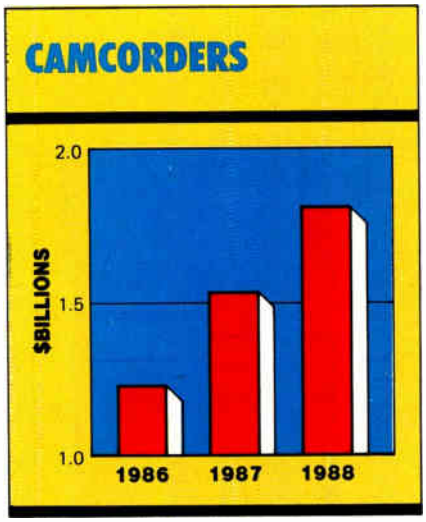
One category that could be primed for a comeback is video-disk players, a play-only medium that lost out to lower-priced play/record VCRs on its first try in the market. Video disks were revitalized last June with the joint launch by some 30 vendors of the Compact Disk Video. CD-V combi-players, as they're known, will handle conventional audio

CONSUMER EQUIPMENT

(millions of dollars)	1986	1987	1988
Consumer audio equipment, total	**5,462**	**5,621**	**5,927**
Car audio	2,566	2,700	2,710
Stereo equipment, total	1,716	1,745	2,000
Compact systems (miniaturized components)	516	520	550
Components (turntables, speakers, tuners, etc.)	1,200	1,225	1,450
Phonographs and radio-phonographs	70	60	40
Radios (including table, clock, and portable)	494	455	450
Tape recorders/players	270	280	250
Compact disk players (home)	346	381	457
Digital audio tape players	0	0	20
Consumer video equipment, total	**12,543**	**12,988**	**13,372**
TV receivers, total	6,241	6,518	6,621
Color	5,941	6,238	6,363
Monochrome	300	280	258
Projection TV receivers	537	480	490
Video cassette players and recorders	4,114	4,032	3,911
Video disk players	48	58	72
Camcorders, total	1,248	1,540	1,810
8-mm	238	230	260
1/2-in.	1,010	1,300	1,550
Home satellite receiving stations	355	360	468
Personal consumer products, total	**3,687**	**3,793**	**4,161**
Calculators	596	623	648
Electronic musical instruments and equipment	488	513	528
Microwave ovens	2,010	1,720	1,715
Telephone answering devices	345	400	430
Video games (including software)	248	537	840
CONSUMER ELECTRONICS, TOTAL	**21,692**	**22,402**	**23,460**

All figures in current U.S. dollars

CDs and 8- and 12-in. video disks, as well as the upcoming 5-in. CD-V format likely to be used for pop-music videos. Pioneer, Magnavox, and Yamaha have already introduced CD-V combi-players in the U.S., and a half dozen more vendors are expected to introduce products at this month's Winter Consumer Electronics Show. *Electronics* projects that video-disk player sales will rise by 24% in 1988 to $72 million.



Makers of home satellite-receiving stations are also hoping that 1988 will be the year that sales break out from a market that was flattened in 1985 when HBO and other cable companies began scrambling their signals. The resurgence didn't materialize last year because of lingering consumer confusion over the legality of home dishes, among other factors. 1988's prospects look better. Programming sources say they're willing to work with dish dealers in promoting the technology through package deals that frequently include programming discounts. And integrated receiver descramblers are emerging that eliminate the need for the consumer to buy a separate descrambling box. Following a 1% sales increase last year, *Electronics* projects a 30% rise in dish sales in 1988.

While the outlook for other heavyweight video categories is up, the sales curve for VCRs is expected to dip in 1988 for a second straight year. Following a 2% decline last year, *Electronics* projects an additional 3% drop in 1988 to $3.9 billion, with a small uptick in unit sales not enough to offset expected continuing price erosion. But some think the market still holds some surprises. "People who say VCRs have run their course are wrong," says Harry Elias, senior vice president at JVC Co. of America, Elmwood Park, N.J. "There is only 50% market penetration, and look how color TVs have been climbing for the last five years with 90% penetration."

U.S. MARKET REPORT

INDUSTRIAL

GROWTH WILL HOLD AT 6%, AS THE MARKET EXPANDS BEYOND RELIANCE ON THE AUTO INDUSTRY

The industrial electronic-equipment sector climbed out of the dumps in 1987. The market managed 6% growth, despite the continuing effects of sharp automotive industry cutbacks that zapped it in 1986, when sales dropped by 5%. *Electronics* is forecasting a second straight year of growth in 1988, with another 6% rise that will push the market beyond the $6 billion mark.

The sector failed to meet last year's projections for an upswing in 1987 largely because of a slowdown in process-control equipment, which accounts for some 58% of the market. Instead of the 13% rise anticipated last year, the segment grew by only 4%. Brisk sales to the chemical and some other industries were dragged down by sluggishness elsewhere.

Among the reasons for the optimism for 1988, however, is the continuing diversification of the automation customer base beyond its top-heavy reliance on the automakers. Prospects are improving in a number of segments, including electronics, aerospace, chemicals, pharmaceuticals, food and beverages, and pulp and paper.

There is one dark cloud on the horizon, however. With the up-and-down market dropping 5% in 1986 and rising slightly in 1987, equipment manufacturers are now keeping a wary eye on the stock market. Continued volatility there could cause nervous customers to trim capital expenditures, some fear. But suppliers and market watchers alike say they see no signs of recession yet. Capital spending budgets are already in place for 1988, and most believe that the ill effects of the stock market crash—if any—probably won't surface until the second half of the year. They point out also that election years have traditionally been good ones for factory equipment makers.

One particularly bright spot in 1988 is inspection systems, where vendors should score a 16% gain on top of last year's heady 17% growth rate and bag sales of $464 million. They owe this boom to the growing emphasis on quality control among manufacturers, who are also demanding better output from their production lines. Both needs are resulting in the purchase of more inspection systems. For the same reasons, makers of machine vision equipment could be in for a

INDUSTRIAL EQUIPMENT

	1986	1987	1988
		(millions of dollars)	
Energy-management equipment	452	461	475
Inspection systems	342	400	464
Motor controls (speed, torque)	586	648	676
Numerical-control systems	241	255	268
Process-control equipment, total	3,175	3,320	3,510
Data-acquisition systems	222	231	240
Process instrumentation	2,319	2,482	2,632
Programmable controllers	634	607	638
Robot systems	476	480	509
Vision systems	100	111	127
INDUSTRIAL ELECTRONIC EQUIPMENT, TOTAL	5,372	5,675	6,029

All figures in current U.S. dollars.

good year, as the electronics industry in particular begins to step up its use of sophisticated vision-based inspection of complex surface-mounted device assemblies. Though still only a small piece of the total industrial pie, vision systems will show continued momentum, *Electronics* projects, with 14% growth to $127 million, building on 1987's 11% spurt.

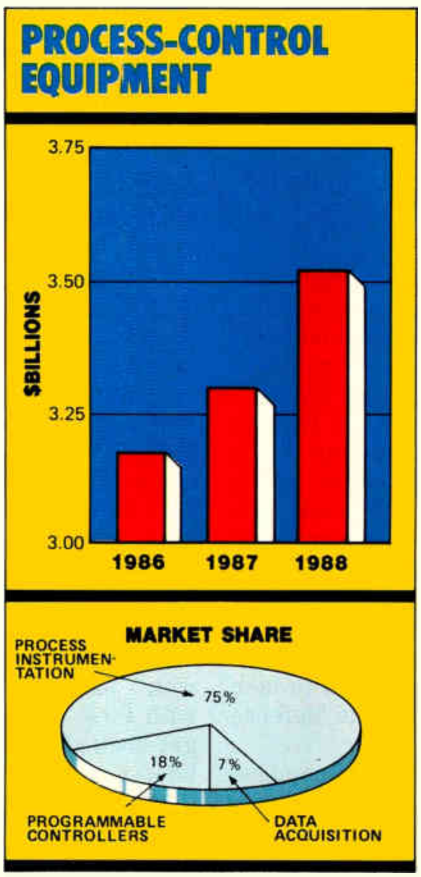
Robot makers are also counting on the electronics industry to help soften their reliance on the automakers, who currently account for about half of all robot purchases. Though Ford and Chrysler are still buying, the U. S. robot industry suffered through massive 1986 and 1987 spending cutbacks by its largest customer, General Motors Corp. One of the hardest hit was industry leader GMFanuc Robotics Corp., co-owned by GM. The Rochester Hills, Mich., firm was forced to lay off more than a third of its work force in late 1986 and early 1987 due to $88 million in lost GM business. Overall, the robot industry suffered a flat year in 1987. But prospects are for 6% growth in 1988 to $509 million.

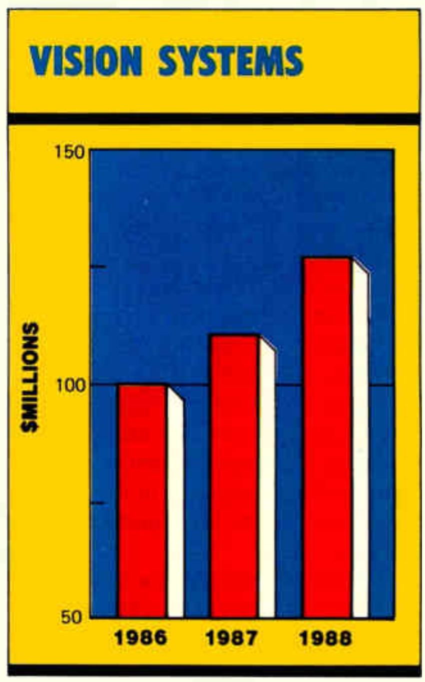
Few are expecting to see dramatically increased auto-industry spending for robots and other automation gear this year. But at GMFanuc, marketing manager Marc W. Carlson notes that shipments to other segments—including aerospace, food processing, and pharmaceuticals—are expanding. And like many industry watchers, he singles out electronics as a particularly promising near-term opportunity.

Indeed, the use of robots for board-population tasks alone amounted last year to a $50 million to $60 million market that is growing at a 20% annual rate, says Charles-Henri Mangin, president of Ceeris International Inc., an Old Lyme, Conn., firm specializing in electronics assembly consulting. In many cases, manufacturers of computer and telecommunications gear are turning to robot systems that integrate sophisticated vision equipment to assure high-quality assembly of increasingly dense and expensive surface-mounted components and assemblies. In fact, for these kinds of systems, "1987 was a boom year," says Mangin, "and the first half of 1988, at least, is also going to be excellent."

Robot makers aren't the only ones struggling to make a comeback. The programmable controller market, which relies on the carmakers for an estimated 35% of volume, was hard hit last year by a 4% market contraction. *Electronics* projects that sales next year will make up for that loss, however, rising by 5% to $638 million. "We're expecting the auto market to come back some this year. That's probably one of the main reasons the [programmable controller] market will go up a little bit," allows Rick Armbrust, marketing director for Square D Co.'s automation products division in Milwaukee. He also expects continued strength in the food and beverage segment, which is rising at about a 7% annual rate.

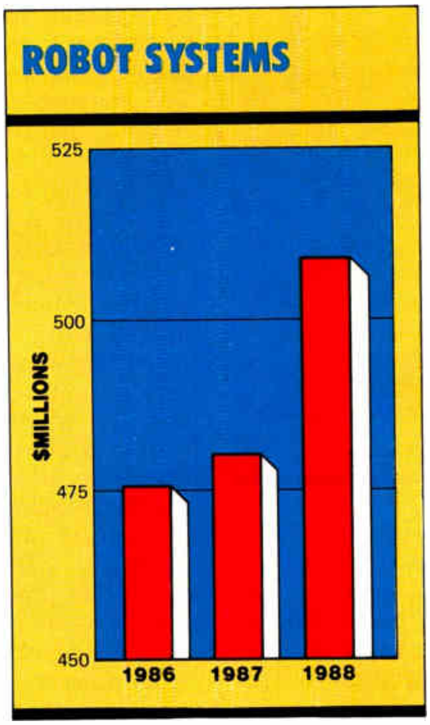
For process control equipment in general, the oil price drop that caused trouble in 1986 again held down demand last year among oil refinery customers. But the petroleum industry's price problems touched off a countervailing boom in related chemical industries, such as plastics, points out David Penning, director of manufacturing automation services for Dataquest Inc., a San Jose, Calif., market research firm. "The chemical industry is busting its seams," Penning says, with many suppliers running at full capacity. That, as well as strength in other segments such as pulp and paper, helped produce overall 4% growth in process control equipment sales last year. Additional 6% growth is





projected for 1988, with total volume topping $3.5 billion.

While lower petroleum prices have brought prosperity to the chemical industries, they have had the opposite effect on energy-management equipment sales. "The hot button of energy management is not as hot as it was five years ago," observes John G. Ehlen, marketing director for the systems business unit of Honeywell Inc.'s Building Controls Division, Albuquerque, N. M. But Ehlen notes that as microprocessors increasingly bring more functionality at lower costs, vendor emphasis is shifting. "We're not just talking about energy management. We're talking about building communications, diagnostics, environment for comfort, and control of lighting for safety." For 1988, the outlook is for 3% growth, to $475 million. Though that's not outstanding, it tops 1987's sluggish 2% expansion rate.



Current trends also point to modest market improvements for other industrial electronic equipment categories, including motor controls, with a 4% rise to $676 million, and numerical-control systems, where gains are projected at 5%, to $268 million.

In all, the mood of vendors and some industry watchers is cautiously upbeat. And Dataquest's Penning is willing to go a step further. "Curiously, the twist might be that the stock market crash has caused people to say that maybe our economy is weak, and that maybe we need to invest in manufacturing, which is an important part of our economic strength, and that maybe now is the time to do it," he says. "That's the kind of attitude I'm detecting from all the manufacturers I've talked to."

U.S. MARKET REPORT

MILITARY & GOVERNMENT

CUTS IN DEFENSE BUDGET WILL MEAN A 5.6% DIP; SENSORS, SMART WEAPONS, SOFTWARE SEEM SAFE

After half a decade of rising defense budgets, the federal government is pulling in the reins. Government spending is on the decline, and most defense and government contractors are going to feel the squeeze for at least the next two years.

The reasons are many. Much of the the Reagan Administration's planned defense buildup—such goals as a 600-ship Navy, for example—have finally been met. At the same time, the Oct. 19 stock market crash, and the market's ensuing downward slide through November and early December, have put pressure on Congress and the Administration to hold down government spending. Meanwhile, the Gramm-Rudman-Hollings deficit-reduction act is giving a Democratic Congress more power in its push to take the lion's share of those cuts out of the defense budget.

For the electronics industry, these factors combine to mean less government business and more competition ahead. Military electronics revenues are expected to drop 5.6% in 1988 to $45.5 billion.

Defense budget cuts first struck in 1986, when a 4.3% cut brought the Defense Department's budget to $301.5 billion. Last year's cut was less severe, only 1.6%. But indications are that the 1988 budget—which still isn't final—will be the toughest yet, with defense spending falling 5% below the 1987 level.

The Electronics Industries Association, which tracks defense spending closely, estimates that the DOD budget will continue its steady decline until 1992, when it bottoms out at around $273 billion—$28 billion less, in constant 1988 dollars, than the Pentagon spent in 1986. It will be 1995 before the DOD can play with even a 1% budget boost.

"The rain will come down, and everyone will get wet," says Wolfgang Demisch, a defense analyst with First Boston Corp. in New York. But some will get soaked more than others, he adds. Big systems houses are the most likely to suffer damage; electronics specialty firms should stay high and dry. "The guys who are in sensors, smart weapons, software, space—those are the areas that are relatively

FEDERAL EQUIPMENT & SOFTWARE

	(billions of dollars) 1986	1987	1988
Hardware purchases	2.7	2.6	2.6
Hardware leases/rentals *	1.0	0.9	0.9
Commercial software and some related equipment	0.2	0.3	0.2
Custom software and related consulting	1.7	2.0	2.1
Systems and network engineering	0.1	0.3	0.1
FEDERAL TOTAL	5.7	6.1	5.9

Figures, in current U.S. dollars, represent U.S. civilian and military purchases of data processing and telecommunications equipment and software.
* Includes some operating costs that cannot be broken out.

MILITARY EQUIPMENT

	(billions of dollars) 1986	1987	1988
Aircraft, total	11.9	10.7	8.9
Procurement	10.4	9.1	7.3
R&D, testing, and evaluation	1.5	1.6	1.6
Electronics and communications, total	9.1	9.1	9.3
Procurement	5.7	5.8	6.0
R&D, testing, and evaluation	3.4	3.3	3.3
Missiles, total	8.6	8.4	8.2
Procurement	5.3	5.1	5.0
R&D, testing, and evaluation	3.3	3.3	3.2
Ordnance and weapons, total	1.2	1.2	1.2
Procurement	1.0	1.0	1.0
R&D, testing, and evaluation	0.2	0.2	0.2
Ships, total	5.4	5.7	4.8
Procurement	4.5	4.8	4.1
R&D, testing, and evaluation	0.9	0.9	0.7
Space, total	5.3	6.0	6.4
Procurement	2.9	3.1	3.1
R&D, testing, and evaluation	2.4	2.9	3.3
Vehicles, total	0.9	0.8	0.8
Procurement	0.9	0.8	0.7
R&D, testing, and evaluation	0	0	0.1
Other, total	6.9	6.3	5.9
Procurement	3.4	2.5	2.2
R&D, testing, and evaluation	3.5	3.8	3.7
MILITARY EQUIPMENT TOTAL	49.3	48.2	45.5

All figures in current U.S. dollars
Figures represent only the value of electronic content in military equipment.

safe," Demisch says. Defense platform builders, however, such as General Dynamics, Grumman, and Northrop, "will feel more pain."

When budgets are cut, analysts say, the first things to go are often new systems, and that's what these companies thrive on. With cancellations likely, programs such as the Small ICBM (intercontinental ballistic missile) will most likely be deferred, especially in light of the recent arms-control talks. Other projects, such as the LHX helicopter and the B-22 bomber, may also be put off.

But while these programs are the lifeblood of the big platform makers, their loss will not have as much of an impact on the specialty companies, such as Raytheon Corp. "While actual defense spending is going down, we expect electronic content to go up a little," an EIA official says. That doesn't mean total electronic expenditures are on the rise, but it does indicate that electronics will play an increasingly important role in military systems.

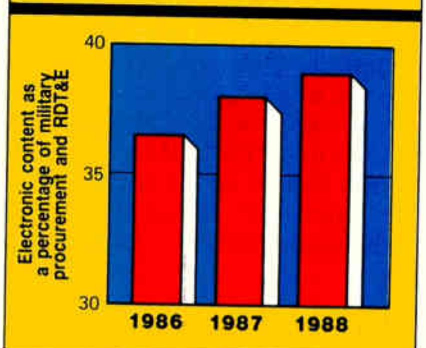
EIA statistics bear that out. The DOD spent $134.7 billion on total procurement, research, development, testing, and engineering in 1986. Of that total, $49.3 billion, or 37%, was spent on electronics. By contrast, the DOD's 1988 budget for procurement and RDT&E was down 14% from the 1986 level, to $116.5 billion. But the proportion of money spent on electronics will rise to 39% and total $45.5 billion.

Electronics businesses therefore are faring better than their counterparts in other defense industries. That trend should continue through 1997, according to the EIA, when electronic content of military procurement and RDT&E will reach the 41% level. One reason for the rise, says an EIA official, is that when budgets are tight, the DOD has to upgrade existing equipment instead of replacing it. And that often means building in new electronics.

Another emerging trend is the DOD's increased interest in research and development—perhaps at the expense of current procurement. EIA statistics show that total defense electronics R&D rose 5% from 1986 to 1987, while equipment purchases sank 6%. R&D for aircraft electronics rose 7% in the same period, while procurement of avionic and other airborne electronic equipment dropped 13%. This year, as total military electronics procurement falls even further—9% to $29.4 billion—electronics R&D will inch up 0.6% to $16.1 billion.

Nonmilitary government spending on data processing and telecommunications gear is harder to track. The military accounts for about half of the government's spending on "information technology," says the Office of Management & Budget. Other big spenders—with information technology budgets totaling over $150 million—are the National Aeronautics and Space Administration and the Departments of Agriculture, Commerce, Energy, and Health and Human Services. But total government information-technology spending will decline by 3.3% in 1988. Whether that will come from telecommunications, data processing, or both is hard to say. An OMB analyst says the department no longer breaks out the two categories separately because it's difficult to sort them out. The boundaries between the two are now so blurred, he says, that it no longer makes sense to differentiate.

MILITARY ELECTRONIC CONTENT



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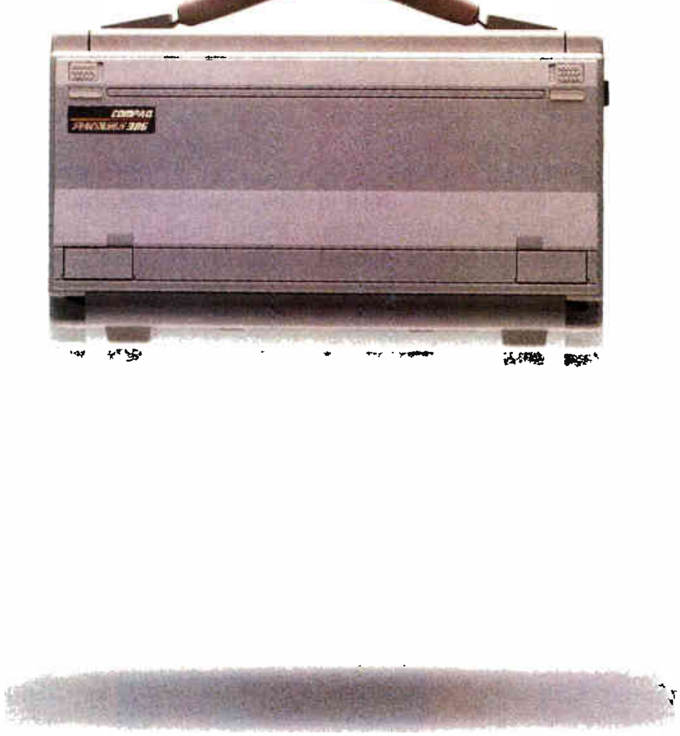

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ket. "In recent years, high-density DRAMs have not been able to keep pace with the improvements in performance in microprocessors, especially when used as main memory," he says. "In order to eliminate the wait states necessary when using slower DRAMs, many systems designers moved to cache-oriented systems in which higher-speed static RAMs are inserted between the central processing unit and the slower DRAMs used in the main memory."

The new products with their faster access times mean that in many applications, designers can eliminate the static RAMs or caches and in so doing significantly lower system costs—despite having to pay a high price for 1-Mbit memories. This is resulting in a slower growth rate for SRAMs, says deDios of Dataquest. SRAMs are also being zapped by a maturing of the technology and a resulting decline in the average selling price. The *Electronics* survey shows SRAMs rising by a still-respectable 13% to $900 million—but that's a far cry from the 23% hike to $800 million achieved in 1987. Within this category, bipolar SRAMs should grow by 13% to $170 million, while the maturing MOS and CMOS segment rises 12% to $730 million—a comedown from its heady 24% growth rate in 1987.

Balancing out the precipitous up-and-down performance of RAMs is the steady and solid showing of

SEMICONDUCTORS

(millions of dollars)	1986	1987	1988
Discrete semiconductors, total	**1,764**	**1,909**	**2,094**
Diodes, total	808	891	981
Arrays (including bridges)	25	26	27
Rectifiers, total	598	663	736
Low power (less than 25A)	526	582	645
High power	72	81	91
Signal	72	80	87
Special purpose, total	113	122	131
Microwave (above 1 GHz)	18	19	20
Varactor	10	11	12
Zener	85	92	99
Protection devices	20	22	24
Thyristors	121	125	132
Transistors, total	815	871	957
Bipolar, total	600	640	697
Power (1 W or more)	331	355	390
Rf and microwave power	77	84	92
Small-signal	192	201	215
Field effect, total	150	161	175
Power, total	108	117	128
High-power (above 20W)	22	26	32
Power (to 20W)	86	91	96
Small-signal	42	44	47
Gallium arsenide	65	70	85
Integrated circuits, total	**9,151**	**10,901**	**13,127**
Custom and semicustom ICs, total	1,425	1,911	2,438
Custom, total	695	903	1107
Standard cell	166	256	370
Other (including hand-crafted)	529	647	737
Gate arrays	500	700	945
Programmable logic devices, total	230	308	386
Electrically reprogrammable	30	48	100
Fuse programmable	200	260	286
Linear ICs, total	1,934	2,176	2,436
Amplifiers, operational	200	224	240
Amplifiers, instrumentation	19	21	26
Analog switches	87	100	102
Communications (codecs, etc.)	139	156	175
Consumer-product ICs	620	700	749
Data conversion, total	595	691	841
A-D converters	260	310	376
D-A converters	242	280	350
Multiplexers	38	41	44
Sample and hold	55	60	71
Interface	144	149	160
Voltage references and regulators	130	135	143
Memories, total	2,491	2,697	3,698
Magnetic bubble devices (incl. support chips)	17	19	20
Random access memory, total	1,703	2,038	2,562
Dynamic RAM, total	1,053	1,238	1,662
64K or smaller	310	174	102
256K	613	714	600
1Mb	130	350	960
Static RAM, total	650	600	900
Bipolar	125	150	170
CMOS and MOS	525	650	730
Integrated circuits (continued)			
Read-only memory, total	771	910	1,116
Bipolar, total	290	320	356
Fuse-programmable (PROMs)	120	130	145
Mask-programmable (ROMs)	170	190	211
CMOS and MOS mask-programmable, total	16	21	25
Electrically erasable, total	100	150	270
EEPROMs	70	100	200
Shadow (NVRAMs)	30	50	70
EPROMs (ultraviolet-erasable)	365	419	465
Microprocessors and microcomputers, total	1,568	1,879	2,294
Bipolar, total	349	379	430
LSI peripheral chips	195	209	233
Processors	154	170	197
CMOS and MOS, total	1,219	1,500	1,864
LSI peripheral chips, total	389	418	467
Controllers (disk-drive, CRT, etc.)	159	178	205
Other peripherals	230	240	262
Microprocessors, total	452	652	927
8-bit	160	200	210
16-bit	230	290	370
32-bit	62	162	347
One-chip microcomputers and microcontrollers	378	430	470
4-bit	50	40	35
8-bit	320	350	355
16-bit	8	40	80
Special-purpose processors, total	308	376	459
Digital signal processors	58	92	129
Floating point processors	50	59	70
Multipliers	170	190	220
Other	30	35	40
Standard logic families, total	1,425	1,592	1,802
BiCMOS	8	32	90
CMOS	293	342	394
ECL	254	295	325
TTL, total	870	923	993
High-speed (AS, ALS, FAST, etc.)	242	278	320
Low-power (LS)	570	587	616
Standard (S)	58	58	57
Optoelectronic devices, total	**306**	**341**	**384**
Imaging arrays, total	71	90	107
CCD	46	65	81
MOS	25	25	26
Laser diodes	10	11	15
Light-emitting diodes (discrete), total	76	79	88
Infrared, near infrared	24	25	29
Visible	52	54	59
Optically coupled isolators	80	90	100
Photoconductive cells (light dependent diodes)	17	17	17
Photodiodes	6	6	6
Phototransistors	18	20	22
Photovoltaic cells	28	28	29
SEMICONDUCTORS, TOTAL	11 221	13 151	15,605

All figures in current U.S. dollars

$90 million. On the down side, TTL circuits will grow only 8% to $993 million, as faster families replace them in high-performance systems. Emitter-coupled logic should increase 10% to $325 million to satisfy the increasing demands from supercomputers, mini-supercomputers, and superminicomputers.

