SPECIAL ISSUE

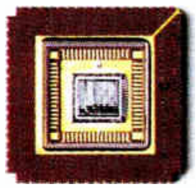
A McGRAW-HILL PUBLICATION SIX DOLLARS APRIL 2, 1987

Electronics

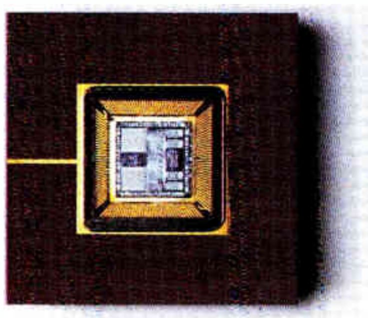
THE CHIP MAKERS: WHERE THEY'RE HEADING

GLOBAL ALLIANCES, SYSTEMS ON CHIPS, AND DESKTOP DESIGN WILL PULL A STRUGGLING INDUSTRY INTO THE 21ST CENTURY

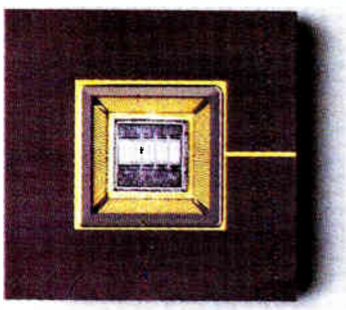
PAGE 59



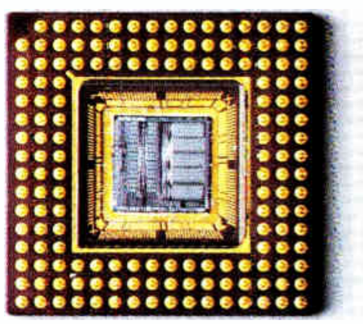
Our MACGEN silicon compiler developed the world's fastest 16-bit multiplier accumulator.



High Performance cell-based 1750 CPU combines logic, ROM and processors.