Remarkable for their rock-solid growth rates, linear circuits are expected to increase in 1988 by about 12% to $2.4 billion, compared with 13% in 1987. This steady, if relatively modest, performance is due to maturity of some product lines and also to increased levels of integration, says Brian Gillings, director of strategic planning and applications at Maxim Integrated Products Inc. of Sunnyvale, Calif. "New process technologies are allowing us to integrate more functions onto the same chip," he says. In some cases, as in operational amplifiers and data-conversion devices, this means selling duals and quads for the same price as stand-alone functions. In other cases, it means integrating on-chip functions such as analog switches, sample-and-hold, and references that were previously implemented externally.

Reflecting this trend toward higher integration is the op amp category, which is expected to increase by only 7% to $240 million against a 12% growth rate last year. Similarly, consumption of stand-alone analog switches is expected to increase by only 2% to $102 million, a marked falloff from the 15% increase scored in 1987.

Still recording the largest gains in linear circuits are data-conversion devices, with analog-to-digital converters increasing by 21% to $376 million and digital-to-analog circuits garnering a 25% gain to $350 million.

Among discrete semiconductors, gallium arsenide devices are poised for a hefty 21% rise to $85 million, well above the 8% hike attained in 1987. Though their market is still small, high-power FETs are another star performer: these devices should grow 23% to $32 million in 1988. More typical of growth rates in the discretes category are diodes, rising 10% to $981 million; transistors, also increasing 10%, to $957 million; and thyristors, growing 6% to $132 million.

10% GROWTH WILL CONTINUE THE COMEBACK IN CHIP-MAKING GEAR

The good news for the semiconductor-equipment industry is that last year's strong upturn in the chip business was enough to raise equipment sales 9% from severely depressed 1986 levels, to $2.4 billion. But while it was welcomed by equipment makers who have been struggling to regain profitability, the improvement fell far short of fatter increases that seemed in sight a year ago. Now, *Electronics* projects for 1988 a slightly better 10% growth rate, to send the industry back within shooting distance of the $2.7 billion sales peak it reached in 1985.

The reason for the slower-than-expected 1987 pace is not hard to spot, says G. Dan Hutcheson, president of VLSI Research Inc., an industry consultant in San Jose, Calif. Unused integrated-circuit capacity in the U. S. caused chip firms to hold back on buying new equipment. "Although we're not entirely out of the woods yet, everything is coming back," he says. Leading the recovery: demand for submicron production equipment as semiconductor houses gear up for next-generation devices.

In this move toward submicron geometries, one major shift will have a dramatic impact on the market. Chip makers now say that optical lithography can take them down to 0.5-μm and perhaps below, a turnaround from the standard wisdom that prevailed as recently as a year ago. The upshot for suppliers of wafer steppers is that their equipment will have a longer product life.

The renewed interest in steppers surfaced too late in the year to influence 1987 figures, but is likely to trigger higher sales beginning in 1988, says Hutcheson. The *Electronics* survey indicates a 20% gain in 1988, to $276 million, compared with only a 2% rise in 1987.

Improvements in stepper lenses and light sources, along with new photoresists, are driving the upsurge, explains Howard K. Dicken, editor of DM Data Inc.'s *Semiconductor Economics Report* in Scottsdale, Ariz. The significance for chip makers is plain, he says: "They can keep the basic stepper framework through the next decade, which means lower costs than [replacing optical systems with] e-beam." Dicken has done studies for clients that estimate the savings can amount to as much as 40%.

By the same token, sales of electron-beam direct-write units, which had been widely expected to take over the fine-line lithography load into the 1990s, could be held back. Currently, e-beams are still in an upswing, logging a 9% gain for 1987 and a whopping 28% jump for 1988, to $109 million. The principal force behind the gains is the steady sales of Perkin-Elmer Corp.'s Aeble 150 e-beam system, which is finally available after development delays.

SEMICONDUCTOR PRODUCTION EQUIPMENT

(millions of dollars)	1986	1987	1988
Assembly (wire bonders etc.)	350	388	431
Lithographers, total	461	474	555
Contact (proximity)	32	32	31
Direct wafer-stepping	225	230	276
Electron-beam	78	85	109
X-ray	6	7	9
Projection	120	119	119
In-line handling (scrubbers, coaters, ovens, etc.)	80	89	99
Mask generation (digitizers, E-beam mask makers, etc.)	52	58	64
Wafer preparation (crystal growers, etc.)	35	39	43
Wafer processing (furnaces, implanters, etchers, deposition, etc.)	1,250	1,388	1,485
SEMICONDUCTOR PRODUCTION EQUIPMENT, TOTAL	2,228	2,435	2,666

All figures in current U.S. dollars

Keep telling yourself
it's only a game.
it's only a game.
it's only a game.
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it's only a game.

(Or is it?)

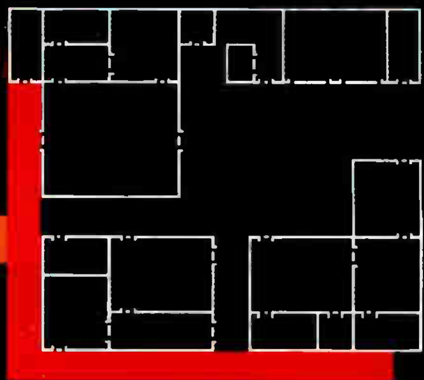

Diagram of Cramoisy Brigade camp. You'll need this to complete your mission.

Life's a game, or so we are told. And yet, when you're in a critical development mode and you encounter a buried "bug" it can seem like you're the victim. Now, ZAX challenges you to strike back by experiencing the ultimate in investigative tactics with Ground Zero! Ground Zero is an intriguing computer game that solicits shrewd thinking, lightning reflexes and sturdy nerves—plus the ability to face the sometimes unfavorable consequences of your actions.

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Circle 97 on reader service card

and cable, rising 11% to $2.6 billion. Capacitors should post a 6% gain, to $1.4 billion, while electron tubes should rise by 5% to $2.3 billion.

The $4 billion connector industry should maintain "continued solid, steady growth," says Dominic J. Pileggi, vice president of marketing at connector maker Thomas & Betts Corp. Pileggi's 8% to 9% forecast is a bit more bullish than the 6% predicted by *Electronics*. "Generically, we expect to see the fastest growth in applications with higher pin counts," he says. Technology drivers include surface mounting and miniaturization, a trend favoring vendors who offer complete tooling packages. In other words, says Pileggi, as interconnection technologies become more sophisticated, customers will migrate to products that include an assembly tool or insertion tool. The Raritan, N. J., company is particularly bullish on fiber optics, largely because it sees an upsurge of fiber use in industrial and office LANs.

The robust printed-circuit board and interconnection industry, on the other hand, is gearing up for a 13% growth year and $5.1 billion in sales. Leading the way on a percentage basis, chip carriers will grow at a whopping 63% clip, largely because of the surge in high-pin-count processors. Sales should reach $65 million.

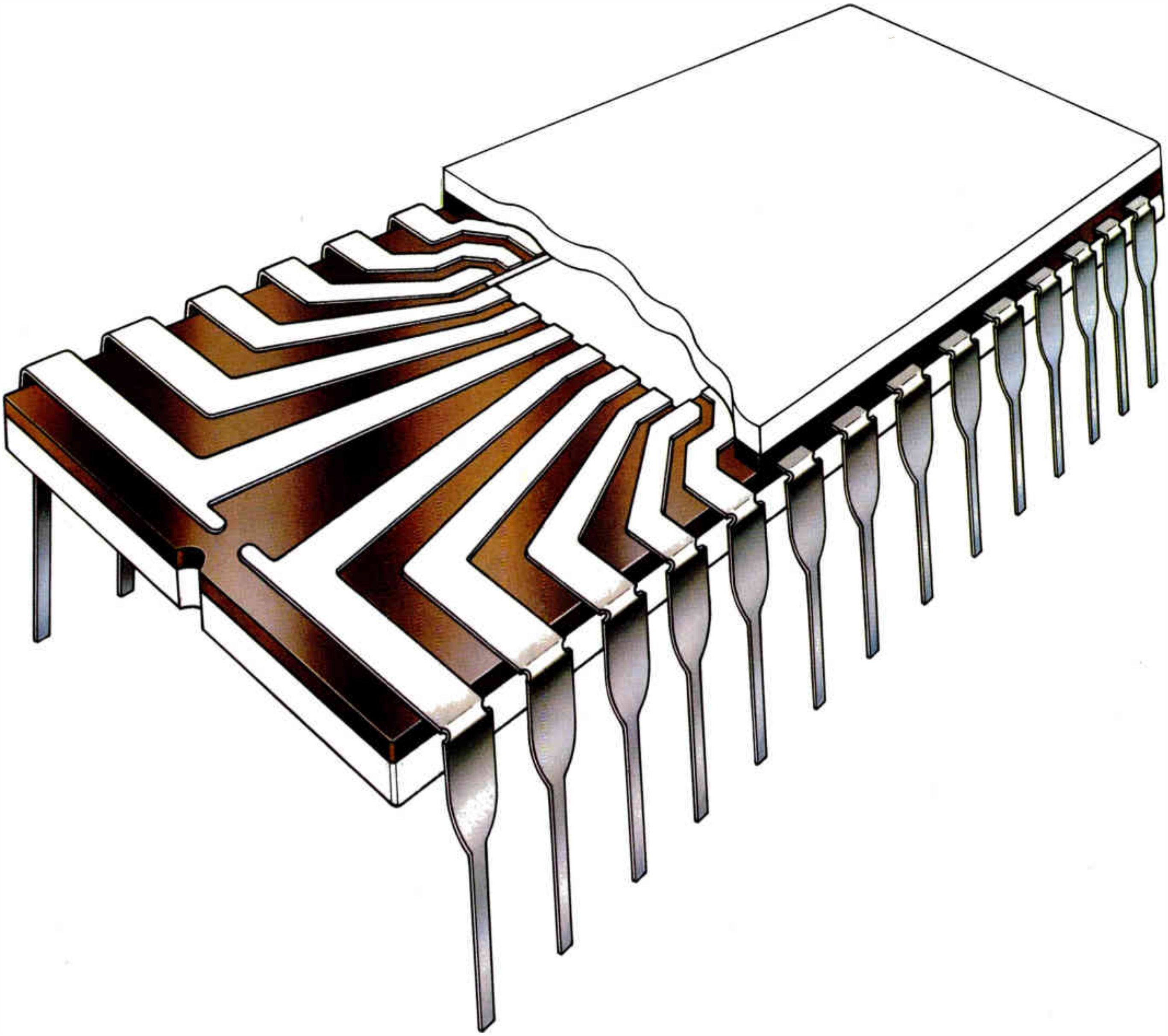
Among pc boards themselves, multilayer boards will be leading the way, zooming upward by 19% to $2.3 billion. The strong growth in multilayer boards, which are still in their infancy, is largely due to one major breakthrough, says Dale Reed, marketing manager of Roger Corp.'s Soladyne Division: the knotty technical problem of calculating the interaction between layers at microwave frequencies has finally been solved by superfast computers.

Profits are also expected to rise, a pleasant experience after five years in which only a few companies in very narrow applications were making much money, says Reed. The reason is that domestic pc-board makers have been battered by offshore competition, he adds. But the combination of a weak dollar slowing Japanese market incursions and an expected surge in office automation should provide the elixir. "I see terrific growth in printed-circuit boards generally," says Reed.

	(millions of dollars) 1986	1987	1988
Microwave components, total	**416**	**441**	**464**
Amplifiers	180	190	200
Detectors	27	29	32
Ferrite devices	100	105	108
Mixers	52	57	61
Passive components, total	57	60	63
Coaxial and strip-line	45	47	50
Waveguide	12	13	13
Passive filters and networks, total	**248**	**270**	**287**
RC networks	30	32	35
Rfi and emi filters	136	152	160
Other	82	86	92
Power supplies, noncaptive, total	**1,607**	**1,928**	**2,338**
Switching	640	850	1,020
Linear	367	358	348
Uninterruptible	600	720	970
Printed circuits and interconnection systems, total	**4,097**	**4,530**	**5,135**
Chip carriers	27	40	65
Interconnections, total	530	585	644
Backplanes	240	270	304
Socket and socket panels for DIPs	290	315	340
Printed circuits, total	3,540	3,905	4,426
Flexible circuits	300	340	360
Rigid boards, total	3,240	3,565	4,066
Double-sided	1,200	1,235	1,330
Multilayer	1,710	1,953	2,326
Single-sided	330	377	410

	(millions of dollars) 1986	1987	1988
Relays, total	**680**	**690**	**703**
Crystal-can	122	123	122
General purpose	230	228	229
Reed	61	66	69
Solid state	60	66	75
Telephone-type	44	43	42
Time delay	22	20	21
Other	141	144	145
Resistors, total	**731**	**753**	**769**
Fixed, total	262	271	281
Chip	27	36	52
Composition	39	38	37
Deposited carbon film	24	22	20
Metal film	88	92	93
Wirewound	84	83	79
Resistive networks, total	154	166	169
Thick film	142	152	155
Thin film	12	14	14
Thermistors	73	80	84
Variable, total	242	236	235
Potentiometers	131	125	125
Trimmers	111	111	110
Switches and keyboards, total	**1,132**	**1,172**	**1,215**
Dual-in-line	63	63	67
Keyboards, keypads and matrixes	440	462	494
Lighted	138	142	142
Push-button	143	148	152
Rotary	68	69	69
Slide	43	44	45
Snap-action	105	106	106
Thumbwheel	32	33	34
Toggle	100	105	106
Transducers (electronic), total	**1,157**	**1,300**	**1,391**
Flow	124	134	141
Fluid-level	121	135	147
Motion, linear and angular	143	154	169
Pressure (including air, liquid, mechanical)	555	640	683
Temperature (excluding thermocouples and thermistors) Vibration	214	237	251
Wire and cable, total	**2,199**	**2,346**	**2,595**
Coaxial cable	440	480	530
Fiber-optic cable	647	670	749
Flat-cable	101	110	118
Hook-up-wire	282	292	324
Multiconductor	729	794	874
COMPONENTS, TOTAL	**20,970**	**22,630**	**24,636**

All figures in current U.S. dollars



LS-2010 Composite Sealing Glass

Passes 270°C solder dipping test without preheating

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LS-2010 also provides higher hermeticity even after solder dipping at a temperature of 270°C, and does so without preheating.

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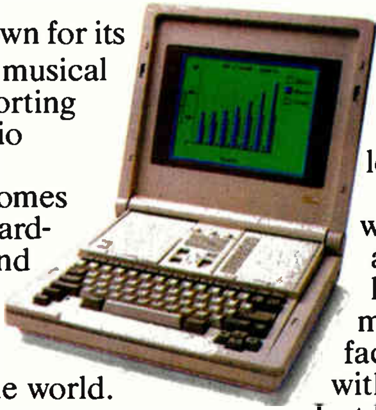

Yamaha CRT and flat panel display controllers are in many popular lap-top computers.

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If you've heard a CD player lately, you've probably heard our signal processing chip in action.

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Yamaha manufactures sound chips. Graphics chips. Communications chips. And signal processing chips.

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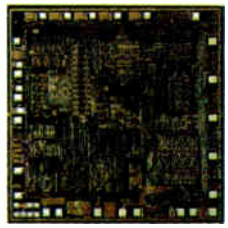

Yamaha engineers use the latest CAD/CAM techniques to customize the functions of a chip.

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In June 1987, Philips confirmed its position as one of the world's leading manufacturers and suppliers of integrated circuits by announcing a major breakthrough in submicron IC technology: the development of a functional 1-Mbit SRAM (Static Random Access Memory) chip measuring only 90 sq. mm. and containing over 6 million transistors.

In fact the low power consumption, fast access speed and high packing density of |this minuscule silicon chip make it the most advanced submicron device of its type in the world.

Submicron technology is fundamental to a new generation of superchips that will outperform all present semiconductors, and make it possible to pack the power of, say, a desk-top computer into a few integrated circuits.

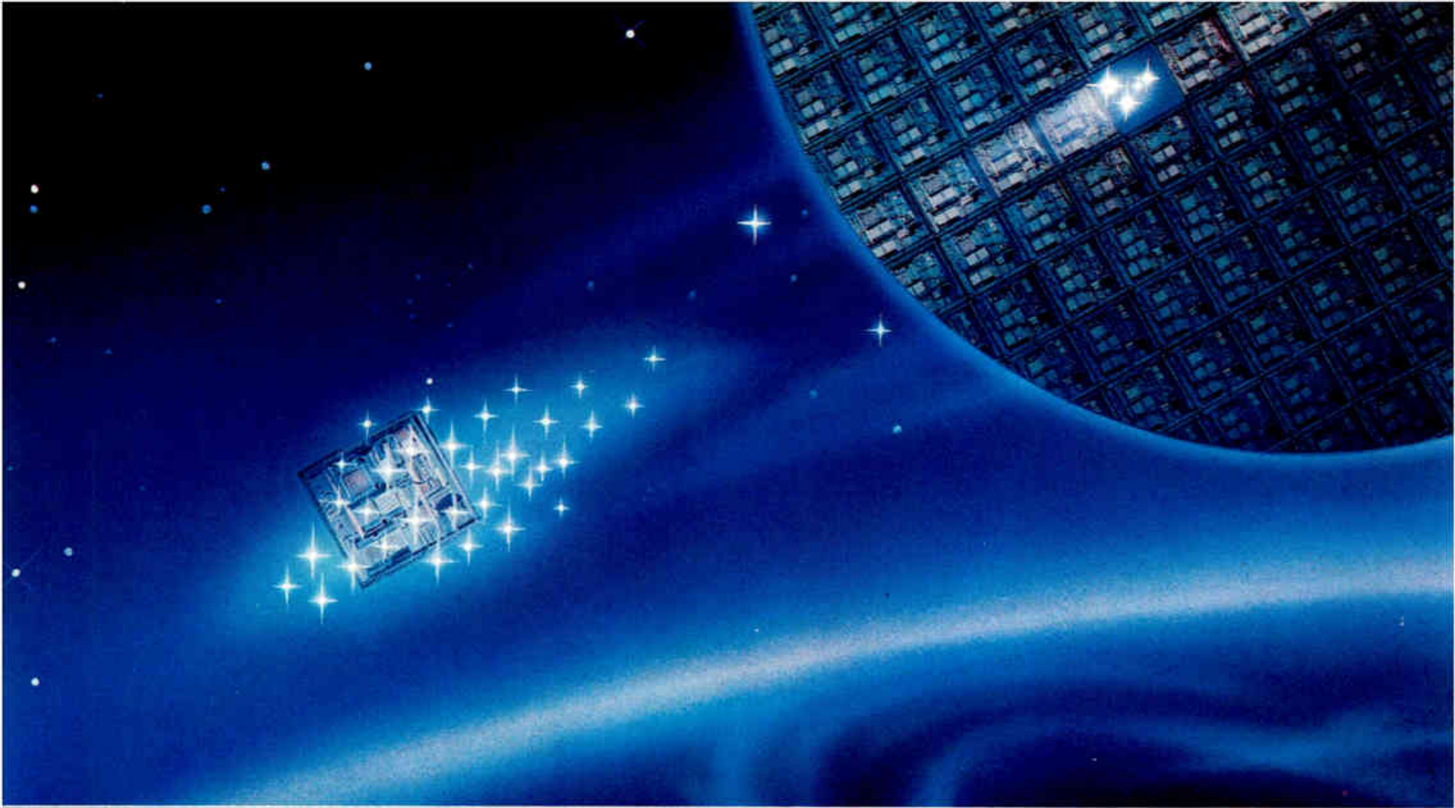
These 'little bits of silicon' are destined to play a profound role in modern society. Extremely inexpensive and highly intelligent, they can provide electronic-based machinery and equipment with unprecedented ability and flexibility.

In turn, this will result in a vast range of new and innovative low-cost products designed to improve the standards by which we live and work.

Ultimately, therefore, the major beneficiary will be the end-user... and that means all of us.

Which says quite a lot about such a little bit.

Philips has a lot to



say about a little bit.

Little bits of silicon are also used in the Philips Smart Card-although the processing power required is, of course, much less than that of the superchip.

The Smart Card contains a microchip within its plastic cover to provide both security and intelligence. In fact, the Smart Card is a tiny personal computer which can be programmed for a variety of cardholder services.

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In France, where Philips helped to pioneer the Smart Card, the national banking association has adopted it for electronic financial transactions.

The 1-Mbit chip and the Smart Card are only two examples of Philips' extensive R&D programme on which the company spends over U.S.$2 billion each year, translating high technology into tangible user benefits.

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Circle 105 on reader service card

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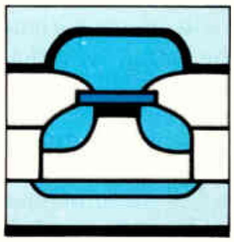


ALLIANCE'S 1-MBIT DRAM RUNS FAST AS A STATIC RAM

A 60-ns access time achieved at the circuit level without exotic processing gives this 1.25-micron CMOS DRAM the potential for high-performance 15- to 40-MHz 32-bit CPUs and eliminates wait states that require SRAM-based cache memory

by Bernard C. Cole

Designers looking for a superfast 1-Mbit dynamic random-access memory should make a beeline for Alliance Semiconductor Corp., where they can tap a new DRAM with only 60-ns access time and 100-ns cycle time. That speed means no wait states are required when the DRAM is used as main memory in high-performance 15- to 40-MHz 32-bit designs.

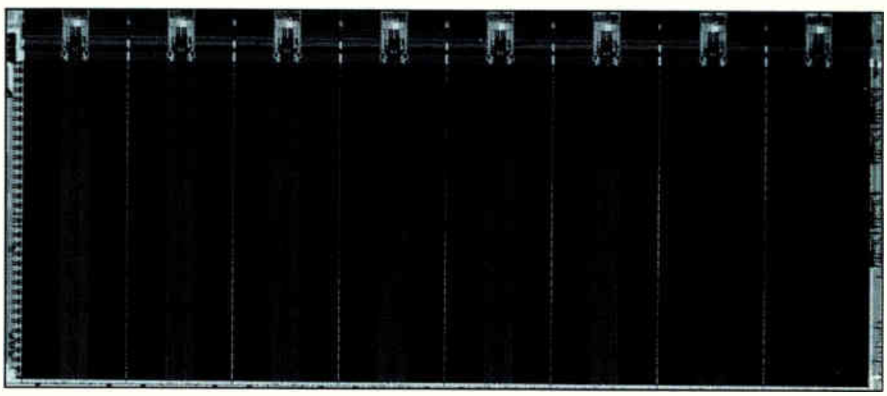
The San Jose, Calif., company, started by two brothers who now serve as president and vice president, has uncorked a device that may not bode well for companies supplying fast static RAMs and cache-tag RAMs. Alliance's AS4C1002 eliminates the need for system designers to use higher-speed SRAM-based cache memory to offset the normally slower access times of a DRAM-based main memory, says C. N. Reddy, vice president of engineering.

The AS4C1002 is fabricated with a relatively conservative 1.25-μm double-polysilicon single-metal n-well CMOS process (see fig. 1). But Alliance's 1.25-μm CMOS DRAM is still twice as fast as competitive 1-Mbit DRAMs fabricated using similar geometries and at least 25% faster than devices fabricated with submicron geometries, says N. D. Reddy, Alliance's president.

Alliance obtained faster speed through circuit design improvements rather than by pursuing exotic process alternatives such as double metal, triple polysilicon and trench isolation, and trenched capacitors. Reducing power-supply noise played a big role in increasing the device's speed and operating margins. A half V_{cc} precharge scheme with sequential restoring circuits, a NAND type decoder-driver configuration, and distributed power supply all contributed toward the noise reduction.

To attack problems involving line capacitances, Alliance used a modified array architecture and optimized performance in critical speed paths. A differential-latch-sensing scheme supplies greater amplifier sensitivity and also contributes to the device's higher speed. The result, Alliance says, is a highly manufacturable circuit that at 81,000 square mils is only 5% to 10% larger than comparable DRAMs using tighter geometries. The AS4C1002 is still small enough to fit in a cost-effective 18-pin, 300-mil wide plastic dual-in-line package. The AS4C1002 is now available in sample quantities at $70 each in 100-unit quantities, N. D. Reddy says. The company also has developed a 256-K by 4-bit version. Samples will be available late in the first quarter.

Although advanced DRAMs have doubled in density every three years in response to demand, C. N. Reddy says that until now, access and cycle times have not shown comparable improvement. Indeed, speed is often sacrificed to achieve higher density. However, with the advent of advanced 32-bit central processing units with 15- to 40-MHz clock speeds, the pressure has been on



1. FAST DRAM. A 1-Mbit-by-1-CMOS DRAM from Alliance uses a variety of circuit techniques to squeeze out 60-ns access time while employing a relatively conservative 1.25-μm process.