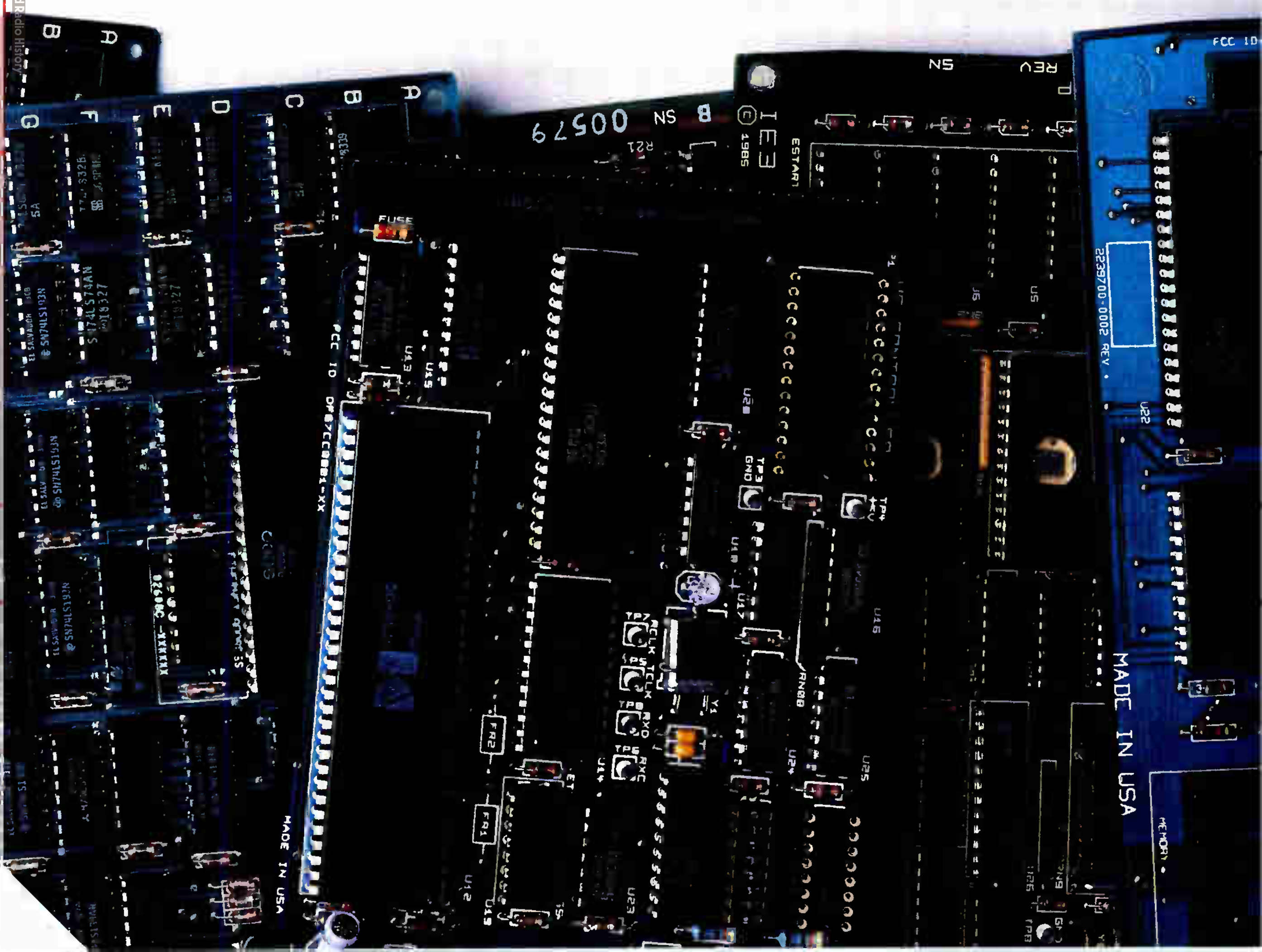
Structured Arrays combine high-density memories with up to 41,000 logic gates.



Channel-free Compacted Arrays combine logic and memory functions with up to 129,000 available (up to 70,000 utilized) gates.

See us at CICC

HOW TO AVOID GOING OVERBOARD.



If your system design looks good on a board, think how impressive it's going to look on a single chip.

Which is precisely where our 1.5-micron ASIC technology will put it.

Now every design is downsized, whether you're working with our Standard and Structured Cells,™ or Structured Arrays™ and channel-free Compacted Arrays.™ Or our silicon-compiled 16-bit and 32-bit MAC chips.

All of them let you design a more powerful system with fewer components and fewer bugs. A system with more functions, in less space.

But it's not just our 1.5-micron CMOS technology that makes your designs more efficient.

It's also our ASIC design tools that let you create any cell or array solution with the same proprietary software methodology.

Use our LDS™ core software with any one of our fifteen add-on modules. Like the advanced behavioral or multi-chip simulator, chip floorplanning or logic simulation accelerator.

And you're guaranteed working parts whether you design on your own mainframe, mini or engineering workstation. Or at any of our 30 ASIC design centers—the largest network in the world.

We've shortened prototype delivery time, too. A mere five to six weeks for Structured Cells, three for Compacted Arrays and Structured Arrays, and as little as ten days for Gate Arrays.

Call your nearest LSI Logic design center, or send us your system design problem. We'll show you just how quickly you can jump into higher integration.

Without going overboard.

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LSI Logic Sales Offices and Design Centers: Milpitas, CA 408-433-8000, San Jose, CA 408-248-5100, Irvine, CA 714-474-2960, Sherman Oaks, CA 818-906-0333, Denver, CO 303-756-8800, Westport, CT 203-222-9336, Altamonte Springs, FL 305-339-2242, Boca Raton, FL 305-395-6200, Bethesda, MD 301-897-5800, Chicago, IL 312-773-0111, Waltham, MA 617-890-0161, Ann Arbor, MI 313-769-0175, Minneapolis, MN 612-835-6161, Poughkeepsie, NY 914-454-6593, Raleigh, NC 919-783-8833, Trevose, PA 215-638-3010, Austin, TX 512-343-4513, Dallas, TX 214-788-2966, Bellevue, WA 206-822-4384, Calgary, Alta 403-262-9292, Edmonton, Alta 403-424-8845, Kanata, Ont 613-592-1263, Toronto, Ont 416-622-0403, Paris, France 33-1-46-21-25-25, Israel 972-3-403741, Ibaragi-ken, Japan 81-298-52-8371, Tokyo, Japan 81-3-589-2711, Osaka, Japan 81-6-947-5281, Sweden, 46-8-520720, United Kingdom, 44-344-426544, Munich, West Germany 49-89-926903-0, Düsseldorf, West Germany 49-211-5961066, Stuttgart, West Germany 49-711-2262151. Distributors: Hall-Mark; Hamilton/Avnet; Schweber; Wyle.

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Tek curve tracers: No other measurements cost so little and save so much!

Affordable and easy to operate, Tek curve tracers visually document the performance characteristics of semiconductor devices.

For tightening design parameters and protecting yourself against the high cost of component failure, nothing compares with the Tek family of curve tracers.

Tek curve tracers help you quickly test semiconductor devices like diodes, transistors, opto isolators, thyristors and operational amplifiers. They can help you design, analyze and evaluate ...to detect problems early, before they become far more costly to remedy.

Curve tracer mainframes include the 576, with both CRT display and scale factor readout ...and the 577, with storage and non-storage CRT displays.

Test fixtures compatible with the 576 include the 176 pulsed high current test fixture that can supply up to 200 amps or 1000 watts to the device under test and the 172 programmable test fixture that offers the convenience and high throughput of semi-automated measurements. Compatible with the 577 are the versatile 177 standard test fixture and the 178, designed to test the performance of linear ICs.

Two curve tracer plug-ins are also available for Tek laboratory oscilloscopes: the 7CT1N for 7000 Series and the 5CT1N for 5000 Series scopes.

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Call 1-800-547-1512.
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Tektronix
COMMITTED TO EXCELLENCE

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Most any resourceful magazine can put together a passable special report that covers its own country. Then it can distribute that report—at home. But when it comes to a worldwide view of the electronics business and technology situation, we like to think that we have the market cornered.

Our prime advantage is our global network of editors. Compared to that, the others have a minimal editorial network. It is no accident that our circulation is worldwide: readers on all continents know that they can keep informed about what's new in electronics and which of the developments is most important simply by keeping up with *Electronics*.

YOUNG: Calm and efficient while organizing the report.

The latest example of that broad-based talent and expertise is the 25-page special report in this issue (p. 59) on the semiconductor industry. This comprehensive study brings home to every reader not only the lesson that in the next century the industry will exist in a form that is quite different from what we know today, but that the semiconductor business is truly global in the same way that other basic industries are. That is why a really useful look at the industry requires our global perspective.

But journalism on that level requires talents and skills that go beyond mere reporting and writing. For example, organizing and keeping track of such a mass of information and scores of illustrations is a truly monumental task that was performed with distinction and calm efficiency by Features Editor Jeremy Young. Of course, he had lots of help: sections of the report were written by Sam Weber, Cliff Barney, Bernie Cole, and Art Erikson in addition to Jeremy. They worked with reporting provided by our own overseas staff of Charlie Cohen in Tokyo, John Gosch in Frankfurt, and Steve Rogerson in London. In addition, Mike Berger and Don Shapiro of McGraw-Hill World News provided coverage of the Pacific Rim countries. Wes Iversen, Chicago; Rob Lineback, Dallas; Tobias Naegele, New York, and Larry Waller, Los Angeles, supplied domestic reporting. And Ben Mason, associate managing editor, made sure all the words say exactly what they are meant to say.