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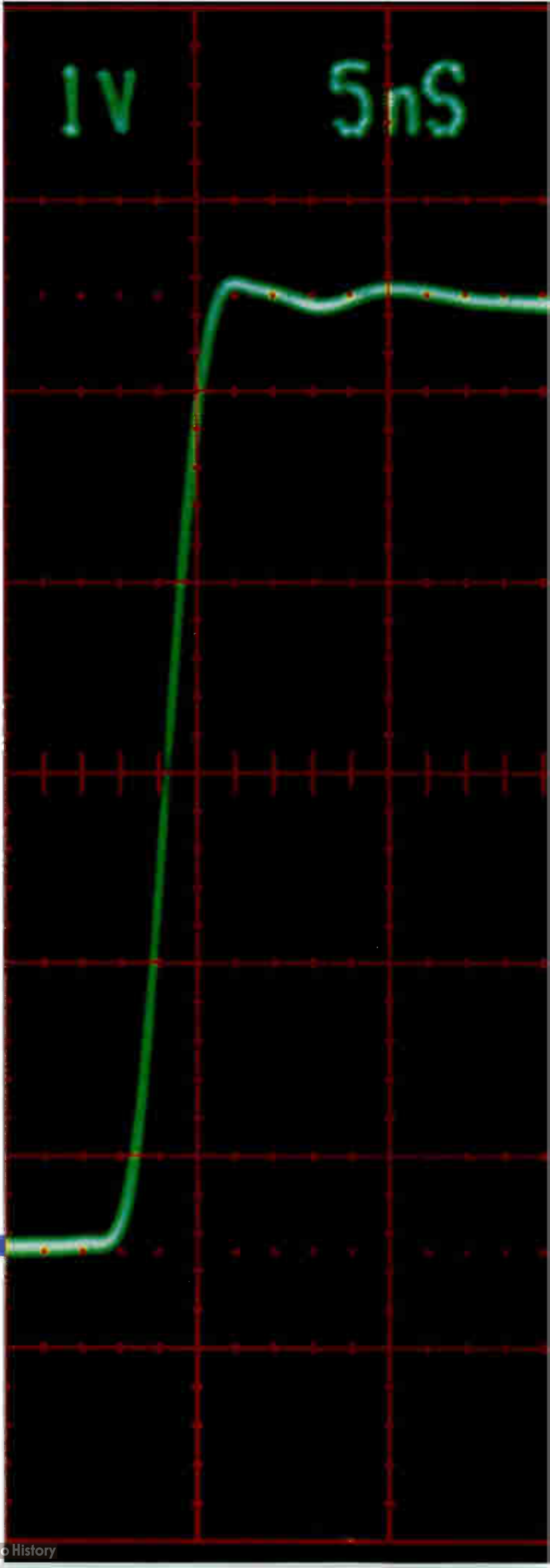

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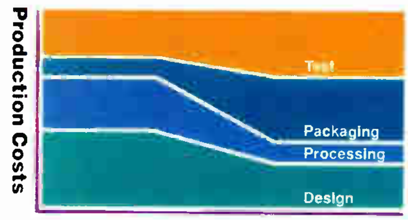
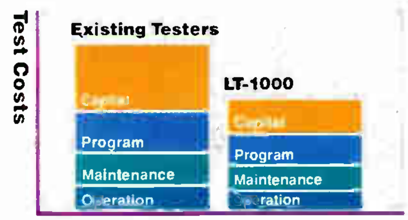


While the cost of designing and producing ICs has steadily dropped, the cost of testing them has increased—to as much as 30% of total manufacturing costs.



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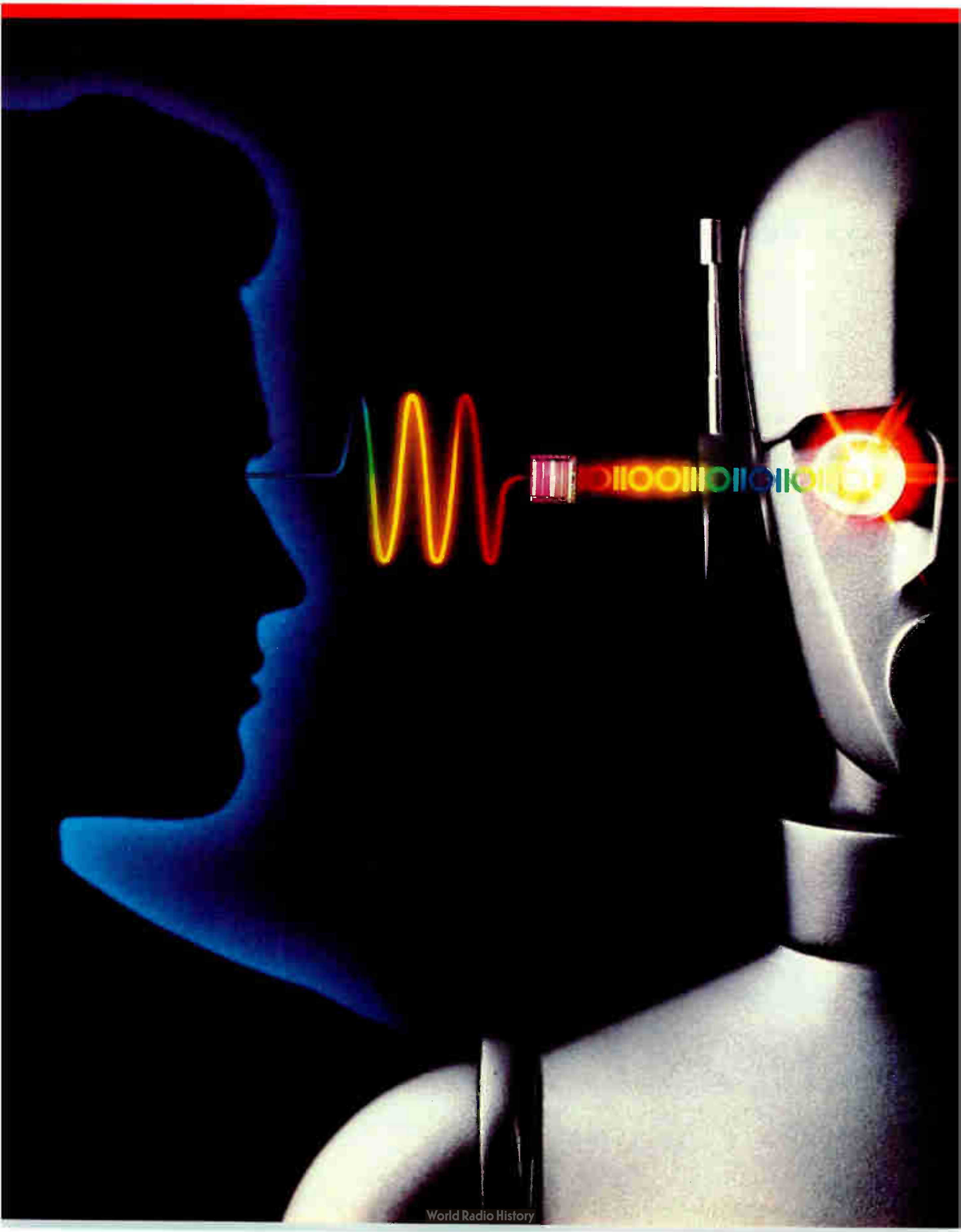

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CA3318E/3318CE	8	15M	150	24	38.50/24.00
CA3310E/3310AE	10	150K	15	24	6.00/8.00
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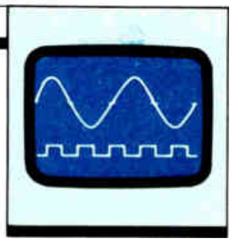
TESTER WRINGS OUT BOARDS BY FAKING FINAL SYSTEM



Computer Automation's SET environment emulates the system for which a board is designed, allowing it to functionally test complex boards crowded with ASICs and VLSI chips

by Jonah McLeod

The burgeoning complexity of printed-circuit boards is driving test engineers up against a seemingly unscalable testing wall. Already, some boards bristling with application-specific integrated circuits and VLSI chips defy practical simulation—modeling and writing test programs for these boards would literally take man-years. Even then, simulation alone probably would be insufficient for thorough testing, and would require gigabytes of data storage. Going to full-system testing might work—if the lack of fault detection and the high cost of system testing doesn't make it impractical.

Computer Automation Inc. has scaled the barrier and is dropping a rope to beleaguered engineers. The Irvine, Calif., company's series of Ironman testers will include a capability called System Emulation Testing that addresses the problem of functionally testing extra-complex printed-circuit boards which are accessible only from their edge connectors. The SET environment replicates the board's intended operating system. That is, a board plugged into a SET tester thinks it's home—it sees no difference between the tester and its final system when it comes to interfacing and data exchange.

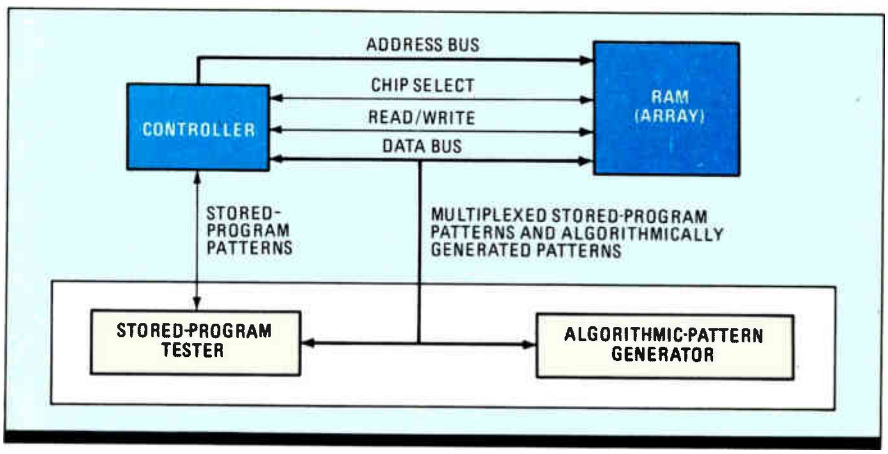
Unlike system testing, SET, which comes in the form of pin electronics, provides fault diagnostics. And it is relatively inexpensive. A system with SET runs between $300,000 and $600,000, and those users who already own an Ironman can add the pin cards at $19,777 each.

Some boards have reached the point at which tens of millions of test patterns, some of which must change on the fly, are necessary to determine proper operation. To create those test patterns—that is, to emulate a system—SET places 2901 bit-slice microprocessors and random-access memory behind its pins. The combination algorithmically generates as many patterns as needed, right at the tester pins. Then, the microprocessors interpret responses to the stimulii and alter the patterns as necessary, on the fly. In addition, other patterns are stored. These are available to establish a base for the algorithmic patterns, and for setup and control purposes (see fig. 1).

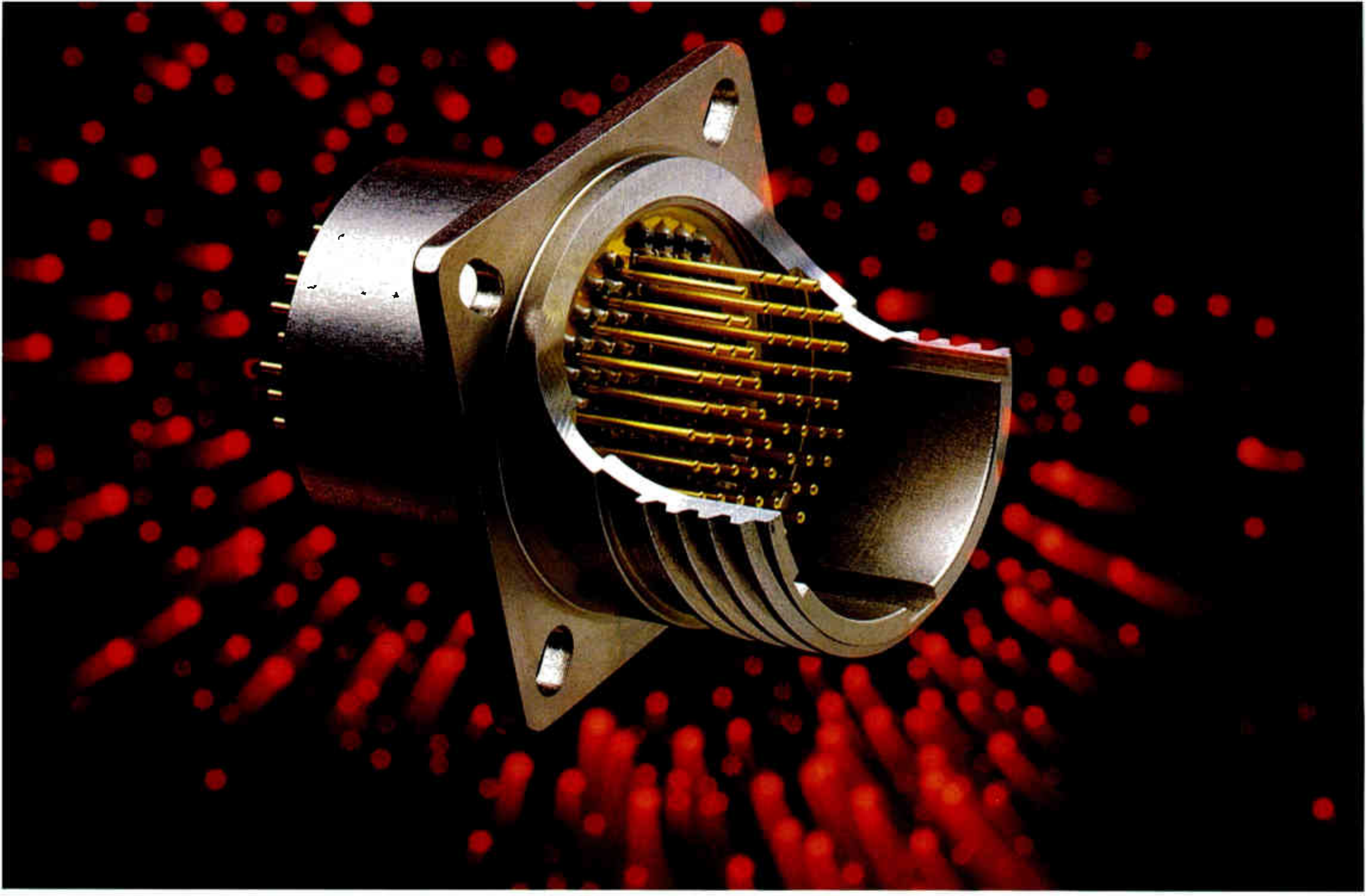
Contemporary boards demand a large number of test patterns applied in parallel to a large number of pins. With SET, a test programmer can configure the memory behind each pin to hold those patterns. Alternatively, the tester provides a feature called automatic-stimulus-based-on-response, which allows the system to capture the response of a board known to be good and use that response to test other boards.

The system has extensive capabilities for testing level-sensitive-scan designs. These are circuits, built into a board to facilitate testing, that require long serial bit streams. For that purpose, the 2901s can generate streams of any length and can apply the data at 30 MHz—faster than any other commercial tester.

Besides a 4-bit-slice 2901 microprocessor, each SET pin-electronics card contains a 4-by-16-Kbit RAM memory to hold stimulus and response data, and a 24-bit, 16-Kbit-deep RAM to contain the 2901's microcoded program. "The 2901 is the automatic pattern generator and can be pro-



1. MAKE-BELIEVE. By combining stored and algorithmically generated patterns, SET fools a printed-circuit card into thinking it is plugged into its intended operating system.



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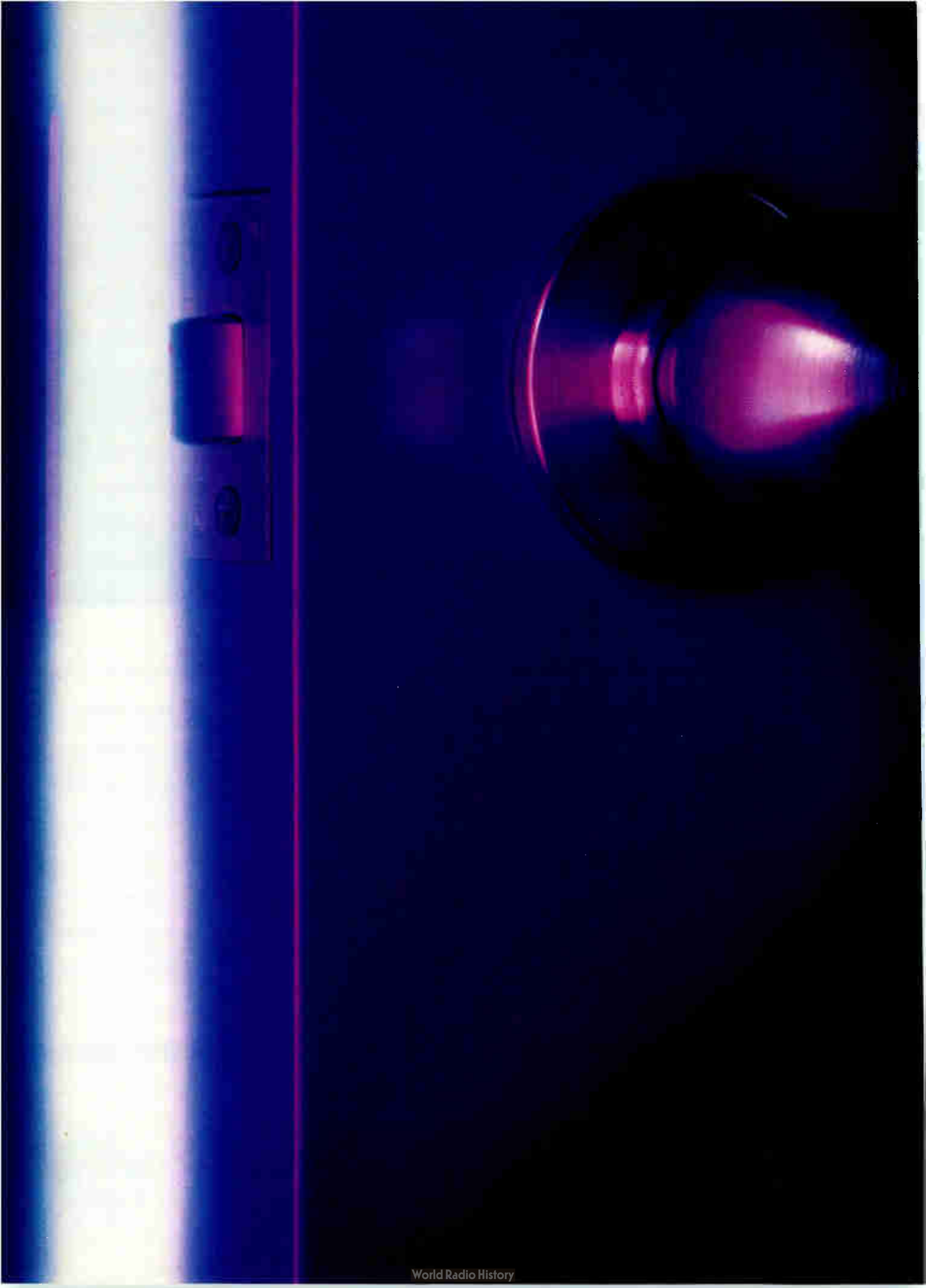

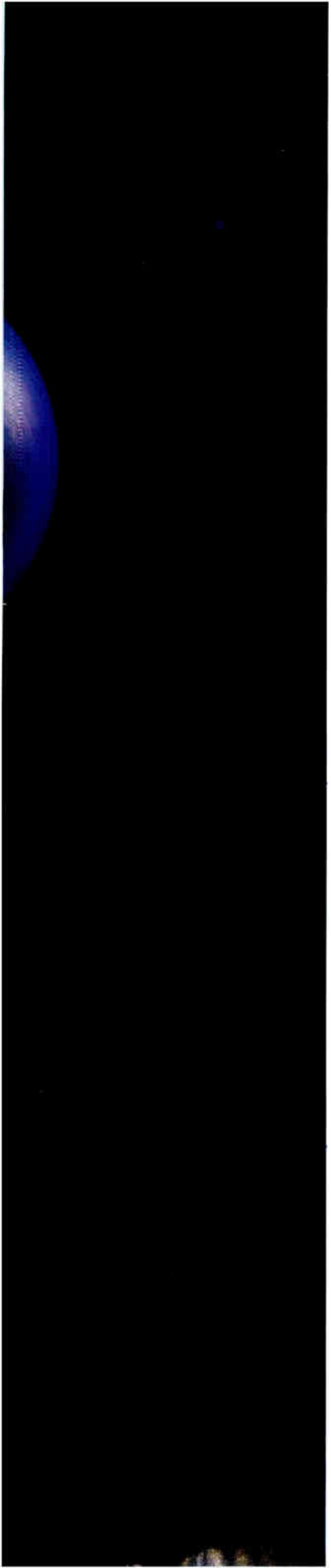

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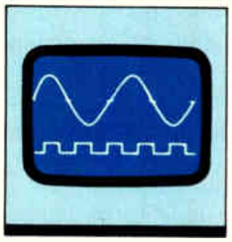
HOW TO TEST MIXED-LOGIC BOARDS FOR ONLY HALF THE PRICE



Zehntel uses a tester-per-pin architecture that provides programmable driver voltages and slew rates—key capabilities for testing a board holding different kinds of logic devices

by Jonah McLeod

Testing the latest generation of printed-circuit boards, with their mixtures of various kinds of logic devices, can now be done for about half the cost of a multiplexed combinational tester that can handle mixed logic. And it can be done on a system that boasts more speed and greater accuracy than its predecessor.

A new in-circuit and functional tester from Zehntel Inc., the Model 8000 (see fig. 1), weighs in at prices ranging from $200,000 to $600,000, says Craig Pynn, vice president of marketing at the Walnut Creek, Calif., company. An average configuration of 1,024 analog and digital test pins (maximum is 2,048) runs about $400,000. Competing systems usually start at $1 million or more. The new system, which ships in April, is also five times faster and an order of magnitude more accurate than the low-end 800, the company's previous-generation in-circuit tester, while costing about twice as much.

Like the 800, the 8000 uses a tester-per-pin architecture, Pynn says, which contributes enormously to its capabilities. At the same time, the 8000 was designed in a way that cut the system's price to half that of testers which use a multiplexed or shared-resource architecture—no small feat, since one reason for multiplexing tester resources is to reduce cost.

Zehntel cut costs by reducing board real estate. "Previously, we could get only 16 nodes on a single board," says Pynn. "We doubled the number without significantly increasing the board size by using multilayer boards." The company also developed custom integrated circuits for the 8000's driver-receiver electronics. Among them is an analog-driver IC, which allows the tester to provide programmable capabilities—driver voltages and slew rates—that are crucial to its handling of different logic families on the same board.

The tester-per-pin architecture also overcomes a big drawback of multiplexed architectures—they are generally clumsy to use. Each pin can be independently addressed and programmed to reduce the time needed to change a test program. Adding a node in the system requires very little rewiring—the test engineer simply connects the new node to an unused pin in the tester and adds the appropriate test vectors. The tester-per-pin architecture also eliminates all the relays that perform the multiplexing of pin electronics to different pins in a multiplexed architecture.

The Zehntel tester-per-pin architecture also stands out in providing the two capabilities for testing different logic devices on the same board: accurate programmable driver voltages and programmable slew rates. Both are essential for a tester that has to handle, for example, emitter-coupled logic on one pin and CMOS on another. Until now, no combinational tester could provide accurate drive-voltage levels to the pins—they provided general-logic-level 1s or 0s. Moreover, none could program the slew rate—the rise time—of the drive signal. But different logic families need different slew rates.

To help to provide those capabilities, Zehntel

1. HIGH VALUE. Zehntel's combination in-circuit and functional tester averages around $400,000, but handles mixed-logic pc boards that usually require a $1 million system.

developed some custom ICs including the linear chip for the analog driver. Comprising both pnp and npn transistors (see fig. 2), the IC uses a feedback circuit to detect changes in drive voltage. This capability is critical in testing different logic device families on the same board, because different logic devices require different levels of voltage. A custom driver is needed because most

A custom IC uses a feedback circuit to detect changes in drive voltage—a big help in testing mixed logic, which requires different voltage levels

off-the-shelf amplifiers are designed to drive a well-defined load. In-circuit and other combinational testers probe with a bed-of-nails test fixture at nodes on a board. Some pins provide a back-drive voltage to isolate a component or section of board under test, while others provide stimulus. The tester can't accurately determine the voltage of the stimulus or back-drive pulse because the impedance of nodes on the board can vary greatly and there is no way to know in advance the impedance of the node to be tested.

Older in-circuit testers optimized their drivers for some nominal impedance and the output driver stage produced either a logic 1 or 0, but the driver was difficult to control and the tester tolerated some amount of error. That was acceptable when boards contained TTL and MOS logic devices, but today's boards are designed with many different logic families combined, especially higher-power ECL components.

"Now, with devices such as Motorola FAST ECL parts on boards, it is possible to drive a pin of the device up to 5 V, " says Terence Lee, engineering project manager at Zehntel. "At that voltage, depending on the node's impedance, the pin can draw nearly an amp of current—too much for either the device or the tester."

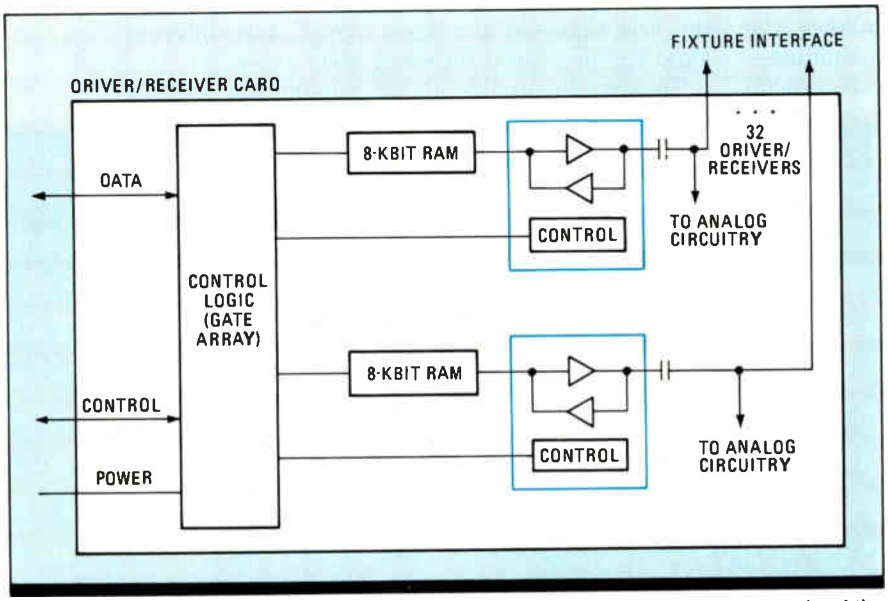
What makes the Zehntel driver stand out is that it can drive any kind of logic family to specified voltage levels with very little error. By controlling the pin drive accurately to only 3.5 V, the maximum current flow possible is around 300 to 400 mA, a much safer level for both the boards under test and the system. "When the test program on the 8000 tester specifies a 3.5-V signal at a pin, feedback from the pin tells the driver circuit how much voltage is actually being dropped," says Lee. This same feedback loop is used for a current-limiting feature that detects overcurrent conditions on the node and shuts the drive electronics off.

Another important requirement in testing boards that contain different logic families is programmable slew rates, points out Cathy Medich, product manager for the 8000. Slew rates on the system can be programmed between 0.5 V/ns and 4.0 V/ns. Other testers offer only a single fixed slew rate, typically 3 V/ns. Slew rate specifies, typically in volts per microsecond, how steeply the leading edges of the drive-pin-pulses rise.