The planning and execution of projects like the semiconductor report are carried out over a period of months. Conditions change during that time, forcing a switch of one sort or another in focus, coverage, or organization. With this report, we had a perfect example of how that is handled.

Art Erikson, whose broad experience overseas provides him with the kind of background that few editors in the electronics trade press can boast, was responsible for the global sections of the report. "Just after I had finished the section discussing strategic alliances between U. S. and Japanese companies and what they will mean in the next 20 years, the planned purchase of Fairchild Semiconductor Corp. by Fujitsu Ltd. was called off. So I had to revise the piece with a somewhat different approach," he recalls. "It was a challenge."

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Electronics

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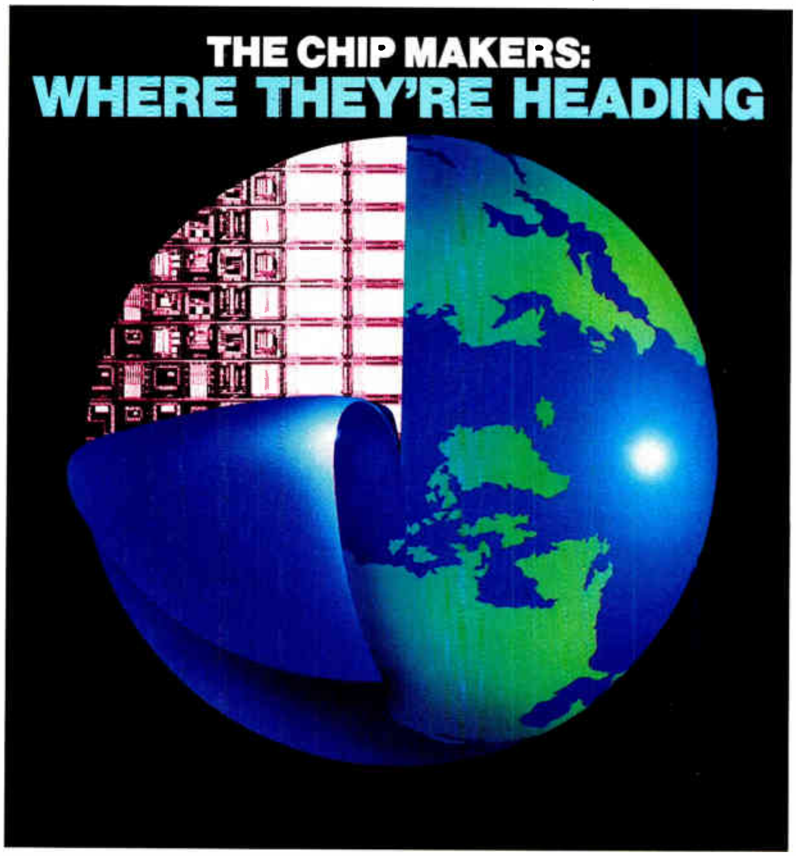