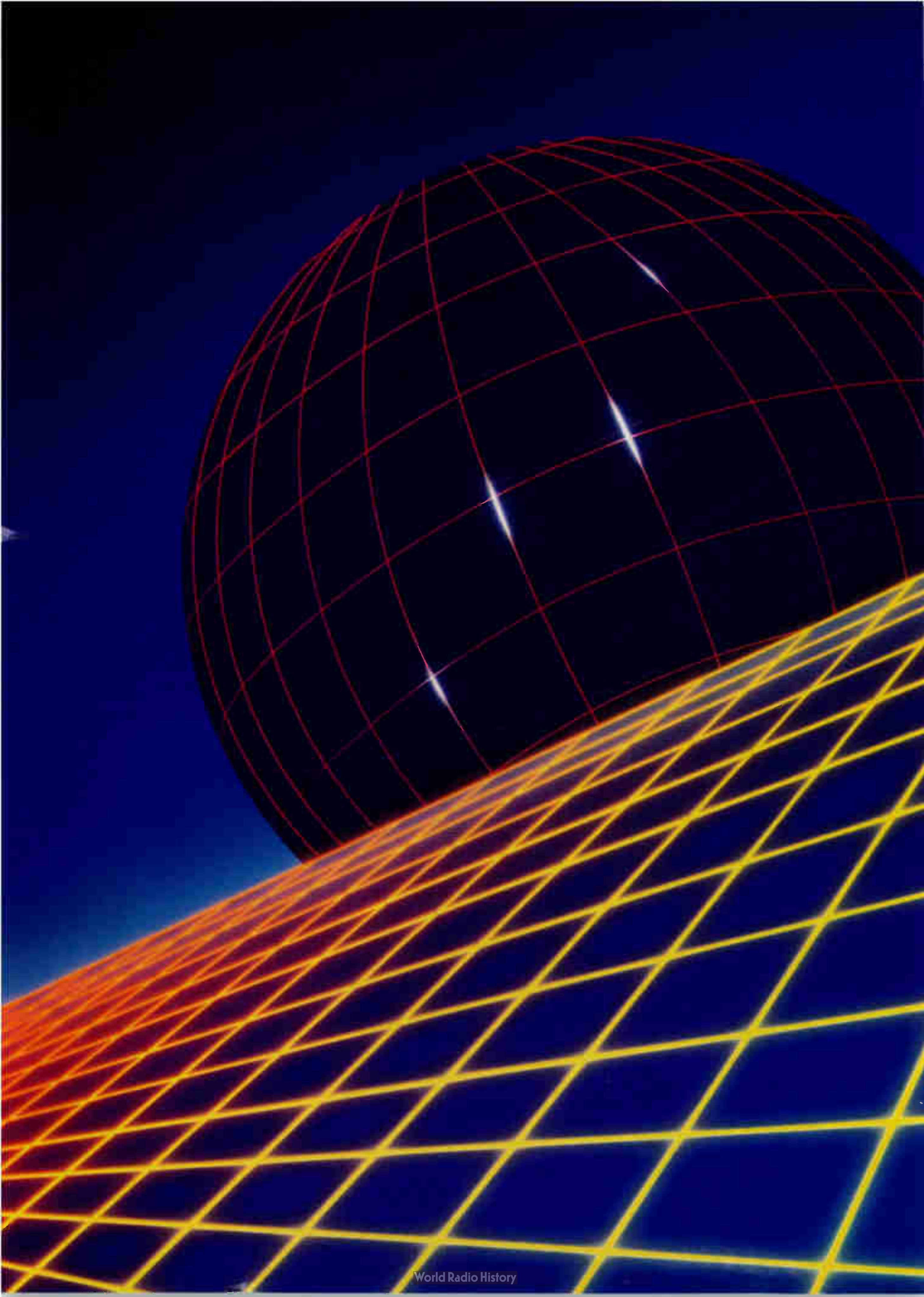
Testers with a fixed slew rate have a difficult time testing CMOS logic. A 3-V/ns slew rate produces a drive pulse with a rather steep leading edge, which when applied to CMOS logic with its characteristically low load impedance will result in an overshoot. For these logic families, a programmable slew allows the test engineer to reduce overshoot in the circuit under test. Also, with a programmable rise time, the tester can eliminate the effects of delay or slew distortion caused by the test fixture or transmission lines in the system.

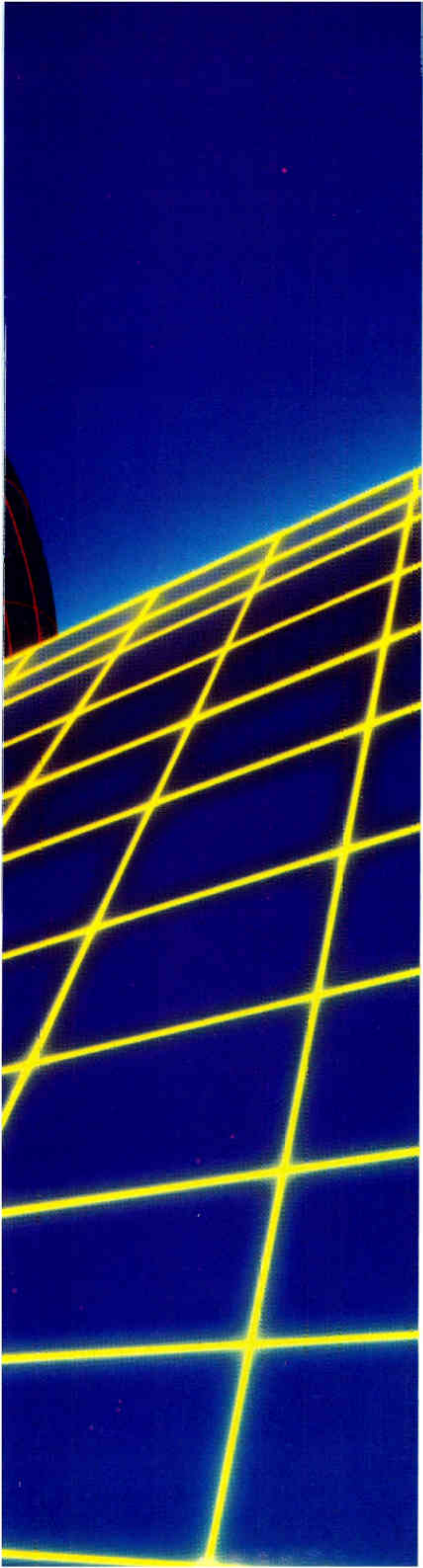
One other capability built into the 8000 is programmable thresholds on the receiver pin electronics. Dual-threshold capability is not new on board testers. Until now, though, on most systems the driver/receiver electronics that could measure the dual threshold were multiplexed among a larger number of pins. The 8000 is the first tester to provide dual-threshold measurement capability per pin. The capability becomes important in testing different logic. "For the ECL family, for example, a valid logic level 1 is any pulse over 3.5 V and a logic 0 is any voltage below 0.8 V," Lee explains. "CMOS voltage levels for a logic 1 and 0 are some other values. With dual-programmable thresholds, the tester can specify the logic high voltage and logic low voltage for each pin on the tester and thus can more accurately gauge if the circuit on the board is within specification." □

For more information, circle 482 on the reader service card.



2. VOLTAGE CONTROL. A feedback loop built into a custom linear IC in every test pin of the Model 8000 accurately maintains a voltage level to each node on a board under test.





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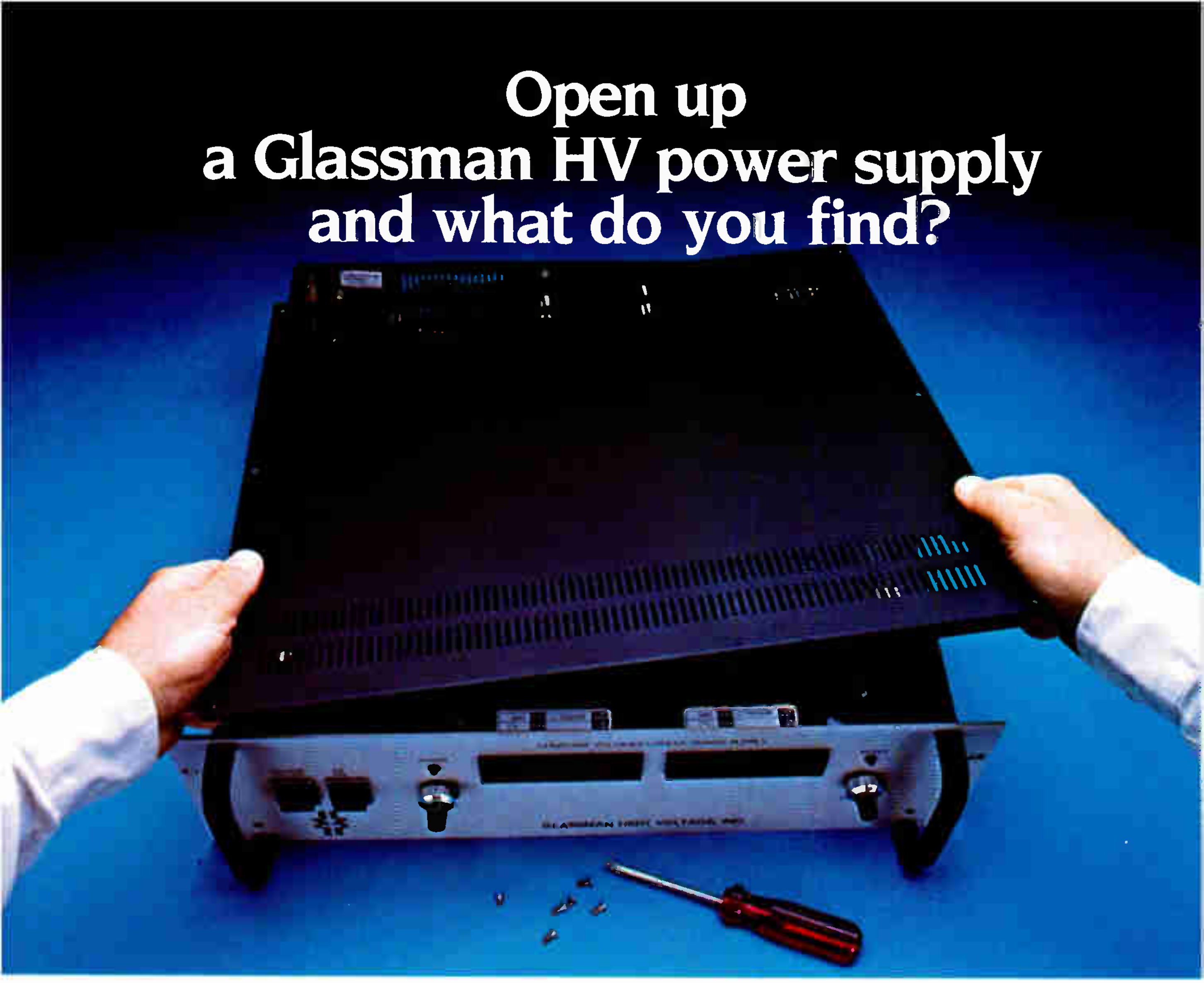

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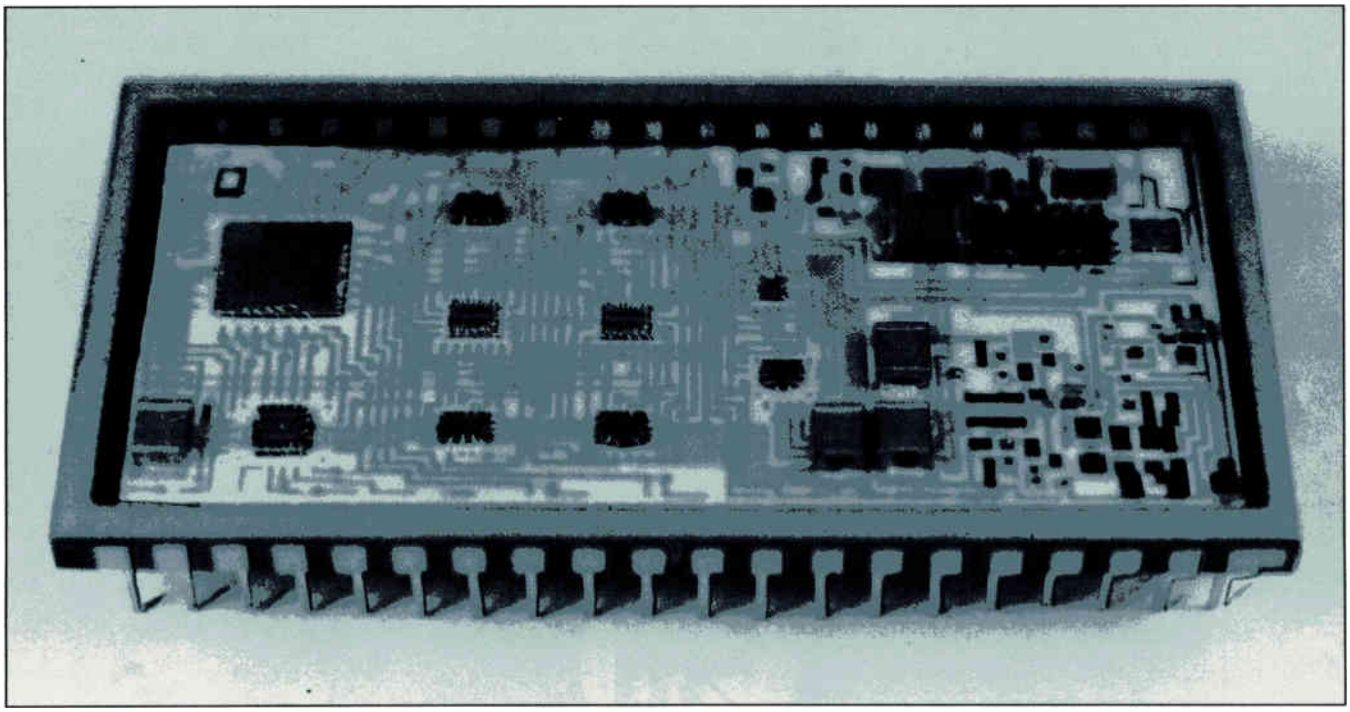
There's finally an alternative to boards and modules for high-end analog-to-digital conversion. Technology advances are yielding monolithic and hybrid ADCs with resolutions of 14 bits and above, in a variety of products.

SWITCHING SUPPLIES MOVE UP TO MEGAHERTZ

Power supplies must optimize efficiency, as their size shrinks and switching frequencies climb to 1 MHz. So designers are turning to new topologies—principally resonant-mode circuits that implement zero-voltage switching.

TRANSIMPEDANCE AMPS: SPEEDY AND PRECISE

A superb buffer device, the transimpedance amplifier provides solid dc characteristics along with outstanding ac performance. The unit's bandwidth does not degrade with increasing closed-loop gain, and distortion is extremely low.



BOARD NO MORE. High-resolution analog-to-digital converters are no longer virtually all modules or boards. Monolithic and hybrid units, like this 22-bit integrating part from Thaler, are expanding the market sector for ADCs with resolutions of 14 bits and above.

HIGH-RESOLUTION ADCs ARE CHANGING THE MARKET

Dramatic advances in both monolithic and hybrid technology are driving the worldwide market for analog-to-digital converters with resolutions of 14 bits and above; as designers adopt these new high-end parts, their market share will grow

by Lucinda Mattera

The most dramatic advances in data conversion unquestionably are in high-resolution monolithic and hybrid analog-to-digital converters. For the first time, designers have ready access to monolithic and hybrid ADCs with resolutions of 14 bits and above—and many of the new converters are fast, to boot. For these reasons and more, a special report (p. 133) in this inaugural Technology Series covers high-resolution monolithic and hybrid ADCs.

It's not surprising that technological advances in high-resolution ADCs are changing the shape of the marketplace. Of all ADC units consumed worldwide, parts having a resolution of 14 bits or higher now have a worldwide market share of about 23%, says Selantek Inc. By 1990, their share of the total ADC market will be 27%, predicts the Mountain View, Calif., market research house.

It looks like these new hybrid and monolithic parts will be dethroning the present king of high-resolution ADCs, the 12-bit converter, says Selantek. Of the worldwide consumption of 12-bit and above converters, the share of 14-bit or better ADCs will jump from 44% to 53% between 1987 and 1990. (In the total worldwide ADC market, 12-bit and above parts take a consistent 52% share).

In addition, more new designs than ever before are using ADCs, especially as front ends for digital-signal-processing systems. That's good news, since the worldwide market for all stand-alone data converters is, at present, relatively stable. Interestingly enough, in spite of new ADC applications such as DSP, the world continues to consume more digital-to-analog converters. DACs account for about 52% of all data converters, says Selantek. Of course, ADCs are usually more expensive than DACs, so 52% of dollars will continue to be spent on ADCs. By 1990, says Selantek, ADCs will have worldwide revenues of around $898 million, compared with about $816 million for DACs.

Fast-moving technological change also is erupting in other areas of the analog and power world. Power-supply technology is harnessing resonant circuits to shrink supply size without degrading efficiency, as switching frequencies climb to the megahertz region, and a technical article in this Technology Series takes a close look at this development (p. 145). And for another aspect of analog technology, a second technical article (p. 151), looks at the transimpedance amplifier, which combines superb ac performance with exceptional dc accuracy in the same device. It's rare to find both those attributes in the same amplifier.

WHY THE TECHNOLOGY SERIES IS BEING LAUNCHED

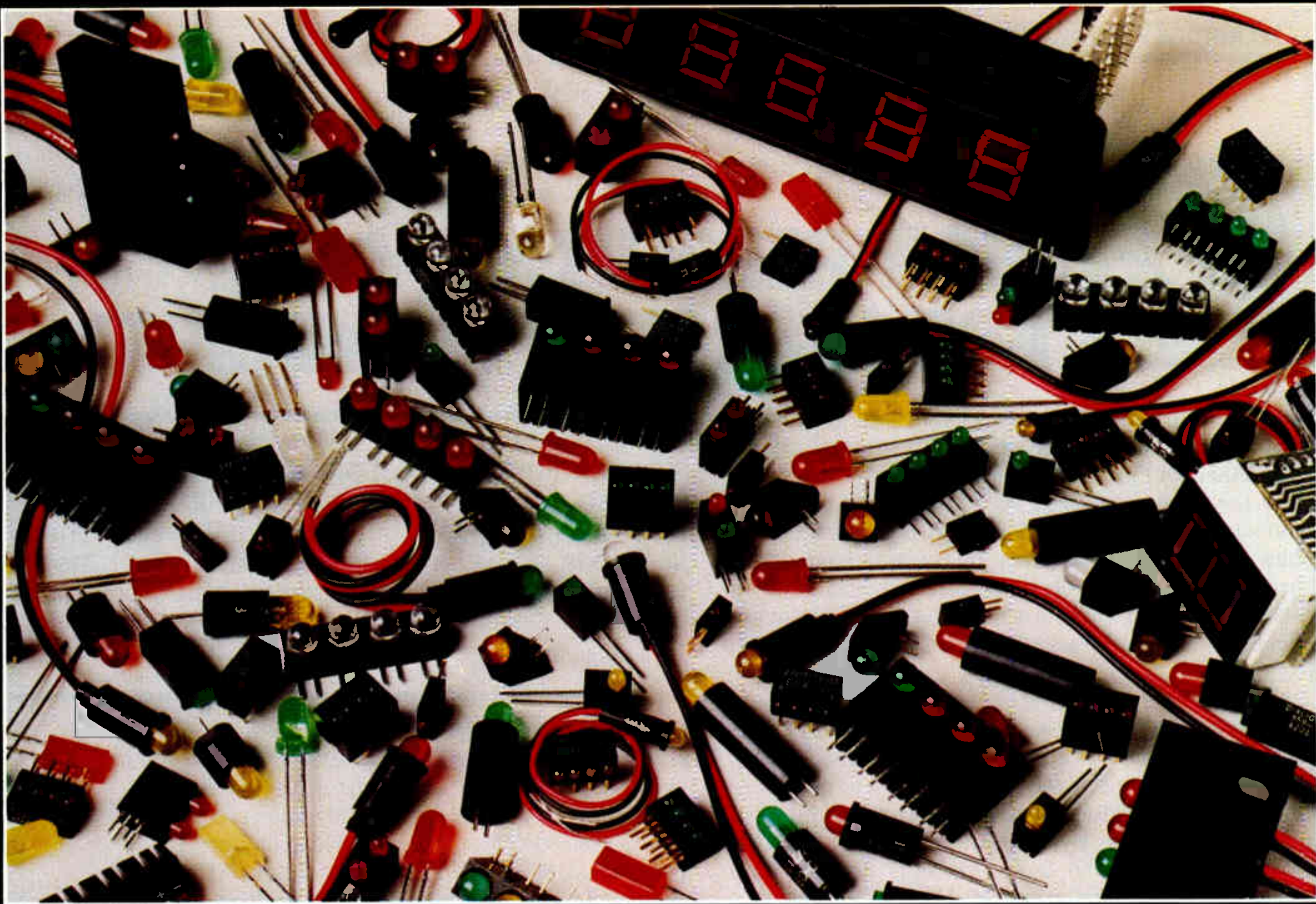
With this issue, *Electronics* introduces a new Technology Series that will appear monthly throughout 1988. The series will offer engineering managers and senior engineers the in-depth information and analysis needed to make critical project-design decisions involving three of the industry's most important technologies.

Chances are, no matter what the project, at least one of these fundamental umbrella technologies will come into play. The three are: analog and power technology, components and interconnections, and test and measurement. The Technology Series will deal with each technology once a quarter: this issue's topic is analog and power; next month, it will be components and interconnections; and in March, it will be test and measurement.

Every month, the series will offer a staff-written special report focusing on one area within that month's umbrella topic. This report will survey the most important technologies and products just coming to the fore in that area.

Similarly, in-depth contributed technical articles written by experts from the electronics industry will examine important developments. They will assess the pros and cons of controversial technical issues or explain a complex or confusing subject.

Most often, the technical articles and the special reports each will cover a different area within that month's umbrella technology. This will give readers a broad range of vital information each month.



SPECIAL REPORT: HIGH-RESOLUTION ARRIVES FOR ADC CHIPS AND HYBRIDS

Monolithic and hybrid ADCs combine innovative architectures with the latest in advanced semiconductor technology to hit 14 bits or more—resolution that a board or module usually provides

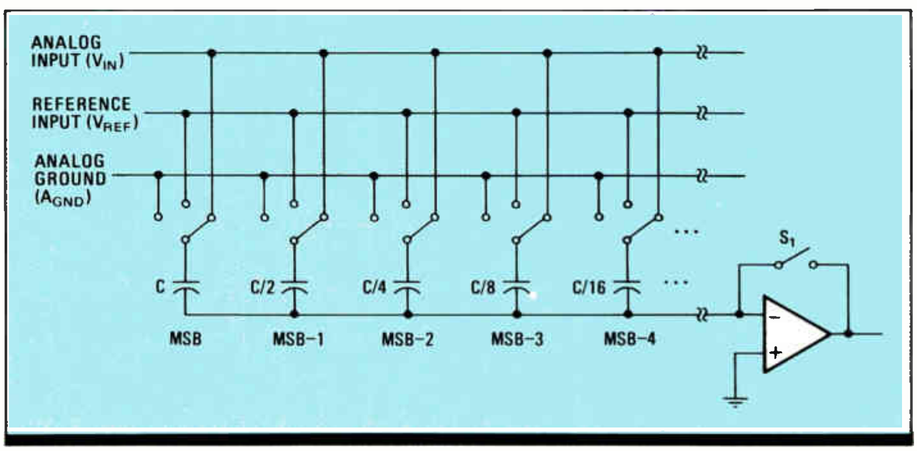
by Mike Riezenman

There's a shakeup going on in the world of high-resolution ADCs as new monolithic and hybrid analog-to-digital converters move in on the traditional boards and modules. By combining innovative converter architectures and advances in semiconductor technology, monolithic devices are now delivering 16-bit performance, while hybrids are reaching 22 bits. Until recently, an analog-to-digital converter having a resolution of 14 bits or above would usually have been either a board or a module.

To boost resolution in monolithic chips while keeping costs within bounds, converter makers are turning to self-calibration. In hybrids, they are combining the latest monolithic devices with the finest in precision chip components to boost performance to unprecedented levels. And for both types, they are incorporating the sampling amplifier required by virtually every ADC right on the same chip or in the same package.

But neither self-calibration nor integrated sampling circuitry will make a converter run faster. A parallel (flash) architecture would do the job. But it's not generally suitable for high-resolution devices because it would require too much circuitry: the complexity of a flash converter grows exponentially with its resolution. That's why many converter manufacturers are turning to the half-flash converter, also called the subranging, or two-pass, converter. It breaks a high-resolution conversion, of say 14 bits, into two parts, of say 8 and 6 bits, and then does each part very quickly with a conventional flash unit. The result is conversion speeds on the order of 1 μs.

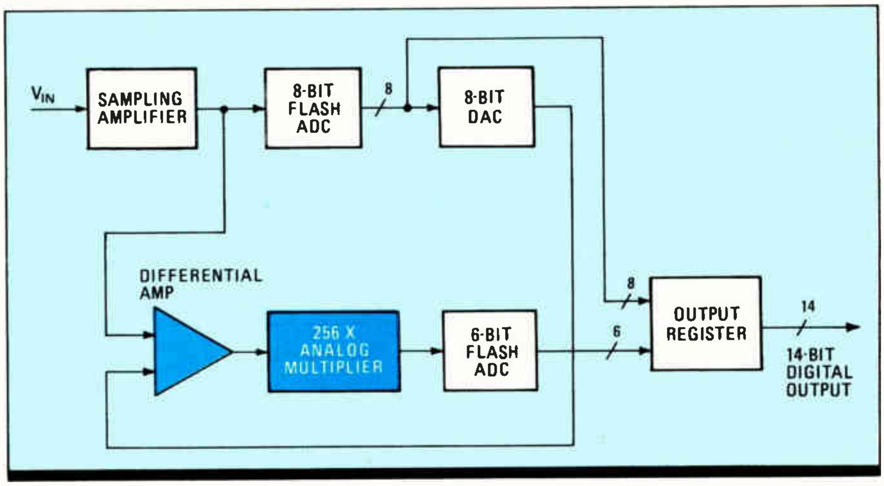
The changes shaking the leading edges of the ADC world also are rocking its base—the traditional integrating converter. A new type of integrating converter, the oversampling, or delta-sigma, part is beginning to appear in the marketplace. It reduces the conversion time of high-resolution integrators from hundreds of milliseconds to well under 100 μs. And it costs much less, to boot. This sophisticated descendant of the well-known voltage-to-frequency (v-f) converter employs clock rates that are hundreds of times higher than the bandwidths of the signals it converts. At present, therefore, it is limited to fairly low-frequency applications—digitizing voice, for example. Whether delta-sigma converters will speed up in the future depends



1. SELF-CALIBRATOR. Digital control circuitry on Crystal's converter switches subcapacitors in or out to ensure that each bit capacitor balances the sum of all LSB capacitors plus one additional LSB.

effects of time and temperature on whatever reference is used with it.

The Crystal converters are switched-capacitor successive-approximation devices that substitute an array of capacitors for the resistor network that lies at the heart of every successive-approximation ADC (see fig. 1). The capacitors, which share a common node at the input to the comparator, can be switched among V_{in}, V_{ref}, and A_{gnd}. When switch S_1 is closed and the capacitors are all connected to V_{in}, the converter tracks the input signal. At the beginning of a conversion, S_1 opens, creating a floating node with a fixed charge at the comparator input. Since the charge is not affected by subsequent changes in V_{in}, the entire capacitor array serves the same function as the hold capacitor in a sampling amplifier.



2. SPEED AND PRECISION. The half-flash device executes conversions in two steps. In this case, the first conversion covers 8 bits; the second, 6 bits.

As is well known, the key to maintaining 16-bit accuracy over time and temperature is to maintain the ratios among the elements in the capacitor (or resistor) array to very tight tolerances. Toward that end, each of the capacitors in the array is actually made up of several smaller capacitors. For calibration, extensive digital control circuitry on the CSC5016 switches these subcapacitors in or out as required to ensure that each bit capacitor exactly balances the sum of all of the less-significant-bit capacitors plus one additional least significant bit. It does that by conducting a series of "calibration experiments." A total of 1,443,840 master clock cycles are required for a full calibration cycle. With a 4-MHz clock, that translates into 361 ms.

CALIBRATION SCHEME AT WORK

And the chip can do this at any time. It can calibrate itself at startup, on demand, periodically, or continuously as a background task. In this last mode, called interleaving, the calibration procedure is invisible to the user, except for a throughput reduction of about 20%.

Adjusting their capacitor weightings to within ±¼ LSB is not the only calibration technique that is used by the Crystal converters. They also employ an autozeroing scheme to null out the offsets caused by poor threshold matching and other inherent characteristics of their CMOS circuitry.

The bottom line of all this effort is a fast monolithic converter that offers true 16-bit performance over time and temperature—and that includes units rated for operation from –55° to +125° C. The conversion time of the CS5016 is just 16.25 µs, which corresponds to a maximum throughput of 50 kHz. And its lower-resolution counterparts are even faster: the 14-bit CS5014 clocks in at 14.25 µs (56 kHz), while the 12-bit CS5012 has corresponding specifications of 7.2 µs and 100 kHz.

Interestingly, there is at least one hybrid ADC on the market that offers more than 16-bit resolution—22 bits to be exact—and does not employ self-calibration to do it. That converter, from Thaler Corp., Tucson, Ariz., is a dual-slope integrator, an intrinsically monotonic type of ADC. Called the ADC100, it comes complete with an on-board voltage reference and a clock and is guaranteed to miss no codes over the temperature range from –25° to +85° C.

The Thaler part derives a good part of its performance from its use of a single, floating voltage-to-current (v-i) converter to handle both positive and negative inputs for charging the integrating capacitor. Doing so eliminates a major source of nonlinearity that has plagued integrating converters in the past, namely the imperfect matching of their separate positive and negative v-i converters. The only significant source of nonlinearity that remains is in the input stage of the hybrid's single v-i converter, and the nonlinearity of that subcircuit is minimized by the use of extremely stable precision chip resistors.

The small amount of nonlinearity that remains is sufficiently stable that it can be compensated for by an on-board microprocessor, which also handles all of the converter's other digital control functions. The ADC100's only drawback is that, like all integrating converters, it is slow. It has a conversion time of 320 ms, which corresponds to about three readings a second.

At the monolithic level, dual-slope converters, such as those made by Datel and Teledyne, have reached 16 bits at two to three readings per second. The MAX133/134 from Maxim Integrated Products, Inc., Sunnyvale, Calif., are significantly faster at 20 readings per second. The Maxim units have 9's-complement binary-coded-decimal outputs that span ±40,000 counts.

Most converter makers would agree that there are only two practical ways of getting truly high-resolution in an ADC converter. One is to use an integrating scheme, with its attendant low speed; the other is to apply self-calibration to one of the faster conversion schemes—successive approximation and flash conversion.

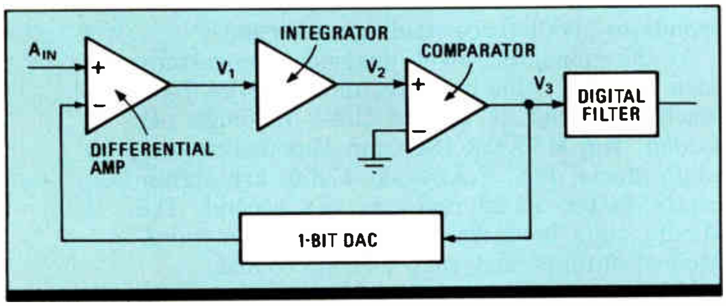
One noteworthy part that uses neither approach, but can be regarded as pointing the way to self-calibration, is the 14-bit ICL7115 from Intersil Inc., Cupertino, Calif. That part, which was the first monolithic converter to offer 14-bit resolution with 14-bit linearity, achieves its performance by combining successive approximation with calibration factors measured in the factory and stored in an on-chip PROM.

Most converter makers would say the best ways to get high resolution are with an integrating scheme or self-calibration applied to fast conversion

The ICL7115 is unusual in that its internal digital-to-analog converter has a greater resolution than the converter itself—17 bits, rather than 14. In other words, the overall ADC makes 17-bit decisions. This fine-grained decision making, combined with the PROM-based error correction, means that the individual bits can have substantial errors and yet not compromise the 14-bit performance of the ADC.

Of course, since the PROM is programmed only once, at the factory, it cannot compensate for changes caused by time and temperature in the field. To minimize those effects, Intersil uses high-quality thin-film resistors and autozeroing circuitry. Nevertheless, the converter is only guaranteed to maintain 14-bit linearity at 25° C. Its performance degrades very little, however, over temperature. The 7115 delivers 13-bit performance over the full military temperature range from –55° to +125° C. It has a conversion time of 40 µs.

The increasing popularity of digital signal processing has pressured converter manufacturers to improve the frequency-domain performance of their devices and—more important—to document it. As a result, data sheets are starting to sport distortion specifications and signal-to-noise ratios—either along with or instead of—more conventional data. More manufacturers are likely to follow suit just as soon as they can get the necessary test equipment installed and running.



3. DOING THE LOOP. A delta-sigma modulator loop continually tracks the input signal. The average value of its 1-bit output, V_3, reflects the input level.

Closely related to the trend toward providing dynamic specifications is the one toward incorporating the sampling function into the ADC chip itself. The reason, basically, is that timing errors introduced in the sampling process can mess up a converter's dynamic specs every bit as badly as nonlinearities within the converter itself.

On a practical level, therefore, the dynamic specs of a system based on a nonsampling converter are limited by the quality of the associated sampling amplifier. Once the two circuits are integrated on the same chip or in the same hybrid, however, their overall behavior can be specified as a single set of numbers.

But there is another reason for merging the sampling and conversion functions: to simplify system design. The task of matching a sample-and-hold amplifier to a particular converter and then of making the two parts work together properly is an extremely subtle business. It requires a great deal of knowledge and experience in analog design. Layout is critical, and timing relationships must be judged to a nicety. Engineers have never found the job easy, and recent engineering graduates, whose training often emphasizes computer concepts at the expense of basic circuit theory, are less well prepared than their predecessors to do the job.

So one of the major trends in data conversion today is the introduction of new products that are virtually identical to older ones except for the inclusion of sampling. Micro Networks' MN6290, for example, is essentially a sampling version of its older MN5290. It is a 16-bit successive-approximation converter with a 20-kHz sampling rate. The hybrid circuit is tested by feeding it a pure sine wave and executing a fast Fourier transform on its output data. It is available in versions specified over the full military temperature range.

Similarly, the Hybrid Systems division of Sipex Corp., Billerica, Mass., is introducing this month the model 9476, a hybrid ADC with the same pinout and performance as its older 9576 but with the addition of a sampling amplifier. These 16-bit successive-approximation parts offer 14-bit performance over their specified temperature range of –55° to +125°C.

When a converter user needs to go beyond audio frequencies, it becomes necessary to abandon the successive-approximation approach and move toward parallel conversion, in which the bits are converted simultaneously, or perhaps in two passes, rather than one at a time. In a basic parallel, or flash, converter, all of the bits are converted at the same time. The technique is simplicity itself: the input is applied to a string of comparators, each of which is fed a slightly different reference voltage, taken from adjacent taps on a precision voltage divider driven by a reference voltage.

The only problem with the technique is that it requires 2^n precision comparators, where n is the resolution of the converter. That's okay for an 8-bit converter, which requires 256 comparators, but not so terrific for a 16-bit device, which would have to integrate more than 65,000 precision comparators. Moreover, comparators are tricky analog circuits that don't lend themselves to large-scale integration as readily as AND gates, to say the least.

The solution here is the subranging, or half-flash, converter, which performs its conversions in two passes instead of one, and saves an enormous amount of hardware at a modest penalty in speed. In the hypothetical 14-bit subranging converter shown in fig. 2, the input signal is latched into the input sampling amplifier and then digitized by the 8-bit flash converter. The 8-bit digital output, which represents the 8 most significant bits of the final output, is converted back into analog form by the DAC, whose output is a replica of the input signal corrupted by the quantization error of the 8-bit ADC.

That signal is then subtracted from the original analog signal, which is still being held by the sampling amplifier, to yield the quantization error. That error is then multiplied by 256 and applied to the 6-bit ADC to generate the 6 LSBs. Since the second, 6-bit, conversion operates on the quantization error of the first one, it is essential that the differential amplifier and the analog multiplier be very accurate and stable.

Practical converters, of course, are more complex than the preceding bare-bones description would suggest. For example, they often carry a second sampling amplifier to allow the converter to acquire a new analog sample while the current one is being processed. At this time, this very fast technique, which yields conversion times on the order of a microsecond or two, has only been applied to relatively low-resolution devices (12 bits and less). But just about every manufacturer is working on a 14- or 16-bitter with a second sampling amp, for introduction within the next few months. And the numbers they mention are almost all the same: 14 bits at 2 μs.

One thing is clear, the long heyday of the successive-approximation converter is beginning to come to an end. They'll be around for a long time yet, but fewer and fewer new parts will be made with that architecture. Flash converters will dominate the low-resolution area; subranging units will take over the high-resolution/high-speed area; and integrating types will remain as the first choice when precision is all important and the ultimate in speed is not required.

But the integrating converter of the future may look different from, and work much faster than, the venerable dual-slope or multislope units of today. There's a good chance that it will consist of a delta-sigma modulation loop followed by a low-pass digital filter (see fig. 3). The delta-sigma modulator gets its name from its two main functional blocks—a differential amplifier followed by an integrator. Its fundamental operating principle is that of a 1-bit ADC embedded in an analog negative-feedback loop with high open-loop gain. Such a configuration can be thought of as the generalized case of a v-f converter whose output is accumulated to get a digital count. The counter in such a situation acts as a very simple low-pass filter.

Delta-sigma products are still so new that the ultimate performance hasn't been wrung out of them, but already they are much faster than other integrator types. Conversion time for the one product on the market is 50 μs, and that's a thousand times better than conventional dual-slope units. There's no comparison with the latest successive-approximation types, however, at least one of which comes in below 10 μs.

The heyday of the successive-approximation converter is coming to an end—they'll be here for a while, but will account for fewer new parts

Basically, the delta-sigma modulator is a 1-bit converter that samples its analog input at a rate many times faster than the highest frequency of interest. The output of the comparator, which operates as a 1-bit ADC, is the output of the loop itself. The DAC converts that comparator output into either plus or minus full scale. The differential amplifier subtracts that full-scale value from the actual analog input and applies the result to the switched-capacitor integrator.

That integrator acts as an analog accumulator, adding its new input voltage at node V_1 to the old voltage at node V_2 to get a new value for V_2. The comparator then compares the new V_2 with ground, generating a +1 on node V_3 if V_2 is

HOW DELTA-SIGMA CONVERSION WORKS

Clock period	Differential amp output (V_1)	Integrator output (V_2)	Comparator output (V_3)	DAC output
1	0.6	0.6	1	+1
2	−0.4	0.2	1	+1
3	−0.4	−0.2	0	−1
4	1.6	1.4	1	+1
5	−0.4	1.0	1	+1
6	−0.4	0.6	1	+1
7	−0.4	0.2	1	+1
8	−0.4	−0.2	0	−1

In this example of the operation of the delta-sigma loop of Fig. 3, a 0.6-V dc signal is applied to the input. At clock period zero, the integrator and DAC outputs are grounded to force a well-defined initial state. The system then proceeds through the subsequent states. The state of the system is identical at clock periods 2 and 7 because the system behavior is periodic with a period of five clock cycles—so long as the input does not change. Averaging the DAC output over a five-cycle period does indeed yield a value of 0.6 V: (+1−1+1+1+1)/5 = 0.6.

LR SERIES:

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VOLTAGE AND CURRENT RATINGS

	MAX CURRENT AT AMBIENT OF (AMPS) 40°C	50°C	60°C	71°C	DIMENSIONS (inches)	PRICE	MODEL
5V ±5% ADJ.	15.0	13.7	11.1	5.9	2 × 4 7/8 × 6 1/4	$ 275	**LRS-52-5**
	25.0	21.5	17.5	10.0	2 3/8 × 4 7/8 × 8 1/2	375	**LRS-53-5**
	40.0	34.0	27.5	19.5	3 × 4 7/8 × 11	460	**LRS-54-5**
	60.0	51.0	41.0	30.0	3 3/4 × 4 7/8 × 10 1/2	585	**LRS-55-5**
	90.0	77.0	61.0	45.0	4 7/16 × 4 7/8 × 11 1/2	725	**LRS-56-5**
	130.0	110.0	90.0	68.0	5 × 4 7/8 × 12	950	**LRS-57-5**
	180.0	147.0	120.0	83.0	5 1/2 × 4 7/8 × 13 1/8	1150	**LRS-58-5**
	250.0	200.0	165.0	125.0	6 5/8 × 4 7/8 × 13 25/32	1400	**LRS-59-5**
6V ±5% ADJ.	13.5	12.2	9.9	5.2	2 × 4 7/8 × 6 1/4	275	**LRS-52-6**
	21.0	18.5	16.0	8.3	2 3/8 × 4 7/8 × 8 1/2	375	**LRS-53-6**
	35.0	31.0	24.0	17.0	3 × 4 7/8 × 11	460	**LRS-54-6**
	52.0	44.0	36.0	26.0	3 3/4 × 4 7/8 × 10 1/2	585	**LRS-55-6**
	80.0	69.0	54.0	39.0	4 7/16 × 4 7/8 × 11 1/2	725	**LRS-56-6**
	110.0	93.0	76.0	58.0	5 × 4 7/8 × 12	950	**LRS-57-6**
	150.0	123.0	100.0	70.0	5 1/2 × 4 7/8 × 13 1/8	1150	**LRS-58-6**
	210.0	170.0	140.0	105.0	6 5/8 × 4 7/8 × 13 25/32	1400	**LRS-59-6**
12V ±5% ADJ.	7.8	6.8	4.9	2.3	2 × 4 7/8 × 6 1/4	275	**LRS-52-12**
	12.5	11.2	9.6	7.2	2 3/8 × 4 7/8 × 8 1/2	375	**LRS-53-12**
	22.0	18.5	15.0	10.0	3 × 4 7/8 × 11	460	**LRS-54-12**
	30.0	26.0	22.0	16.0	3 3/4 × 4 7/8 × 10 1/2	585	**LRS-55-12**
	47.0	41.0	34.0	21.9	4 7/16 × 4 7/8 × 11 1/2	725	**LRS-56-12**
	65.0	58.0	48.0	34.0	5 × 4 7/8 × 12	950	**LRS-57-12**
	84.0	69.0	56.0	40.0	5 1/2 × 4 7/8 × 13 1/8	1150	**LRS-58-12**
	110.0	92.0	74.0	53.0	6 5/8 × 4 7/8 × 13 25/32	1400	**LRS-59-12**
15V ±5% ADJ.	6.4	5.6	4.0	1.9	2 × 4 7/8 × 6 1/4	275	**LRS-52-15**
	10.0	9.0	7.7	5.8	2 3/8 × 4 7/8 × 8 1/2	375	**LRS-53-15**
	18.0	15.0	12.0	8.0	3 × 4 7/8 × 11	460	**LRS-54-15**
	25.0	22.0	19.0	13.0	3 3/4 × 4 7/8 × 10 1/2	585	**LRS-55-15**
	38.0	33.0	28.0	17.9	4 7/16 × 4 7/8 × 11 1/2	725	**LRS-56-15**
	52.0	46.0	38.0	27.0	5 × 4 7/8 × 12	950	**LRS-57-15**
	68.0	56.0	45.5	32.0	5 1/2 × 4 7/8 × 13 1/8	1150	**LRS-58-15**
	90.0	75.0	60.0	43.0	6 5/8 × 4 7/8 × 13 25/32	1400	**LRS-59-15**
20V ±5% ADJ.	4.9	4.3	3.0	1.5	2 × 4 7/8 × 6 1/4	275	**LRS-52-20**
	7.7	6.9	5.9	4.5	2 3/8 × 4 7/8 × 8 1/2	375	**LRS-53-20**
	13.5	11.5	8.5	5.5	3 × 4 7/8 × 11	460	**LRS-54-20**
	19.0	16.5	14.0	10.0	3 3/4 × 4 7/8 × 10 1/2	585	**LRS-55-20**
	29.5	27.0	22.0	13.8	4 7/16 × 4 7/8 × 11 1/2	725	**LRS-56-20**
	40.0	36.0	30.0	21.0	5 × 4 7/8 × 12	950	**LRS-57-20**
	52.0	43.0	35.0	24.5	5 1/2 × 4 7/8 × 13 1/8	1150	**LRS-58-20**
	70.0	58.0	46.0	33.0	6 5/8 × 4 7/8 × 13 25/32	1400	**LRS-59-20**
24V ±5% ADJ.	4.1	3.6	2.6	1.2	2 × 4 7/8 × 6 1/4	275	**LRS-52-24**
	6.5	5.8	5.0	3.8	2 3/8 × 4 7/8 × 8 1/2	375	**LRS-53-24**
	11.5	9.5	7.5	4.5	3 × 4 7/8 × 11	460	**LRS-54-24**
	16.0	14.0	12.0	8.0	3 3/4 × 4 7/8 × 10 1/2	585	**LRS-55-24**
	25.0	22.5	18.5	11.6	4 7/16 × 4 7/8 × 11 1/2	725	**LRS-56-24**
	33.5	29.0	24.0	17.0	5 × 4 7/8 × 12	950	**LRS-57-24**
	44.0	36.0	29.5	20.5	5 1/2 × 4 7/8 × 13 1/8	1150	**LRS-58-24**
	60.0	50.0	40.0	28.0	6 5/8 × 4 7/8 × 13 25/32	1400	**LRS-59-24**
28V ±5% ADJ.	3.5	3.1	2.2	1.1	2 × 4 7/8 × 6 1/4	275	**LRS-52-28**
	5.7	5.1	4.4	3.3	2 3/8 × 4 7/8 × 8 1/2	375	**LRS-53-28**
	9.5	8.5	6.5	4.0	3 × 4 7/8 × 11	460	**LRS-54-28**
	14.0	12.0	10.0	7.0	3 3/4 × 4 7/8 × 10 1/2	585	**LRS-55-28**
	22.0	20.0	16.0	10.0	4 7/16 × 4 7/8 × 11 1/2	725	**LRS-56-28**
	29.0	25.5	21.0	15.0	5 × 4 7/8 × 12	950	**LRS-57-28**
	38.0	31.0	25.5	17.5	5 1/2 × 4 7/8 × 13 1/8	1150	**LRS-58-28**
	52.0	43.0	34.0	24.0	6 5/8 × 4 7/8 × 13 25/32	1400	**LRS-59-28**
48V ±5% ADJ.	2.0	1.7	1.2	0.6	2 × 4 7/8 × 6 1/4	275	**LRS-52-48**
	3.3	2.8	2.4	1.8	2 3/8 × 4 7/8 × 8 1/2	375	**LRS-53-48**
	5.8	5.1	3.6	2.3	3 × 4 7/8 × 11	460	**LRS-54-48**
	8.2	7.2	6.2	4.2	3 3/4 × 4 7/8 × 10 1/2	585	**LRS-55-48**
	13.0	12.0	9.5	6.0	4 7/16 × 4 7/8 × 11 1/2	725	**LRS-56-48**
	17.5	15.5	12.5	9.0	5 × 4 7/8 × 12	950	**LRS-57-48**
	22.5	18.5	15.0	10.5	5 1/2 × 4 7/8 × 13 1/8	1150	**LRS-58-48**
	31.0	26.0	21.0	15.0	6 5/8 × 4 7/8 × 13 25/32	1400	**LRS-59-48**

NOTE: 2 Volt output models available from stock. 2 Volt models have same current ratings as 5 Volt models. Add 12% to price.

resolution of the converter. That's okay for an 8-bit converter, which requires 256 comparators, but not so terrific for a 16-bit device, which would have to integrate more than 65,000 precision comparators. Moreover, comparators are tricky analog circuits that don't lend themselves to large-scale integration as readily as AND gates, to say the least.

The solution here is the subranging, or half-flash, converter, which performs its conversions in two passes instead of one, and saves an enormous amount of hardware at a modest penalty in speed. In the hypothetical 14-bit subranging converter shown in fig. 2, the input signal is latched into the input sampling amplifier and then digitized by the 8-bit flash converter. The 8-bit digital output, which represents the 8 most significant bits of the final output, is converted back into analog form by the DAC, whose output is a replica of the input signal corrupted by the quantization error of the 8-bit ADC.

That signal is then subtracted from the original analog signal, which is still being held by the sampling amplifier, to yield the quantization error. That error is then multiplied by 256 and applied to the 6-bit ADC to generate the 6 LSBs. Since the second, 6-bit, conversion operates on the quantization error of the first one, it is essential that the differential amplifier and the analog multiplier be very accurate and stable.

Practical converters, of course, are more complex than the preceding bare-bones description would suggest. For example, they often carry a second sampling amplifier to allow the converter to acquire a new analog sample while the current one is being processed. At this time, this very fast technique, which yields conversion times on the order of a microsecond or two, has only been applied to relatively low-resolution devices (12 bits and less). But just about every manufacturer is working on a 14- or 16-bitter with a second sampling amp, for introduction within the next few months. And the numbers they mention are almost all the same: 14 bits at 2 µs.

One thing is clear, the long heyday of the successive-approximation converter is beginning to come to an end. They'll be around for a long time yet, but fewer and fewer new parts will be made with that architecture. Flash converters will dominate the low-resolution area; subranging units will take over the high-resolution/high-speed area; and integrating types will remain as the first choice when precision is all important and the ultimate in speed is not required.

But the integrating converter of the future may look different from, and work much faster than, the venerable dual-slope or multislope units of today. There's a good chance that it will consist of a delta-sigma modulation loop followed by a low-pass digital filter (see fig. 3). The delta-sigma modulator gets its name from its two main functional blocks—a differential amplifier followed by an integrator. Its fundamental operating principle is that of a 1-bit ADC embedded in an analog negative-feedback loop with high open-loop gain. Such a configuration can be thought of as the generalized case of a v-f converter whose output is accumulated to get a digital count. The counter in such a situation acts as a very simple low-pass filter.

Delta-sigma products are still so new that the ultimate performance hasn't been wrung out of them, but already they are much faster than other integrator types. Conversion time for the one product on the market is 50 µs, and that's a thousand times better than conventional dual-slope units. There's no comparison with the latest successive-approximation types, however, at least one of which comes in below 10 µs.

The heyday of the successive-approximation converter is coming to an end—they'll be here for a while, but will account for fewer new parts

Basically, the delta-sigma modulator is a 1-bit converter that samples its analog input at a rate many times faster than the highest frequency of interest. The output of the comparator, which operates as a 1-bit ADC, is the output of the loop itself. The DAC converts that comparator output into either plus or minus full scale. The differential amplifier subtracts that full-scale value from the actual analog input and applies the result to the switched-capacitor integrator.

That integrator acts as an analog accumulator, adding its new input voltage at node V_1 to the old voltage at node V_2 to get a new value for V_2. The comparator then compares the new V_2 with ground, generating a +1 on node V_3 if V_2 is

HOW DELTA-SIGMA CONVERSION WORKS

Clock period	Differential amp output (V_1)	Integrator output (V_2)	Comparator output (V_3)	DAC output
1	0.6	0.6	1	+1
2	−0.4	0.2	1	+1
3	−0.4	−0.2	0	−1
4	1.6	1.4	1	+1
5	−0.4	1.0	1	+1
6	−0.4	0.6	1	+1
7	−0.4	0.2	1	+1
8	−0.4	−0.2	0	−1

In this example of the operation of the delta-sigma loop of Fig. 3, a 0.6-V dc signal is applied to the input. At clock period zero, the integrator and DAC outputs are grounded to force a well-defined initial state. The system then proceeds through the subsequent states. The state of the system is identical at clock periods 2 and 7 because the system behavior is periodic with a period of five clock cycles—so long as the input does not change. Averaging the DAC output over a five-cycle period does indeed yield a value of 0.6 V: (+1−1+1+1+1)/5 = 0.6.

above ground and a −1 if it is below. The entire operation is repeated with every clock cycle, resulting in a single-bit data stream whose average analog value tracks the analog input voltage to the converter (see table, p. 137).

The key to the operation of the converter is that its input must appear static during the averaging period—in other words, that the sampling rate must be very much higher than the maximum input frequency. When that condition is met, an extremely sharp low-pass filter can be used to decimate the digital bit stream (thereby reducing the converter's effective sampling rate) and filter out the high quantization noise associated with a 1-bit converter.

So far, this conversion technique has been applied to only one high-resolution ADC, the CSZ5316 from Crystal. The device is a 16-bit chip with a maximum output rate of 20 kHz and a maximum input signal bandwidth of 9.6 kHz. In the 5316, the input sampling rate is 128 times the output rate, or 2.56 MHz, which makes it clear why delta-sigma units are also called oversampling converters.

One big attraction of the delta-sigma technique is the possibility of unlimited resolution, albeit at the price of unlimited integration time. Unlimited resolution comes about because the all-important output filter on the device need not be a real analog circuit, but can be a digital filter, which can realize any function that can be mathematically described. With digital technology, then, the designer can make the filter as narrow and as sharp as is necessary for the specified resolution. The CSZ5316, for example, utilizes a 384th-order filter, but there's no law that says that future parts can't go even higher. The real limitation here is that engineers don't want to wait past their retirement parties for their converters to settle.