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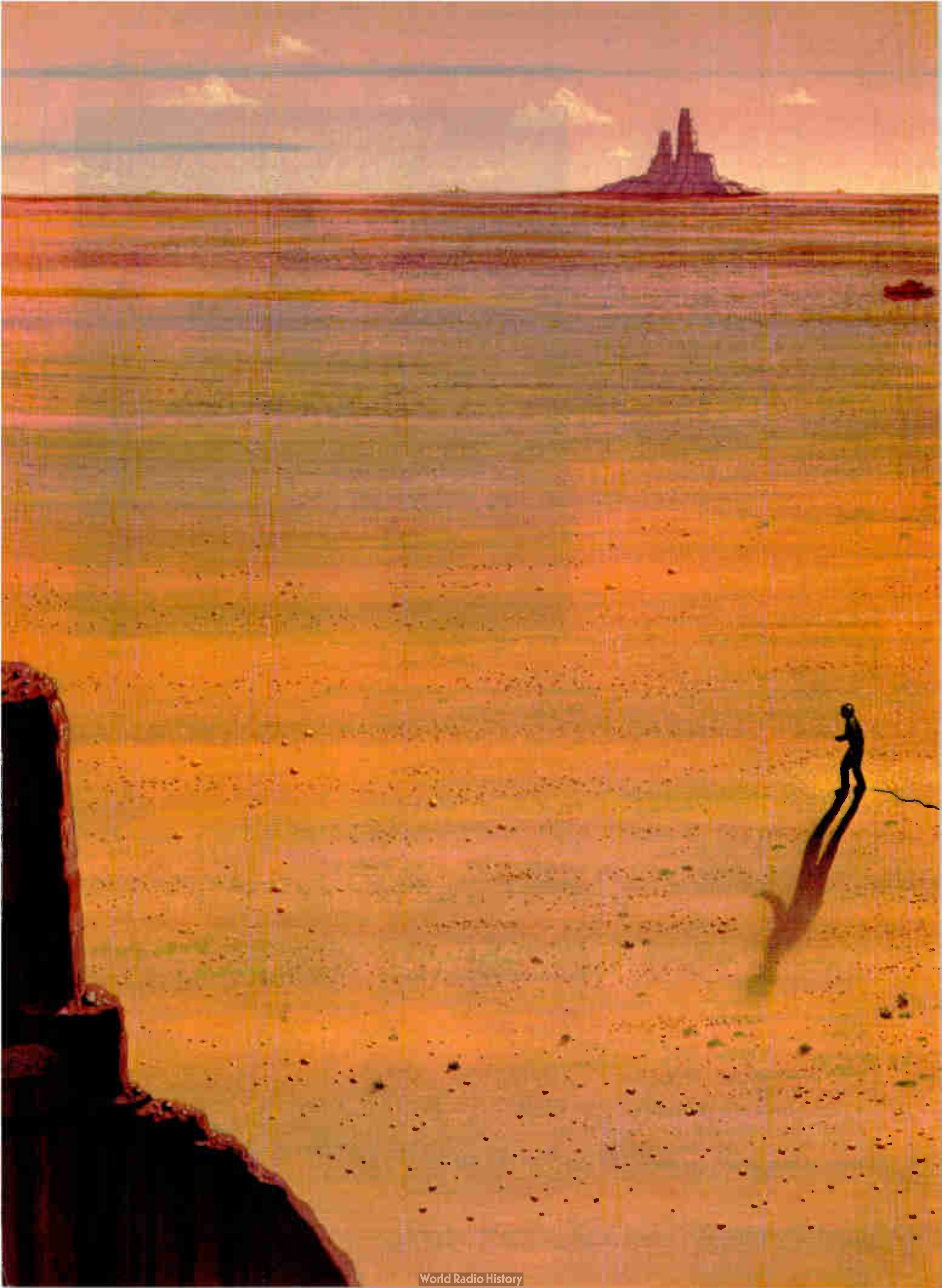