Still, oversampling converters have another big advantage to offset their lethargy: they're cheap. The 5316 sells for about $25 in large quantities, less than half the price of current industry alternatives. And that's for an innovative new product with no direct competitors. The price can only go down as competition comes along and the technology matures. □

REPRESENTATIVE MONOLITHIC AND HYBRID HIGH-RESOLUTION ADCs

Company	Model No.	Resolution (bits)	Conversion time	No missing codes performance: Temperature	No missing codes performance: Bits	Type	Comments	Circle No.
Analog Devices Inc. (617) 329-4700	AD 376	16	17 µs	0° to 70°C	14	Hybrid; successive-approximation	Includes reference and clock	381
Burr Brown Corp. (602) 746-1111	ADC 76	16	17 µs	0° to 70°C	14	Hybrid; successive-approximation	Includes reference and clock	382
Crystal Semiconductor Corp. (512) 445-7222	CS 5016	16	16.25 µs	−55° to +125°C	16	Monolithic; successive-approximation	Self-calibrating; needs no external sampling amplifier	383
	CSZ 5316	16	Note 1	−40° to +85°C	Note 2	Monolithic; delta-sigma	Includes track-and-hold amplifier	384
Datel (617) 339-3000	ADC-800	15 + sign	400 ms	0° to 70°C	15 + sign	Monolithic; dual-slope	Includes clock; needs external reference and integrating capacitor	385
Hybrid Systems (617) 667-8700	9576	16	17 µs	−55° to +125°C	14	Hybrid; successive-approximation	Includes reference and clock	386
	9476	16	17 µs	−55° to +125°C	14	Hybrid; successive-approximation	Includes track-and-hold amplifier reference and clock	387
Intersil	ICL 7115	14	40 µs	−55° to +125°C	14	Monolithic; successive-approximation	Includes PROM calibration table; provides 3% useable overrange	388
Micro Networks (617) 852-5400	MN 5295	16	17 µs	−55° to +125°C	14	Hybrid; successive-approximation	Includes reference and clock	389
	MN 6290	16	40 µs	−55° to +125°C	14	Hybrid; successive-approximation	Includes track-and-hold amplifier, reference, and clock	390
Philips (408) 991-2000	TDA 1534	14	8.5 µs	0° to 70°C	14	Monolithic; successive-approximation	Current input; includes reference and clock	391
Teledyne Semiconductor (415) 968-9241	TSC 800	15 + sign	400 ms	0° to 70°C	15 + sign	Monolithic; dual-slope		392
	TSC 500A	16	500 ms	−25° to +85°C	15	Monolithic; dual-slope	Requires a microprocessor	393
Thaler Corp. (602) 742-5572	ADC 100	22	320 ms	0° to 70°C	22	Hybrid; dual-slope	Needs external crystal and integrating capacitor	394

Note 1: Dynamically specified unit; has maximum output rate of 20 kHz and maximum input bandwidth of 9.6 kHz.
Note 2: Dynamically specified device; has minimum full-scale signal to distortion ratio of 72 dB at 1 kHz.

LR SERIES:

LAMBDA'S STATE-OF-THE-ART TECHNOLOGY PROVIDES HIGHER DENSITY, EFFICIENCY AND RELIABILITY

VOLTAGE AND CURRENT RATINGS

	MAX CURRENT AT AMBIENT OF (AMPS) 40°C	50°C	60°C	71°C	DIMENSIONS (inches)	PRICE	MODEL
5V ±5% ADJ.	15.0	13.7	11.1	5.9	2 × 4 7/8 × 6 1/4	$ 275	LR5-52-5
	25.0	21.5	17.5	10.0	2 3/8 × 4 7/8 × 8 1/2	375	LR5-53-5
	40.0	34.0	27.5	19.5	3 × 4 7/8 × 11	460	LR5-54-5
	60.0	51.0	41.0	30.0	3 3/4 × 4 7/8 × 10 1/2	585	LR5-55-5
	90.0	77.0	61.0	45.0	4 7/16 × 4 7/8 × 11 1/2	725	LR5-56-5
	130.0	110.0	90.0	68.0	5 × 4 7/8 × 12	950	LR5-57-5
	180.0	147.0	120.0	83.0	5 1/2 × 4 7/8 × 13 1/8	1150	LR5-58-5
	250.0	200.0	165.0	125.0	6 5/8 × 4 7/8 × 13 25/32	1400	LR5-59-5
6V ±5% ADJ.	13.5	12.2	9.9	5.2	2 × 4 7/8 × 6 1/4	275	LR5-52-6
	21.0	18.5	16.0	8.3	2 3/8 × 4 7/8 × 8 1/2	375	LR5-53-6
	35.0	31.0	24.0	17.0	3 × 4 7/8 × 11	460	LR5-54-6
	52.0	44.0	36.0	26.0	3 3/4 × 4 7/8 × 10 1/2	585	LR5-55-6
	80.0	69.0	54.0	39.0	4 7/16 × 4 7/8 × 11 1/2	725	LR5-56-6
	110.0	93.0	76.0	58.0	5 × 4 7/8 × 12	950	LR5-57-6
	150.0	123.0	100.0	70.0	5 1/2 × 4 7/8 × 13 1/8	1150	LR5-58-6
	210.0	170.0	140.0	105.0	6 5/8 × 4 7/8 × 13 25/32	1400	LR5-59-6
12V ±5% ADJ.	7.8	6.8	4.9	2.3	2 × 4 7/8 × 6 1/4	275	LR5-52-12
	12.5	11.2	9.6	7.2	2 3/8 × 4 7/8 × 8 1/2	375	LR5-53-12
	22.0	18.5	15.0	10.0	3 × 4 7/8 × 11	460	LR5-54-12
	30.0	26.0	22.0	16.0	3 3/4 × 4 7/8 × 10 1/2	585	LR5-55-12
	47.0	41.0	34.0	21.9	4 7/16 × 4 7/8 × 11 1/2	725	LRS-56-12
	65.0	58.0	48.0	34.0	5 × 4 7/8 × 12	950	LR5-57-12
	84.0	69.0	56.0	40.0	5 1/2 × 4 7/8 × 13 1/8	1150	LR5-58-12
	110.0	92.0	74.0	53.0	6 5/8 × 4 7/8 × 13 25/32	1400	LR5-59-12
15V ±5% ADJ.	6.4	5.6	4.0	1.9	2 × 4 7/8 × 6 1/4	275	LRS-52-15
	10.0	9.0	7.7	5.8	2 3/8 × 4 7/8 × 8 1/2	375	LR5-53-15
	18.0	15.0	12.0	8.0	3 × 4 7/8 × 11	460	LR5-54-15
	25.0	22.0	19.0	13.0	3 3/4 × 4 7/8 × 10 1/2	585	LRS-55-15
	38.0	33.0	28.0	17.9	4 7/16 × 4 7/8 × 11 1/2	725	LRS-56-15
	52.0	46.0	38.0	27.0	5 × 4 7/8 × 12	950	LR5-57-15
	68.0	56.0	45.5	32.0	5 1/2 × 4 7/8 × 13 1/8	1150	LR5-58-15
	90.0	75.0	60.0	43.0	6 5/8 × 4 7/8 × 13 25/32	1400	LR5-59-15
20V ±5% ADJ.	4.9	4.3	3.0	1.5	2 × 4 7/8 × 6 1/4	275	LR5-52-20
	7.7	6.9	5.9	4.5	2 3/8 × 4 7/8 × 8 1/2	375	LR5-53-20
	13.5	11.5	8.5	5.5	3 × 4 7/8 × 11	460	LR5-54-20
	19.0	16.5	14.0	10.0	3 3/4 × 4 7/8 × 10 1/2	585	LR5-55-20
	29.5	27.0	22.0	13.8	4 7/16 × 4 7/8 × 11 1/2	725	LR5-56-20
	40.0	36.0	30.0	21.0	5 × 4 7/8 × 12	950	LR5-57-20
	52.0	43.0	35.0	24.5	5 1/2 × 4 7/8 × 13 1/8	1150	LR5-58-20
	70.0	58.0	46.0	33.0	6 5/8 × 4 7/8 × 13 25/32	1400	LR5-59-20
24V ±5% ADJ.	4.1	3.6	2.6	1.2	2 × 4 7/8 × 6 1/4	275	LR5-52-24
	6.5	5.8	5.0	3.8	2 3/8 × 4 7/8 × 8 1/2	375	LRS-53-24
	11.5	9.5	7.5	4.5	3 × 4 7/8 × 11	460	LR5-54-24
	16.0	14.0	12.0	8.0	3 3/4 × 4 7/8 × 10 1/2	585	LR5-55-24
	25.0	22.5	18.5	11.6	4 7/16 × 4 7/8 × 11 1/2	725	LR5-56-24
	33.5	29.0	24.0	17.0	5 × 4 7/8 × 12	950	LRS-57-24
	44.0	36.0	29.5	20.5	5 1/2 × 4 7/8 × 13 1/8	1150	LRS-58-24
	60.0	50.0	40.0	28.0	6 5/8 × 4 7/8 × 13 25/32	1400	LR5-59-24
28V ±5% ADJ.	3.5	3.1	2.2	1.1	2 × 4 7/8 × 6 1/4	275	LRS-52-28
	5.7	5.1	4.4	3.3	2 3/8 × 4 7/8 × 8 1/2	375	LRS-53-28
	9.5	8.5	6.5	4.0	3 × 4 7/8 × 11	460	LRS-54-28
	14.0	12.0	10.0	7.0	3 3/4 × 4 7/8 × 10 1/2	585	LRS-55-28
	22.0	20.0	16.0	10.0	4 7/16 × 4 7/8 × 11 1/2	725	LR5-56-28
	29.0	25.5	21.0	15.0	5 × 4 7/8 × 12	950	LRS-57-28
	38.0	31.0	25.5	17.5	5 1/2 × 4 7/8 × 13 1/8	1150	LRS-58-28
	52.0	43.0	34.0	24.0	6 5/8 × 4 7/8 × 13 25/32	1400	LRS-59-28
48V ±5% ADJ.	2.0	1.7	1.2	0.6	2 × 4 7/8 × 6 1/4	275	LRS-52-48
	3.3	2.8	2.4	1.8	2 3/8 × 4 7/8 × 8 1/2	375	LRS-53-48
	5.8	5.1	3.6	2.3	3 × 4 7/8 × 11	460	LRS-54-48
	8.2	7.2	6.2	4.2	3 3/4 × 4 7/8 × 10 1/2	585	LRS-55-48
	13.0	12.0	9.5	6.0	4 7/16 × 4 7/8 × 11 1/2	725	LRS-56-48
	17.5	15.5	12.5	9.0	5 × 4 7/8 × 12	950	LRS-57-48
	22.5	18.5	15.0	10.5	5 1/2 × 4 7/8 × 13 1/8	1150	LRS-58-48
	31.0	26.0	21.0	15.0	6 5/8 × 4 7/8 × 13 25/32	1400	LR5-59-48

NOTE: 2 Volt output models available from stock. 2 Volt models have same current ratings as 5 Volt models. Add 12% to price.

LR SERIES

Specifications

DC OUTPUT
Voltage range shown in tables.

REGULATED VOLTAGE

regulation, line	0.1% from 95 to 132VAC. 95 to 132VAC or 187 to 265VAC on LRS-57, 58 and "M" option models. 187 to 265VAC on LRS-59 and "V" option models.
regulation, load	0.1% from no load to full load.
ripple and noise	10mV RMS, 35mV pk-pk for 5V and 6V models. (25mV pk-pk for 2V models.) 15mV RMS, 100mV pk-pk for 12V through 28V models. 35mV RMS, 150mV pk-pk for 48V models.
temperature coefficient	0.03%/°C.
remote programming resistance	1000Ω/volt.
remote programming voltage	volt per volt.

AC INPUT

line	95 to 132VAC, 47-440Hz. 95 to 132VAC or 187 to 265VAC (user selectable), 47-440Hz on LRS-57, 58 and "M" option models. 187 to 265VAC, 47-440Hz on LRS-59 only.
power	LRS-52: 137 watts maximum. LRS-53: 225 watts maximum. LRS-54: 380 watts maximum. LRS-55: 515 watts maximum. LRS-56: 819 watts maximum. LRS-57: 1100 watts maximum. LRS-58: 1350 watts maximum. LRS-59: 1900 watts maximum.

DC INPUT
145VDC ± 10%. (260 to 370VDC for LRS-57, 58, 59, and "M" and "V" option models.)

EFFICIENCY
55% min for 2V models. 67% min for 5V and 6V models of LRS-52. 70% min for 5V through 15V models of LRS-53, 54. 75% min for 5V and 6V models of LRS-55, 56; 5V through 15V models of LRS-57, 58, 59; 12V through 20V models of LRS-52; 20V through 48V models of LRS-53, 54. 77% min for 12V through 20V models of LRS-55, 56. 78% min for 24V through 48V models of LRS-52. 80% min for 20V through 48V models of LRS-57, 58, 59; 24V through 48V models of LRS-55, 56.

OVERSHOOT
No overshoot at turn-on, turn-off or power failure.

OPERATING TEMPERATURE RANGE
Continuous duty −10°C to +71°C with suitable derating above 40°C. Guaranteed turn-on at −20°C.

STORAGE TEMPERATURE RANGE
−55°C to +85°C.

OVERLOAD PROTECTION
ELECTRICAL
External overload protection, automatic electronic current limiting circuit limits the output current to a preset value, thereby providing protection for the load as well as the power supply.

THERMAL
Self-resetting thermostat.

FUSING
Line fuse removes the power supply from the line if a short occurs in the input circuitry.

OVERVOLTAGE PROTECTION
Overvoltage protection is standard on all models. If output voltage increases above a preset level, inverter drive is removed.

COOLING
All units are convection cooled. No fans or blowers are needed.

IN-RUSH LIMITING
The turn-on in-rush current will not exceed 40 amps peak from a cold start. (50 amps on LRS-57, 58, 59.)

DC OUTPUT CONTROLS
Simple screwdriver adjustment over the entire voltage range.

INPUT AND OUTPUT CONNECTIONS
All input, output, sensing, and remote on/off connections for LRS-52 and LRS-53 are made through barrier strip terminals. All input, sensing and remote on/off connections for LRS-54, LRS-55, LRS-56, LRS-57, LRS-58 and LRS-59 are made through barrier strip terminals. DC output connection is made through heavy duty threaded bus bars.

MOUNTING
Two mounting surfaces and two mounting positions on LRS-52, 53, 54. One mounting surface and one mounting position on LRS-55, 56, 57, 58, 59.

POWER FAILURE
2V, 5V and 6V models will remain within regulation limits for at least 16.7 msec. after loss of AC power when operating at full load, V_O max, and 105VAC input at 60Hz. (105 or 210VAC for LRS-57, 58 and "M" option models. 210VAC at 60Hz for LRS-59.)

REMOTE SENSING
Provision is made for remote sensing to eliminate the effects of power output lead resistance on DC regulation.

REMOTE TURN-ON/TURN-OFF
Provision is made for digitally controlled remote turn-on, turn-off (TTL Compatible).

FUNGUS PROOFING
All units are inherently fungi inert.

MILITARY SPECIFICATIONS
The LR series has passed the following tests in accordance with MIL-STD-810C.
1) Low Pressure — Method 500.1, Procedure I.
2) High Temperature — Method 501.1, Procedures I and II.
3) Low Temperature — Method 502.1, Procedure I.
4) Temperature Shock — Method 503.1, Procedure I.
5) Temperature-Altitude — Method 504.1, Procedure I. Class 2 (−10°C Operating).
6) Humidity — Method 507.1, Procedure I.
7) Fungus — Method 508.1, Procedure I.
8) Vibration — Method 514.2, Procedures X and XI.
9) Shock — Method 516.2, Procedures I and III.

EMI
Conducted EMI conforms to FCC Docket 20780 Class A, and MIL-STD-461A Notice 4 CEO4 for power leads. LRS-57, LRS-58, LRS-59, and "M" and "V" option models also conform to VDE 0871 Class A.

PHYSICAL DATA

Package Model	Lbs. Net	Lbs. Ship	Size Inches
LRS-52	2 1/4	3 1/4	2 × 4 7/8 × 6 1/4
LRS-53	3 1/4	4 1/4	2 3/8 × 4 7/8 × 8 1/2
LRS-54	6 1/2	7 1/2	3 × 4 7/8 × 11
LRS-55	7	8 1/2	3 3/4 × 4 7/8 × 10 1/2
LRS-56	8 1/2	10	4 7/16 × 4 7/8 × 11 1/2
LRS-57	10 1/2	12	5 × 4 7/8 × 12
LRS-58	12 1/2	14	5 1/2 × 4 7/8 × 13 1/8
LRS-59	16 1/2	19	6 5/8 × 4 7/8 × 13 25/32

OPTIONS

AC Input

Add Suffix[1]	For Operation at:	Price
−V (LRS-55, 56 only)	185 to 265VAC 47-440Hz	12%
−M (LRS-52, 53, 54 only)	95 to 132VAC or 187 to 265VAC, 47-440Hz (customer selectable)	12%

[1] Add Suffix after package number, i.e.: LRS-55V-5, LRS-52M-5.

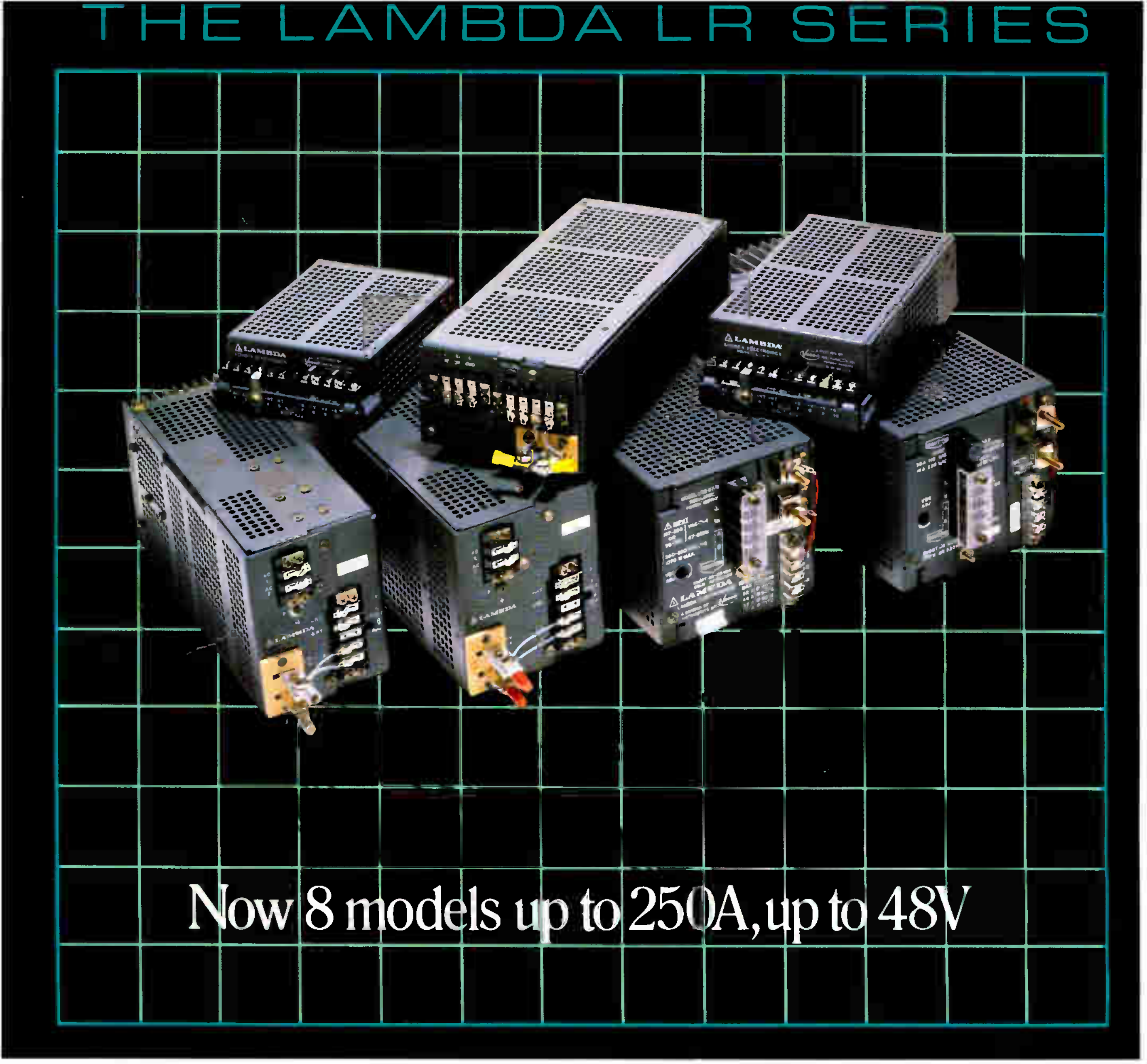
ACCESSORIES
Rack Adapters (LRA-14, LRA-15, LRA-17) and cable system available.

FINISH
Grey, Fed. Std. 595, No. 26081.

GUARANTEED FOR 5 YEARS
Five year guarantee includes labor as well as parts. Guarantee applies to operation at full published specifications at end of 5 years.

UL/CSA
UL Recognized. CSA Certified. LRS-57, 58, 59 under evaluation.

TUV LICENSED
110/220 and 220 input versions.



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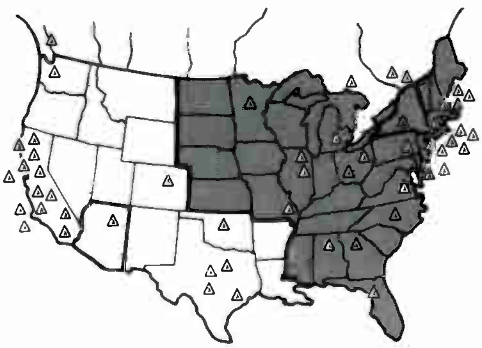
(or call 516-694-4200)



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SWITCHING SUPPLIES: CHANGING WITH THE TIMES

Power supplies are moving to megahertz switching frequencies, shrinking in size, and becoming more efficient—advances that are helping to spread distributed power, the ultimate power supply for the complex systems of today and tomorrow

by John Bassett, *Computer Products*

Switching power supplies are harnessing new technology to meet the demands of today's systems for more power. They are moving to megahertz switching frequencies, they are shrinking in size, and they are becoming more efficient. As a result, switchers are changing to deliver the most power in the smallest package with the best efficiency.

New components are making possible operating frequencies that soar in the megahertz range—and that promises significantly smaller supplies. What's more, to deliver the most power with the best efficiency, switchers are also undergoing fundamental changes in their components and circuit configurations. The new topologies, such as resonant-mode supplies that employ zero-voltage switching, promise to be the wave of the future. And perhaps best of all, these advances are helping to spread distributed power, which stands poised as the ultimate power-supply solution for the complex systems of today and tomorrow.

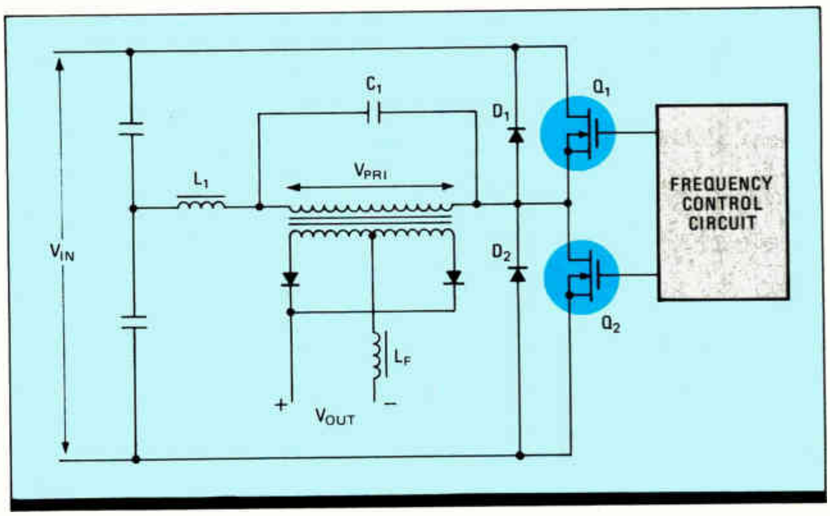
A number of factors are driving these dramatic improvements in power supplies. For one, system designers want smaller supplies in order to have more room for the electronics. Today, the power supply is typically allowed to occupy only 25% of the total system volume. And the supply must put out more power from that limited volume.

The designers of modern electronic equipment also keep packing more functions into their systems. Even though individual circuit elements may consume less power, there are so many more elements for implementing special features that total system power demand is higher than ever.

So, as switching frequencies climb to 1 MHz and beyond, power supplies must produce an increasing amount of power while taking up less space, causing their power density to increase dramatically. For power-supply technology, such a situation only intensifies the crucial need for improved efficiency.

At the component level, the technologies are already in place to take switching frequencies into the megahertz region. For good reason, power MOS FETs are becoming the preferred switching device over bipolar transistors. MOS FETs simplify dealing with magnetic saturation because they do not store charge, thereby decreasing their switching transition times by an order of magnitude or more over bipolar transistors. Moreover, the absence of destructive secondary breakdown, which is inherent with bipolars, reduces or even eliminates the need for speed-limiting snubber circuitry.

Capacitors, too, are now designed to minimize equivalent series resistance and series inductance for more effective operation at high frequencies. What's more, megahertz operation allows capacitance values to be lower and, therefore, capacitor size to be smaller. In addition, new low-loss ferrites for the inductors and transformers have emerged for power applications in the megahertz range. And such high-frequency



1. FOR 200 W OR MORE. In this full-wave resonant converter, the resonant tank formed by inductor L_1 and capacitor C_1 assure zero-current switching for the transistor switches.

magnetics are substantially smaller than their low-frequency counterparts.

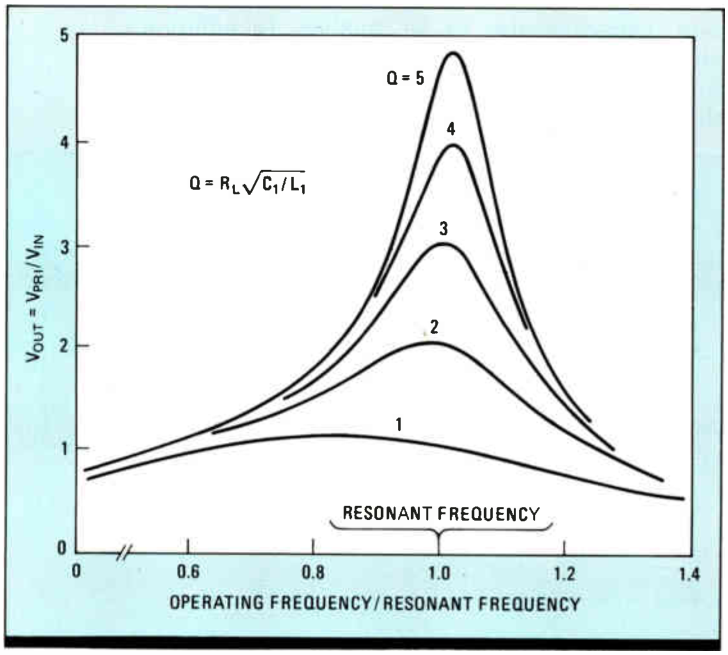
However, power-supply topologies for megahertz operation have lagged developments at the component level. In fact, the topologies that prevail today are pulse-width-modulated (PWM) supplies, and they are inadequate for megahertz frequencies. Their losses are excessive because they are what is called hard-switching circuits. With hard switching, circuit action causes a transistor switch still carrying current (and thus still turned on) to turn off, or a transistor switch still blocking voltage (and thus still turned off) to turn on. And the more often the switch turns on and off, the greater its power losses. Moreover, the transistor's transition time (the time it takes to turn-on or to turn-off) should be as short as possible.

Ideally, for minimal losses, a transistor switch should be turned off when the current through it is zero (known as zero-current switching), and it should be turned on when the voltage across it is zero (known as zero-voltage switching). With such switching conditions, the transistor's transition time becomes unimportant.

In addition, as switching frequency increases, the topology of the power supply becomes extremely complex. At high frequencies, parasitic inductances and capacitances are no longer negligible. Indeed, the switching transistor, be it bipolar or MOS FET, must drive not only the winding of a transformer but also an array of reactive components largely created by parasitics. And the energy stored in the magnetics and reactive components must be dissipated during the transistor's switching interval.

At this time, the best topologies for high-frequency switching supplies appear to be resonant circuits, which are also called resonant converters. Unlike PWM supplies, resonant circuits soften the transition interval so as to minimize switching losses. So, although they are more complex, they are more efficient when operating at the same frequency.

In a resonant electrical circuit, energy "bounces" between being stored as a current in an inductor and being stored as a voltage across a capacitor. The voltage and the current oscillate between extremes, passing through zero periodically. Seemingly, if turn-off happens during a naturally occurring zero of current or if turn-on happens during a naturally occurring zero of voltage, then switching efficiency should be maximized.



2. TRANSFER CHARACTERISTICS. With a resonant converter, the frequency of operation and the load factor (Q) determine the output voltage.

FOR HIGH POWER

Today, most systems require high power (200 W and above), and the most suitable supply configuration is a full-wave circuit like that of fig. 1. That supply combines full-wave operation with zero-current switching.

In this circuit, the frequency controller, which could be an integrated circuit or a set of ICs, produces square waves that alternately turn transistor switches Q_1 and Q_2 on and off. The frequency of the controller, and thus the square waves it produces, is usually variable. A frequency controller is part and parcel of every resonant converter, exactly as a PWM circuit is the inherent controller of a conventional switching topology.

When transistor switch Q_1 turns on, the current in inductor L_1 builds gradually. This current equals the sum of the transformer primary current and the charging current of capacitor C_1, which is in parallel with the primary. Once the voltage across C_1 and the primary equals the input voltage, the voltage drop across L_1 is 0, and L_1 begins to release its stored energy into C_1. At a time determined by the natural resonant frequency of L_1 and C_1, the current in L_1 and therefore Q_1 reaches 0. The current in L_1 now reverses, and C_1 begins to discharge its stored energy, maintaining current flow through diode D_1.

Ideally, for zero-current switching, the changeover from one transistor switch to the other occurs at that point, with Q_1 turning off and Q_2 turning on. Now, C_1 begins to recharge in the opposite polarity, and an identical half-cycle starts.

Because the time before the changeover from one transistor switch to the other is longer than a natural resonant half-cycle, this full-wave circuit operates below its resonant frequency. Turn-off at zero current is very important for bipolar transistors because the majority of losses occur during their turn-off.

The transfer characteristics versus frequency for the full-wave circuit of fig. 1. typify the frequency-domain response of a resonant circuit (see fig. 2). Varying the frequency of operation controls the output voltage. (In contrast, with PWM supplies, varying duty cycle controls the output voltage.) For a given load factor (Q), the output voltage (which equals the ratio of V_{PRI} to V_{IN}) rises to a peak at resonance and then falls again as the operating frequency increases beyond resonance. Such characteristics define two regions of operation: one below the resonant point, and the other above it. In general, operation at frequencies below resonance produces zero-current switching, and operation above resonance yields zero-voltage switching. But zero-current and zero-voltage switching cannot be implemented together in the same topology.

For systems requiring 5 to 200 W, the half-wave resonant configuration (see fig. 3) is the most widely used power supply. Since this circuit allows the resonant capacitor to charge but not to discharge, it is often called a quasi-resonant converter.

Circuit operation is fairly straightforward. When transistor switch Q_1 turns on, the combination of the load current and the charging current of capacitor C_1 stores energy in resonant inductor L_1. When C_1's voltage equals the input voltage, L_1's voltage passes through zero and begins to reverse. This lets L_1 release its stored energy to C_1. This capacitor continues to charge above the input voltage until the current in L_1 and Q_1 reaches 0. Then, diode D_1 blocks reverse current flow so that Q_1 turns off when its current reaches 0.

Although the circuit prevents the resonant discharge of C_1, the capacitor can and does discharge into the filter and load circuits, preparing it for the next cycle. The capacitor charges during one half-cycle (when the transistor is on), and then discharges (powers the load) during the other half-cycle (when the transistor is off). The delay time between charging cycles determines the amount of energy transferred to the output and, therefore, the output voltage.

Both of these resonant topologies are more complex than nonresonant circuits, but they are more efficient—80% vs. 75%—at operating frequencies up to several hundred kilohertz. To reap the reward of smaller size through megahertz operation and yet maintain that excellent 80% efficiency, resonant topologies are changing to take advantage of MOS FET characteristics and zero-voltage switching.

Until recently, transistor turn-on was believed to be relatively free of losses, since no current flows before turn-on. And just before turn on, current should build gradually through the circuit inductance only after the voltage at the collector (bipolar) or drain (MOS FET) falls.

In reality, when a transistor is off, substantial capacitance exists at the collector or drain node, be it in the transistor or from circuit parasitics. When it turns on, the transistor switch totally dissipates the energy stored in that capacitance by rapidly shorting it out each operating cycle. With such hard turn-on, losses can be as high as 25 W for a capacitance of only 2 nF, an operating frequency of 1 MHz, and a transistor voltage in excess of 150 V. Clearly, hard turn-on does not work at high frequencies.

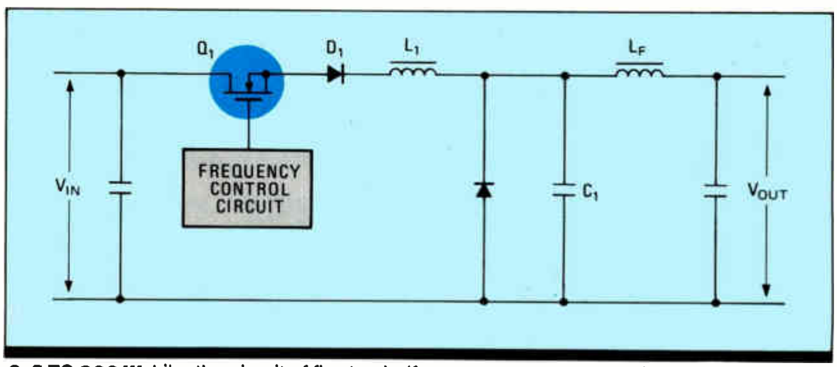
Resonant topologies are more complex than nonresonant circuits, but at frequencies up to several hundred kilohertz, they're more efficient

Moreover, unlike bipolar devices, which can experience large losses during turn-off, MOS FETs turn off without any losses even when carrying current. MOS FET switching times are determined primarily by device capacitance and secondarily by the channel transit time of electrons. Because the gate capacitance is large, existing topologies have actually slowed MOS FET turn-off by limiting the drive current to a few hundred milliamperes. In fact, turning the channel on and off effectively requires pulses of several amperes to charge and discharge the gate rapidly. Fortunately, the gate voltage is only 10 V and the energy required is small, but the drive components must be robust.

Now that MOS FETs are becoming the transistor switch of choice for high-frequency operation, the care that existing topologies take to soften the turn-off interval through zero-current switching has become unneccessary. Instead, new topologies are employing zero-voltage switching to soften the turn-on interval.

In most cases, it is relatively easy to modify an existing resonant converter to handle zero-voltage switching. For example, the resonant converter of fig. 4 uses a parallel snubber capacitor (C_2) to modify the full-wave circuit of fig. 1 for zero-voltage switching. And the circuit's operating frequency is higher than the resonant frequency.

A resonant half-cycle begins when Q_1 turns



3. 5 TO 200 W. Like the circuit of fig. 1, a half-wave resonant, or quasi-resonant, converter implements zero-current switching. Here, C_1 discharges into the filter and load circuits.

TRANSIMPEDANCE AMPS: FAST YET ACCURATE

When the application calls for dc accuracy together with exceptional ac performance, the transimpedance amplifier, which is a current-feedback device, is perfect for the job

By Wyn Palmer, *Analog Devices*

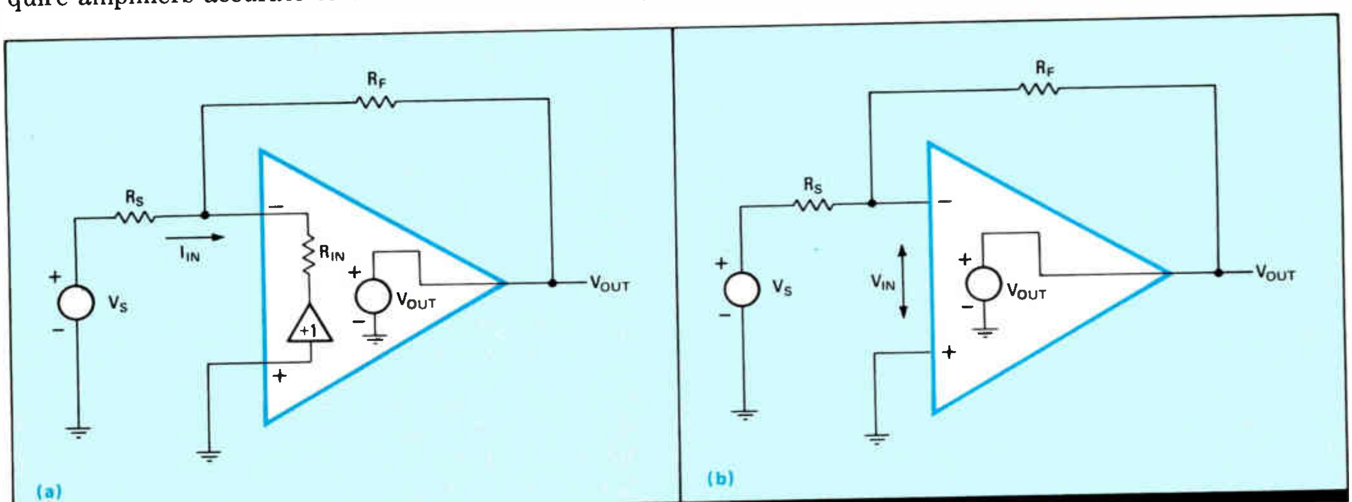
Designers of fast signal-processing systems no longer need make the painful choice between speed and dc accuracy when specifying an amplifier. The new breed of transimpedence amps add precision dc characteristics to their inherently good ac characterstics. So it can be an effective buffer device for these high-speed systems—and it's beginning to nose out the standard operational amplifier, which for decades has been the choice for most amplifier applications.

In the typical amplifier, speed and precision are mutually exclusive characteristics. An amplifier that has high speed (broad bandwidth) must compromise its dc precision to obtain that speed. Similarly, an amplifier boasting low dc errors invariably imposes a penalty on its bandwidth.

However, today's fast signal-processing systems demand amplifiers that excel at both attributes. For example, to convert their output current to a high-level voltage, the latest 12-bit digital-to-analog converters need amplifiers that can settle in under 120 ns to within 0.01% accuracy. Likewise, to drive their high-capacitance inputs, high-speed flash analog-to-digital converters require amplifiers accurate to within 0.1% and having bandwidths that are in excess of 150 MHz.

The transimpedance amp has always had, inherent in its design, ac characteristics (slew rate, bandwidth, and settling time) superior to those of the op amp. But its dc specifications (offset voltage, offset drift, and open-loop gain) tended to be poorer, limiting its use primarily to driving video lines in data communications equipment. However, new bipolar semiconductor processes now add dc precision to the device's excellent broadband performance. Indeed, a key attribute of the transimpedance amp is a bandwidth that is relatively independent of gain, for gain settings of up to 20. Moreover, additional system performance benefits include low distortion as well as excellent gain and bandwidth stability.

Transimpedance amps are finding use in a broad variety of applications. Because of their uniform rise and fall times, they are well suited to digital communications systems as pulse repeaters to regenerate a clean digital pulse from a corrupted input signal. And their low distortion makes them eminently suitable in high-end audio systems, where really good harmonic performance is often the key specification; in radar systems, where radar jammers often pollute the



1. DIFFERENT AC BEHAVIOR. Source resistance (R_s) sets the gain of the transimpedance amp (a), whose bandwidth is independent of gain. With the op amp (b), feedback resistance (R_f) to R_s determines gain, and bandwidth degrades with increasing gain.

rf spectrum; in satellite communications, where transponders often frequency-multiplex a number of channels onto a single carrier; and in digital radio receivers, where digitizing and scanning introduces harmonics.

The performance advantages of the transimpedance amp over the op amp stem from the differences in the basic structures of the two devices. The transimpedance amp (see fig. 1a) is a single-ended current-input device with a single-ended voltage output. At the most simplistic level, it can be regarded as an amplifying current-to-voltage converter. Most important, its inverting input is a low-impedance node, while its noninverting input is a high-impedance node. (In fig. 1a, the unity-gain amp at the noninverting input simply indicates there is no gain between the input terminals.)

The external source resistance (R_s) sets the device's closed-loop gain. More exactly, the LaPlace transform of the transfer function for closed-loop gain is:

$$G(s) = \frac{-R_f / R_s}{1 + C_{comp}\left[R_f + [1 + (R_f / R_s)]R_{in}\right]s}$$

where R_f is the external feedback resistance, R_s is the external source resistance, internal input resistance, R_{in} and C_{comp} is the internal compensation capacitance. The device's closed-loop gain is primarily influenced by the denominator factor of $1 + (R_f/R_s)\ R_{in}$.

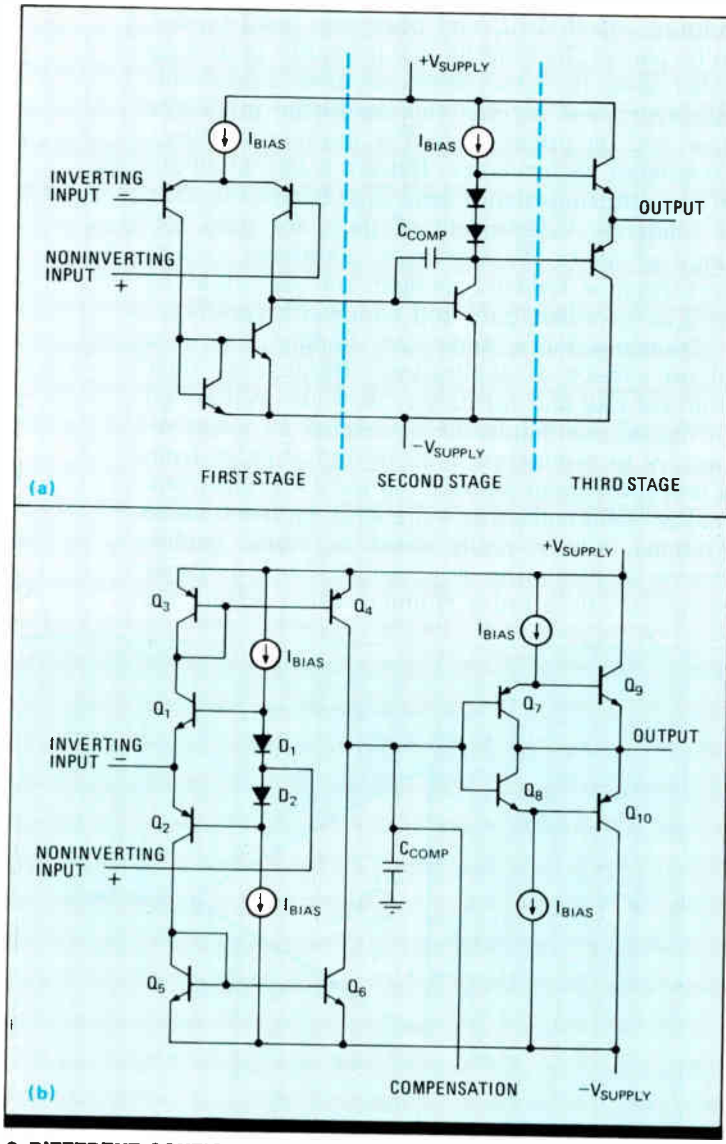
In contrast, a conventional op amp (see fig. 1b) is a differential-input device with a single-ended voltage output. Both its inverting and noninverting input terminals have high impedances and are in fact identical. The ratio of the external feedback resistance (R_f) to the external source resistance (R_s) determines the device's closed-loop gain. The LaPlace transform of the transfer function for closed-loop gain is:

$$G(s) = \frac{-R_f / R_s}{1 + (C_{comp}/g_m)[1 + (R_f / R_s)]s}$$

where g_m is the input transconductance. Here the principal gain-setting factor is $1 + (R_f/R_s)$.

The method used to set an amplifier's closed-loop gain also determines its frequency response. With a conventional op amp, increasing its gain decreases its closed-loop bandwidth proportionally. Conversely, with a transimpedance amp, the bandwidth and the closed-loop gain are relatively independent, for gains of 20 or less. At such low gains, R_{in} is small compared to R_s, so that C_{comp} and R_f determine the closed-loop bandwidth in a transimpedence amp.

For gains above 20, the frequency response of the transimpedance amp starts to mimic that of an op amp. At such high gain values, the gain-setting factor of $1 + (R_f/R_s)R_{in}$ becomes large, compared to R_f. Moreover, the transfer function of the transimpedance amp becomes the same as that of the op amp, because the internal impedance (R_{in}) of the transimpedance amp becomes equal to the inverse of the op amp's input transconductance (g_m).



2. DIFFERENT CONFIGURATIONS. The op amp (a) is a voltage-amplifying device, whereas the transimpedance amp (b) is a current-amplifying device.

The ac performance of the two amplifier types differs because of the way their circuits are configured. In the op amp (see fig. 2a), a common-emitter first stage employs matched input transistors to convert the differential input voltage between the inverting and noninverting terminals to a single-ended voltage. The second stage amplifies this voltage, and the third stage delivers the current necessary to drive an external load.

The high-impedance common-emitter input stage places a number of limitations on the op amp when it operates in the ac domain. Impedance mismatches between the signal source and the amplifier's input stage create a parasitic pole, which leads to reflections that add distortion to the output signal from the input transistors. This distortion compromises bandwidth and pulse fidelity.

In addition, the op amp relies on negative feedback to drive its inverting input to 0 V, so as to

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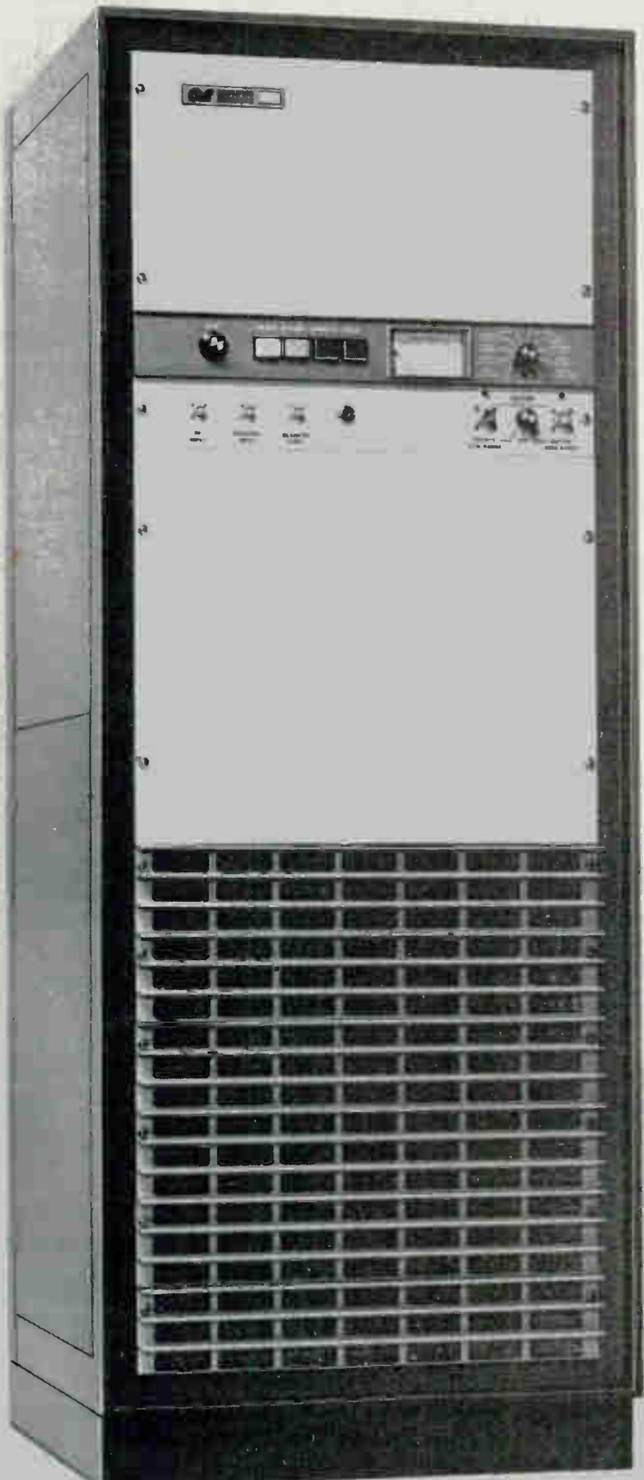

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produce a virtual ground at that input. Negative feedback requires phase-degrading circuit techniques such as ac feedforward to maintain amplifier stability. Feedforward introduces phase nonlinearities (shifts in the phase of the signal from the input to the output of the op amp) over a wide range of input frequencies.

Unlike the op amp, the transimpedance amp (see fig. 2b) does not have two identical input terminals. Instead, its inverting input is connected to the emitters of two complementary transistors (Q_1 and Q_2), creating a low-impedance point. On the other hand, its noninverting input, which is attached to the common point between two series-connected diodes (D_1 and D_2), creates a high-impedance terminal that behaves much like the inputs of the op amp.

In operation, the error current flowing through R_f enters the inverting input terminal. Transistors Q_1 and Q_2 convey that error current to the current mirrors formed by transistors Q_3, Q_4, Q_5, and Q_6. The complementary current set up through transistors Q_4 and Q_6 charges C_{comp}. Finally, the output stage (formed by transistors Q_7, Q_8, Q_9, and Q_{10}) buffers the voltage developed across C_{comp} to drive an output load. In addition to performing a current-to-voltage conversion, C_{comp} also maintains amplifier stability, eliminating oscillations at high frequencies.

The current-feedback operation of the transimpedance amp brings a number of significant performance benefits. Among them are bandwidth stability, low phase nonlinearity, fast slewing, and uniform rise and fall times.

Of these benefits, bandwidth stability is one of the most important in a wide range of applications. Since the error signal from R_f is a current rather than a voltage, the transimpedance amp does not rely on negative feedback to produce a virtual ground at its inverting input terminal. As a result, there is no need for feedback correction techniques, which would degrade bandwidth. Moreover, when R_f is held constant, the closed-loop bandwidth remains stable, independent of the closed-loop gain.

Also, because current feedback eliminates the need for phase-degrading negative-feedback circuitry to maintain amplifier stability, the phase response of the transimpedance amp remains linear over a wide range of input frequencies. A linear phase relationship ensures that all of the harmonic components of a signal are delayed by the same amount of time, regardless of their frequency.

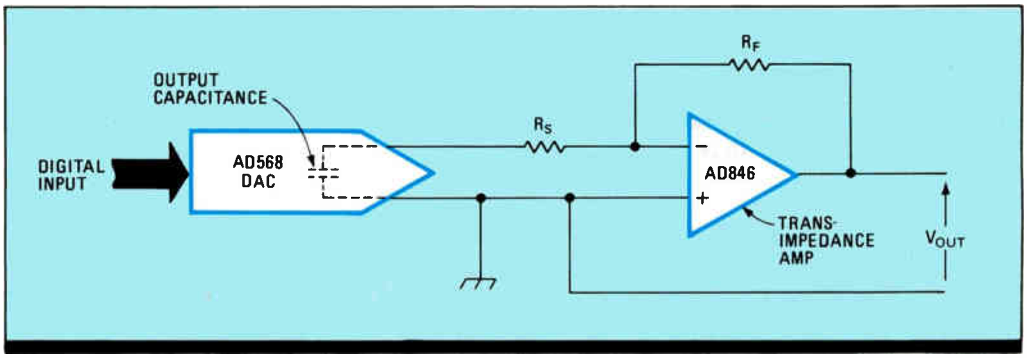
Finally, current-feedback operation also promotes uniform rise and fall times. The transimpedance amp's slew rate increases instantaneously with input signal current. A step input will turn on one side of the amplifier, while turning off the other side—in effect, switching two identical current sources on and off. Because of this behavior, rise and fall times are essentially equal for any given output voltage swing.

Yet another performance benefit of the transimpedance amp is low distortion, because the part uses its internal transistors as current-amplifying, rather than voltage-amplifying, devices. Since bipolar transistors are inherently current devices, they operate in their most linear mode, keeping both harmonic and intermodulation distortion low.

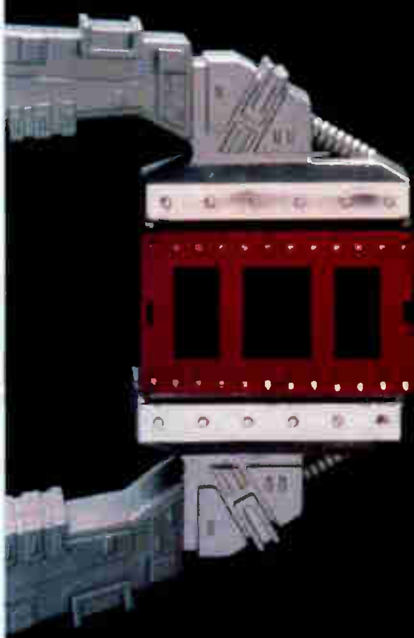
Last but not least, the high transresistance (open-loop gain) of the transimpedance amp minimizes gain error, which is simply the ratio of transresistance (a high value) to feedback resistance (a low value). For example, a 500-MΩ transresistance combined with a 1-kΩ feedback value will hold gain error to merely 0.0005%. Furthermore, gain error stays constant. In contrast, the gain error of the op amp degrades proportionally as closed-loop voltage gain rises.

Not surprisingly, the transimpedance amp's fast settling time over a wide range of gains makes it ideal as a DAC buffer for such jobs as waveform generation, coaxial-cable drivers, and instrumentation displays. With the transimpedance amp, the low input impedance of its inverting input effectively shorts out a DAC's output capacitance at the amplifier's summing node, thus greatly reducing the effect of that capacitance on settling time.