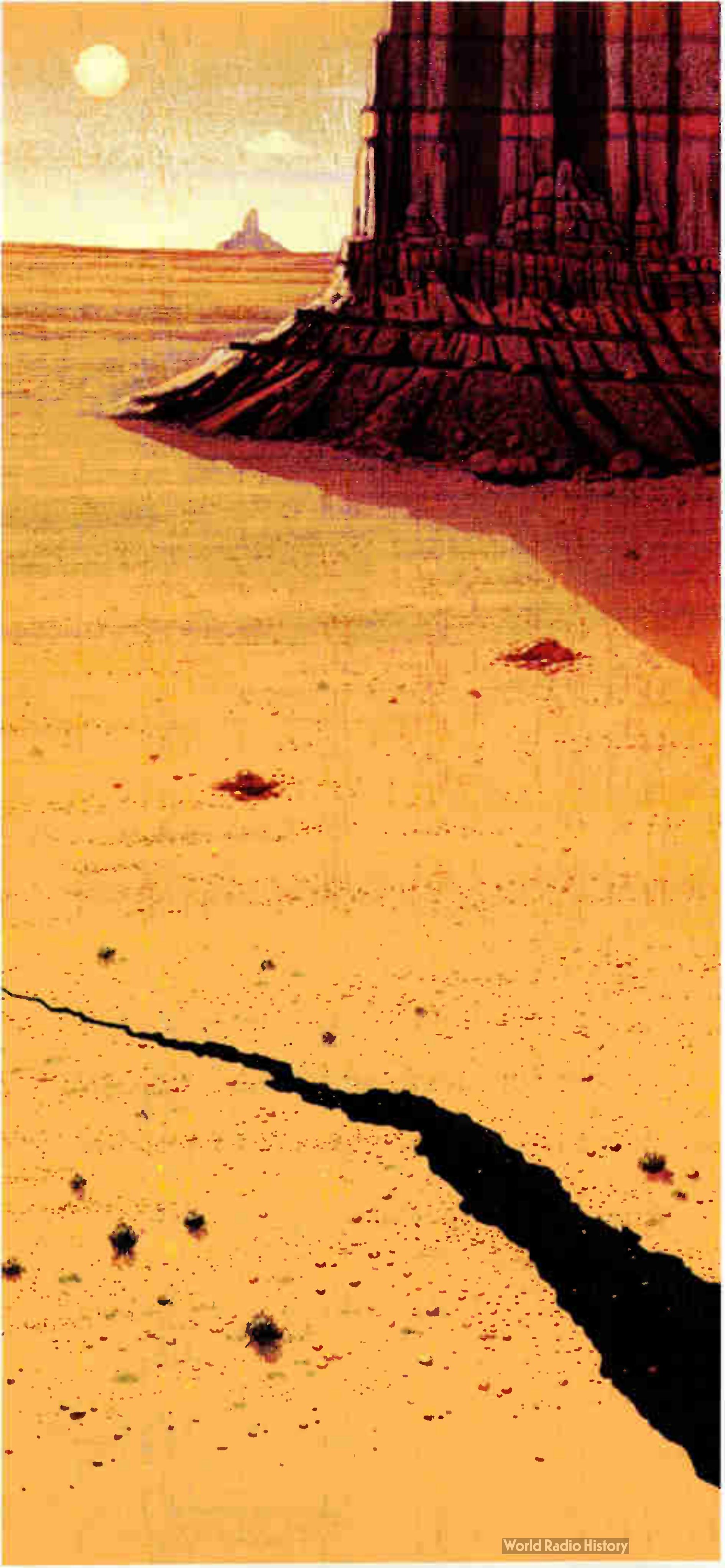
NEW PRODUCTS