The circuit of fig. 3 demonstrates how a DAC can harness the power of a fast-settling wideband transimpedance amp to boost load-driving capability. The AD568 high-speed 12-bit monolithic DAC in the circuit has a current-settling time of 35 ns to within 0.025%, and it takes 40 ns to drive a typical 75-Ω video load from 0 to 1.024 V. To generate a



3. BUFFERING DACs. As an output amplifier for a DAC, the transimpedance amp boosts load-driving capability without slowing the DAC. In effect, its low-impedance inverting input shorts out a DAC's output capacitance.



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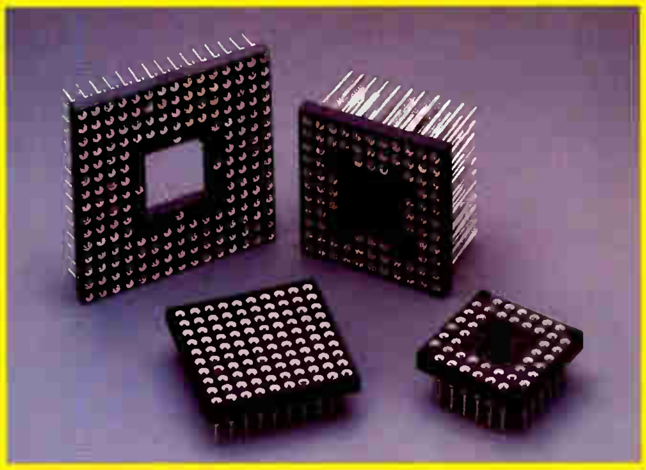

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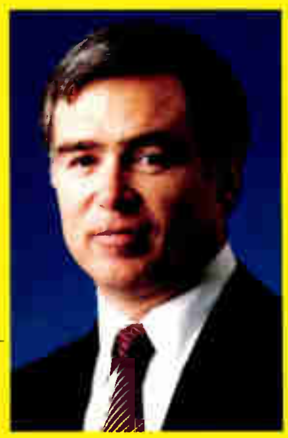

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MILITARY/AEROSPACE NEWSLETTER

THE U.S. WILL SPEND $300 MILLION FOR CHIP RESEARCH IN 1988...

The catch-all spending bill President Reagan signed just before Christmas included some mammoth stocking stuffers for the semiconductor industry. Not only did the bill include a promise of $100 million for Sematech, the industry consortium that hopes to drive U. S. chip-making technology (see story p. 32), but the President and Congress also agreed to fund almost $200 million in other semiconductor research and development projects. The U. S. is now committed to spending $15 million on X-ray lithography research at four labs, including the Brookhaven National Laboratory; $10 million on compound semiconductor research at Sandia National Laboratory; and $25 million on advanced compound semiconductor research, probably at the University of Florida. In addition, the Pentagon's Very High Speed Integrated Circuits Program scored $100 million, and Mimic, the Defense Department's program for microwave and millimeter-wave integrated circuits [*Electronics*, Nov. 26, 1987, p. 121], got $46.1 million. That represents a $3 million cut from what the DOD had requested, but a Mimic official says the cut "shouldn't be too painful." □

...BUT ONLY $2 MILLION FOR THE DOD'S FOCAL PLANE ARRAY INITIATIVE

The Defense Department's planned Focal Plane Array Initiative—a program aimed at developing reliable manufacturing technologies for infrared sensor arrays—was dealt a near-fatal blow by Congress in its final 1988 spending bill. The Pentagon had been seeking $45.1 million for the program but Congress approved only $2 million. Congress said that the DOD should draw more specific program proposals before seeking more money next year, according to an aide to Sen. Jeff Bingaman (D-N.M.). Last fall, sources warned that the DOD and industry had not been able to agree on how the program should be structured [*Electronics*, Oct. 1, 1987, p. 94]. It is not yet clear what strategy the Pentagon will now pursue, but one official close to the program promises "we'll do something." □

HUGHES ADAPTS ITS RADAR SYSTEM FOR AIR-TO-GROUND WEAPONS CONTROL

GMHE/Hughes Aircraft Co. may have found a new market for its workhorse airborne radar equipment with a $58 million contract to develop a weapons-control system for air-to-ground weapons. The Radar Systems Group of the El Segundo, Calif., company, is modifying its APG-70 radar—used in F-15 aircraft—into a weapons-control system for the AC-130U gunship, an Air Force plane based on the C-130H cargo craft. Rockwell International Corp. is building the gunship, which will carry a 105-mm howitzer and 25- and 40-mm cannons. Hughes says its radar was chosen because its synthetic aperture capability provides high-resolution ground imagery. It is now adding target, tracking, and weather functions. The first system is already in production and should be delivered by next December. □

DOD CONTRACTORS ARE LOSING A KEY TAX ADVANTAGE: DEFERRALS

Defense contractors, already reeling from decreased government spending and rising competition, will take an additional hit in 1988 when a provision of the 1986 tax reform act takes effect. Under new regulations, companies will no longer be permitted to defer income taxes on government contracts until the deal is complete. The effect will be "a lower cash level and a higher rate of borrowing," says Paul H. Nisbet, an analyst with Prudential-Bache Securities in New York. Until 1986, companies could defer payment of all federal income taxes on government contracts until the pacts were completed. The 1986 tax law cut that amount to 80% in 1987 and 30% in 1988. □

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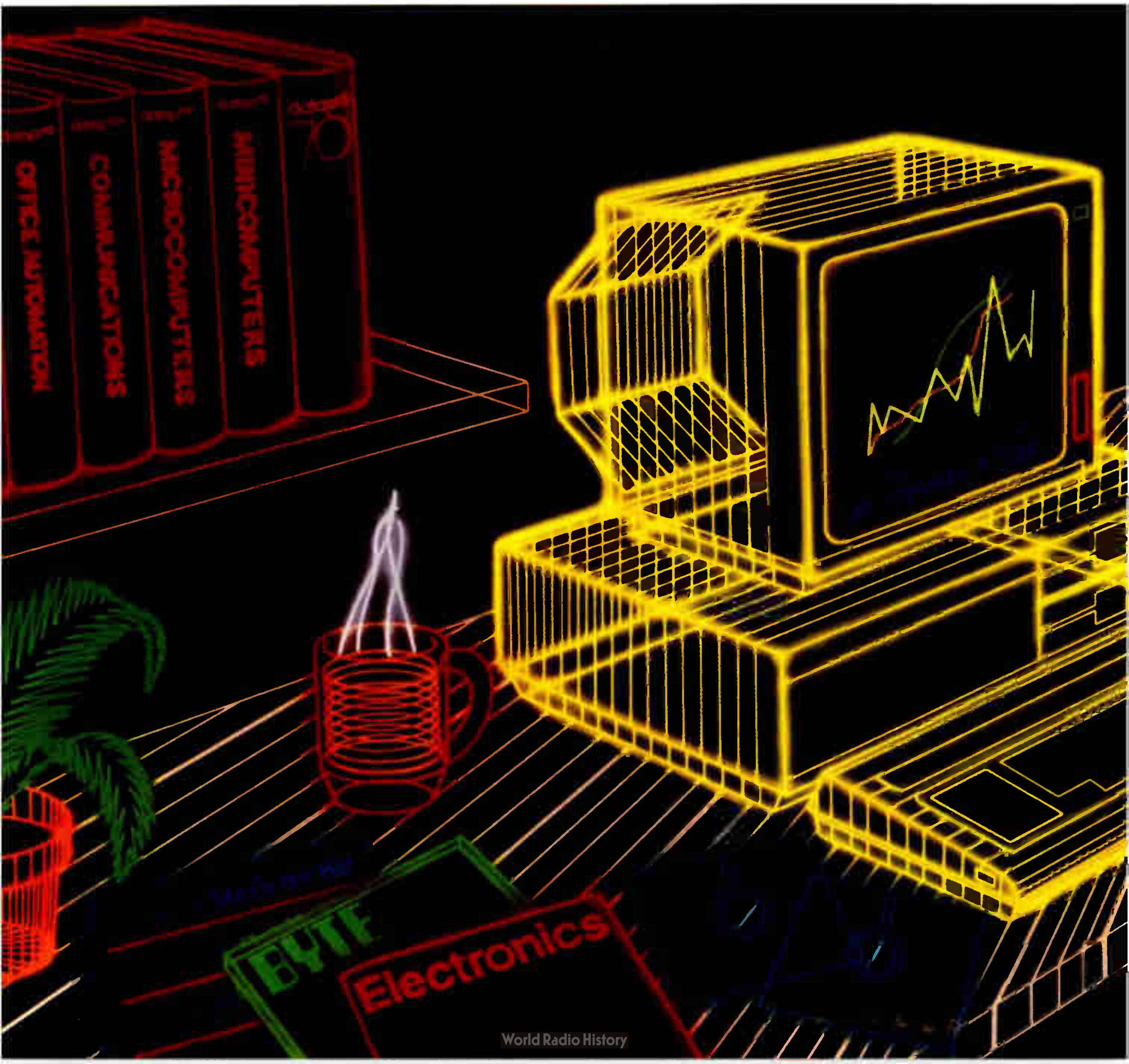


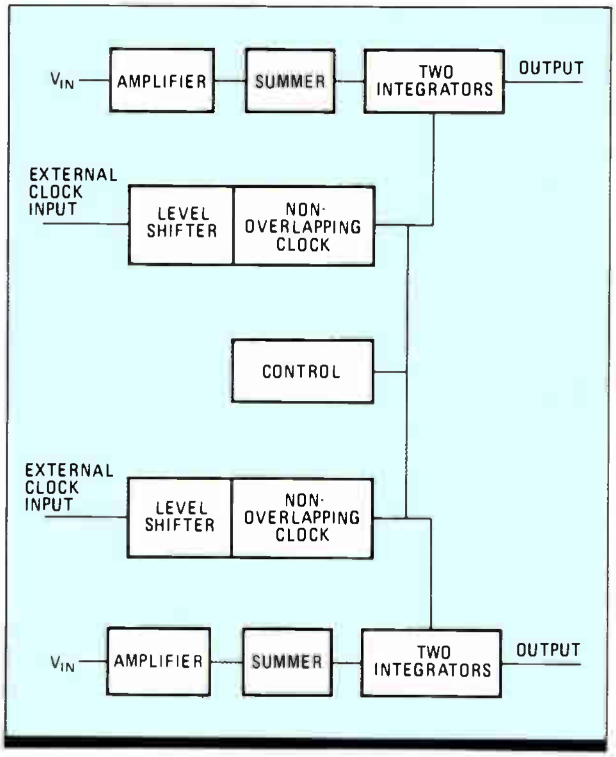
SWITCHED-CAPACITOR FILTER CHIP OFFERS 30 TIMES GREATER BANDWIDTH

MICRO LINEAR USES 3-MICRON LINEAR PROCESS TO DELIVER 150 kHz

Micro Linear Corp.'s ML2111 switched-capacitor filter chip uses an advanced 3-µm CMOS linear process to deliver 30 times the performance of competing monolithic devices. It also delivers superior versatility because it implements two second-order filters on the same chip.

Each of the chip's two second-order filters boasts a guaranteed upper frequency of 150 kHz—compared with a guaranteed upper frequency of 5 kHz for competing switched-capacitor filters. Its operating frequency (Q × center frequency) is 5 MHz. The chip is so far ahead of its monolithic competition that it offers the performance and many of the features of active filters and continuous-time filters implemented in discrete components, the San Jose, Calif., company claims.

By using resistor biasing and simple pin-selection techniques, designers can handle practically any filter configuration, including Butterworth, Chebyshev, Bessel, and Caurer. A variety of outputs can also be implemented with the ML2111, including bandpass, lowpass, highpass, allpass, and notch.



DUAL FILTERS. The ML2111's two on-board filters each can be used as a first-order or second-order quadratic filter.

Such capabilities mean the ML2111 will break new ground for switched-capacitor filters. It can be used in such traditional active-filter and continuous-time-filter applications as ultrasound, sonar, loran, and filtering for communications applications such as data-encryption, baseband transmissions, local-area networks and data communications, says Charles Gopen, vice president of marketing.

A pin-compatible replacement for such industry-standard switched-capacitor filters as the MF10, LMF100, and LTC1060, the ML2111 is priced competitively, says Gopen, but with superior frequency and noise performance. Some manufacturers of currently-available switched-capacitor filters claim frequencies as high as 20 kHz, he says, but such operation is usually specified under certain optimized conditions and not guaranteed.

Unlike competing switched-capacitor filters, the ML2111 permits a 10% tolerance on its 5-V supplies. Up to 150 kHz is guaranteed using ±5-V supplies and up to 100 kHz using a single 5-V supply.

In addition to roughly comparable performance, the ML2111 compares favorably on cost bases with many active filters. This is particularly true for high-frequency applications that must use expensive video-bandwidth operational amplifiers and highly precise and stable passive components. These solutions, of course, suffer from printed-circuit-board-layout problems such as stray capacitances.

By comparison, a high frequency filter realized with the ML2111, says Gopen, eliminates such problems. Because the ML2111 is a monolithic CMOS device, it presents designers with fewer layout problems and can also significantly reduce component count in many applications. For example, a second-order bandpass/lowpass filter can be built with the ML2111 using only two ordinary resistors, the ratio of which sets the Q value of the filter. A more conventional active filter implementation would require three op amps, seven resistors, and two capacitors with tolerances on the order of, or tighter than, the desired tolerance of the center frequency.

The ML2111's center frequency is determined by an external clock and is as stable as that clock. Clock inputs are both CMOS- and TTL-compatible. A sampled-data filter that closely approximates the performance of continuous-time filters, the ML2111 is a dual bi-quad device with two on-board filters. Each of these filters can be used as a first-order or second-order quadratic filter. With one chip, says Gopen, a user can realize two second-order filters or a single fourth-order filter. Each filter consists of a precision, low-offset-voltage amplifier, a voltage summer, two integrators, and control logic. The integrators, says Gopen, are high-speed devices with settling times of about 60 ns.

ACCURATE. The ML2111's other key specifications include center frequency accuracy of ±0.4%, a Q accuracy of 0 to –4%, a dc open-loop gain of 95 dB, and a gain bandwidth product of 2.4 MHz.

The devices come in three temperature ranges: 0° to 70°C; –40° to 85°C; and –55° to 125°C. Available now in sample quantities in standard 20-pin dual in-line plastic or 20-pin small outline packages, the ML2111 ranges in price from $6.95 each in 100 unit quantities, depending on package and temperature specifications.

– Bernard C. Cole

Micro Linear Corp., 2092 Concourse Dr., San Jose, Calif., 95131.
Phone 408-262-5200 [Circle 360]

HYBRID AMP HAS DOUBLE THE AGC OF SILICON ONLY

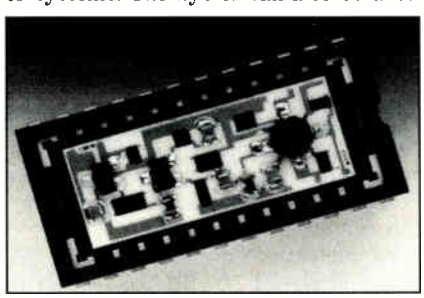
A general-purpose hybrid ac-coupled amplifier component from National Semiconductor Corp. combines the fast input capabilities of depletion-mode gallium-arsenide transistor technology with the high power outputs of bipolar silicon transistors. Among the performance advantages of this hybrid technology is a doubling of the automatic-gain-control range offered by all-silicon devices. What's more, the 24-pin LH4200 runs from 500 kHz to 1 GHz and costs just one-half the competition's price, the Santa Clara, Calif., company claims.

The hybrid has an AGC range of 60 dBm running at 100-MHz, compared with 30 dB offered by similar amplifiers based on silicon-only technology, according to managers at National's Hybrid System Products Group. It targets applications such as voltage-controlled amplifiers, feedback-stabilized amps, mixer amps, ultra-high frequency oscillators, and the video diode receivers that are often used in radar and weapon-guidance systems.

THREE STAGES. National's thick-film hybrid-assembly process marries a dual-gate GaAs FET and a pair of discrete silicon transistors on an alumina substrate. The GaAs FET in the hybrid's input stage delivers a high impedance of 1 MΩ, as well as high-frequency capabilities. The LH4200's two discrete bipolar silicon transistors are used in the second and third stages for low-output impedance. They also provide the capability of driving 50-Ω transmission lines.

The three stages have decoupling capacitors to cut parasitic oscillation, eliminating the need for series inductors at the power-supply pins. The 4200 boasts a noise performance of 3 dB in 50-Ω systems and 2 dB in 800-Ω designs.

Applying –2 V to the GaAs integrated circuit's second input gate makes the part ideally suited for automatic-gain-control or gated radio-frequency amplifier systems. The hybrid can also be used



MARRIAGE. The LH4200 combines GaAs and bipolar for an AGC range of 60 dBm at 100 MHz.

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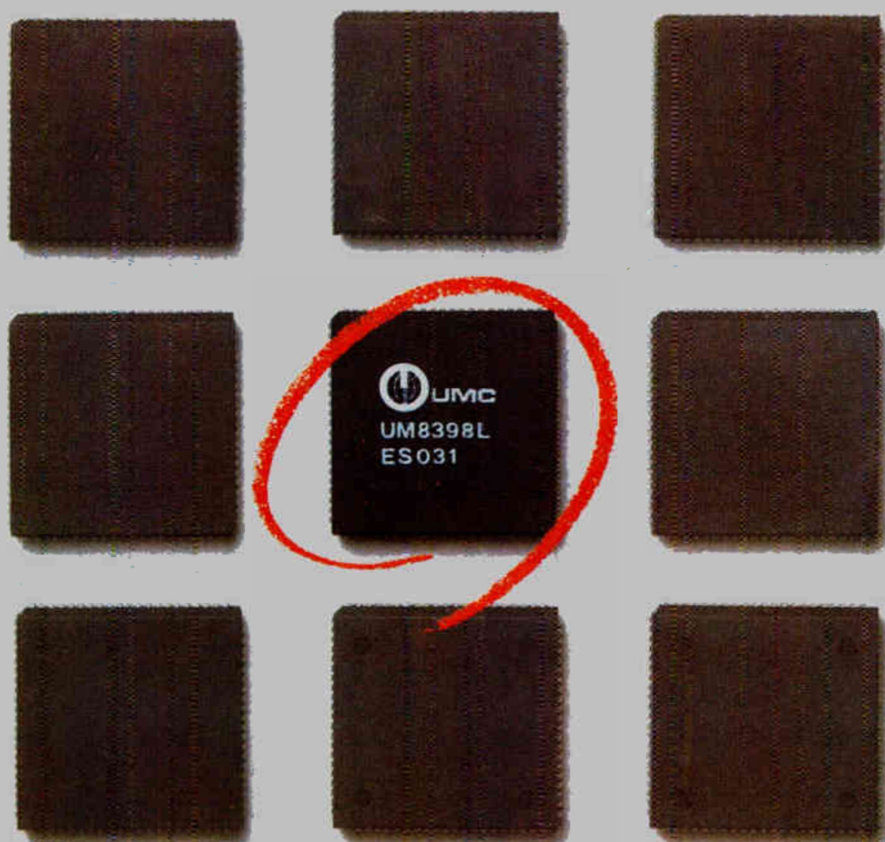

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ferently with metal masks, will be sold as 33-MHz PLS167 and PLS168 parts. All three versions are aimed at meeting the speed requirements of the new 16.7-MHz 32-bit microprocessor hosts, says Robin, who calls them a second-generation PLS family.

The 28-pin PLS105 has 16 inputs, 8 outputs, and 14 flip-flops. The 24-pin PLS167 offers 14 inputs, 6 outputs, and 12 flip-flops; and the 24-pin PLS168 has 12 inputs, 6 outputs, and 14 flip-flops. The family represents the first parts introduced by MMI since it merged with Advanced Micro Devices Inc. last August.

Like the Signetics chips, MMI's sequencers have an array of 48 product or transition terms, which can be shared between all outputs and six buried registers. The buried registers free up the use of input-output pins. System designers can use them for sequencers or state machines with about 30 to 40 states. An internal test array and security fuse features are include on the chips.

MMI is aiming the family primarily at small powerful systems, such as timing waveform generators, shift registers, counters, protocol converters, interface controllers, bus arbitration and handshake devices, data-storage peripherals, graphics, and micro-coded numeric processors.

"There is no other company that will have more ways of doing sequencers," says Robin, referring to the fact that AMD also offers PAL-based chips, the AM29PL141 instruction-based chips, and the recently introduced Prose family, which combines PAL and programmable read-only memory arrays.

In 100-piece lots, the PLS105 costs $17 each. The PLS167 and PLS168 parts cost $11 each in similar quantities. All three are available for standard commercial temperature ranges of 0° to 70° C. The power dissipation of the PLS105 sequencer is 180 mA, while the PLS167 and PLS168 dissipate 160 mA.

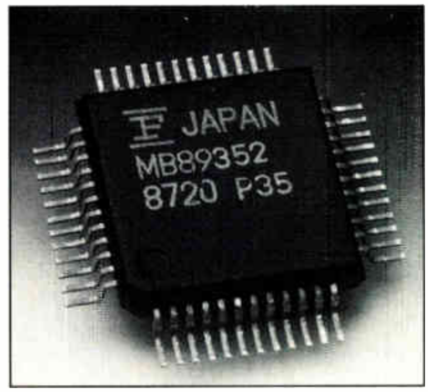
– J. Robert Lineback

Monolithic Memories Inc., 2177 Mission College Blvd., Santa Clara, Calif. 95054. Phone (408) 970-9700 [Circle 362]

SCSI CONTROLLER HAS ON-CHIP DRIVER

A Small Computer Systems Interface controller chip from Fujitsu Microelectronics Inc. eliminates the need for external drivers by integrating a 48-mA driver/receiver for direct connection to the SCSI bus.

The asynchronous MB89352 can be used either as an input/output controller or host adapter. An 8-byte first-in first-out memory and 24-bit transfer-byte counter help it to achieve a 2-Mbyte/s data-transfer rate.



The chip supports all American National Standards Institute X3.131 interface-control procedures except synchronous transfer. It works with both 16- and 8-bit microprocessors.

Available now, the MB89352 costs $7.80 in 1,000-unit purchases and less than $6 each in higher volumes.

Fujitsu Microelectronics Inc., 3320 Scott Blvd., Santa Clara, Calif. 95054.
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IC SWITCH SPEEDS INPUT/OUTPUT FOURFOLD

Gould Inc.'s S618840 crossbar switch breaks computer input/output bottlenecks by switching any input to up to 16 outputs. Port-to-port switching takes 25 ns or less, compared to 100 ns for methods such as shared-memory buses and multiport memories.

Functionally compatible with Texas Instrument Inc.'s 74AS8840, the SS618840 is dynamically programmable, letting users couple a processor to memory, to another processor, or to I/O ports. Reprogrammability also makes the chip suitable for applications such as fault-tolerant routing.

Samples are available now for $59 each in 100-unit quantities.

Gould Inc., Semiconductor Div., 3800 Homestead Rd., Santa Clara, Calif. 95051.
Phone (408) 554-2192 [Circle 366]

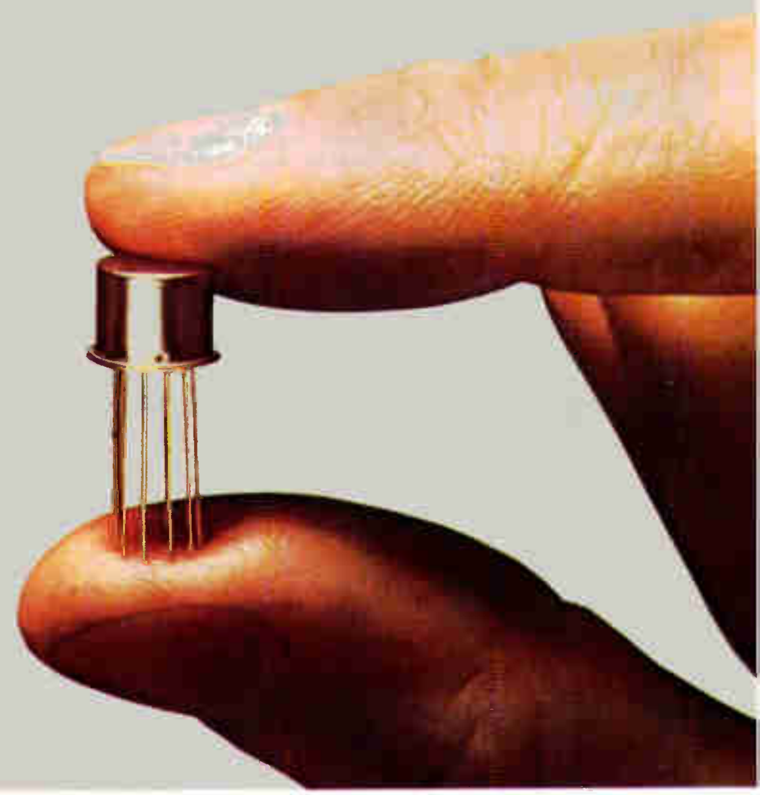
D-TO-A-CONVERTER IC BOASTS 12-BIT ACCURACY

A monolithic, 12-bit CMOS, quad digital-to-analog converter from Hybrid Systems Corp. includes a full microprocessor interface, double-buffered inputs, and is compatible with 8- and 4-bit byte formats. The company claims the device is the first of its type.

Fabricating the four DACs on a single chip gives the HS7584 a high level of gain-error matching between the four devices. CMOS technology ensures both low power consumption and single-source + 5-V operation.

A 100-ns data-set-up time allows the chip to interface with high-speed microprocessors and thin-film silicon-chromi-

New power TO-5 Relays handle loads up to 2 Amps



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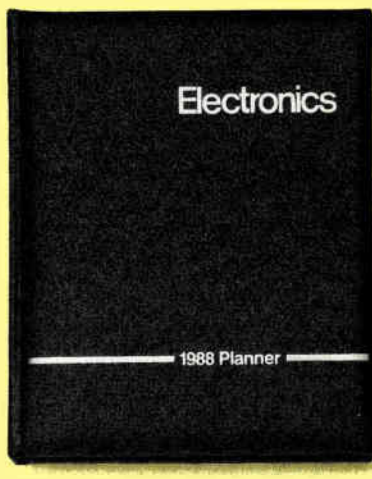

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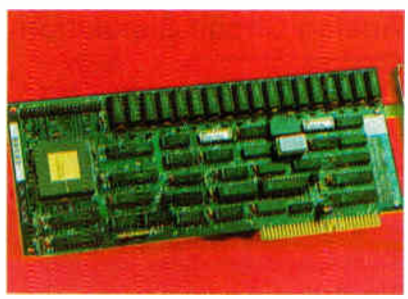

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Director of Circulation
[212] 512-6598
Roseann Lehmann
Office Administrator
[212] 512-3469
Frances M. Vallone
Manager, Reader/Sales Services
[212] 512-6058
Ann Strignano
Billing Specialist
[212] 512-2589
Thomas M. Egan
Production Director
[212] 512-3140
Carol Gallagher
Production Manager
[212] 512-2045
Lynette Albanese
Production Manager Related Products
[212] 512-2044
Postcards/Product Showcase
[212] 512-2143

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