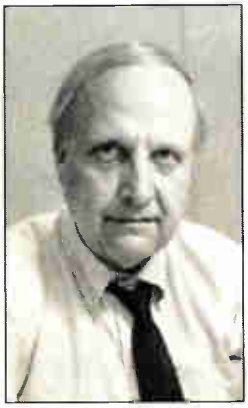
DEPARTMENTS





FYI

2000 is closer than most realize; long-term technology trends tell us plenty, and the outlook for chip makers is far brighter for most than the pessimists would have us believe



It is definitely not true that we decided to examine what the semiconductor industry would look like in the year 2000 (see. p. 59) because it was a much easier task than reporting on what next year holds for the chip business. In fact, few editors and even fewer market researchers would be sufficiently foolhardy or experienced to carry out the effort to figure out where the chip makers are heading.

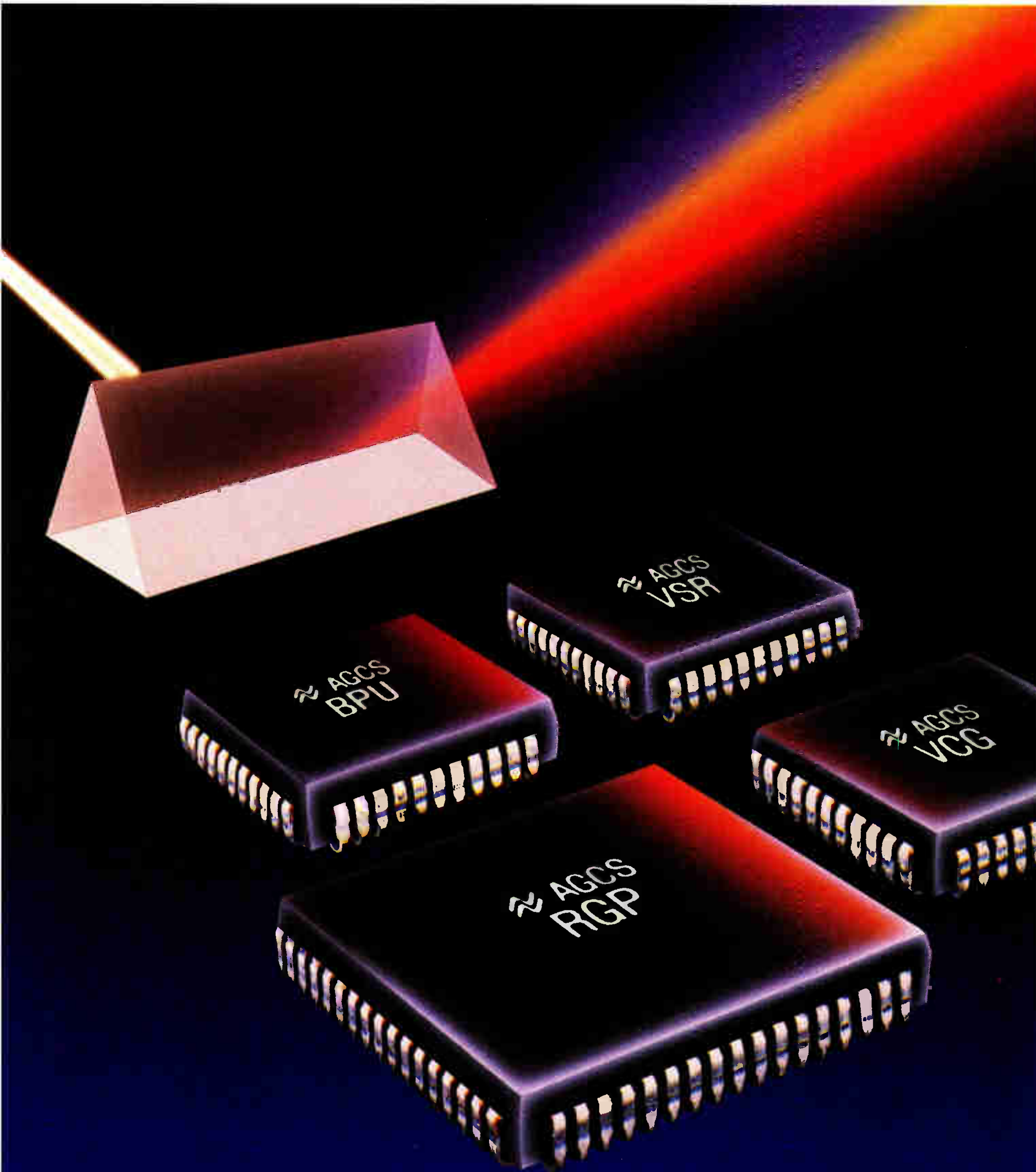
For one thing, 2000 is a lot closer than most people realize. Second, long-term technology trends already tell us plenty about the beginning of the 21st Century. The outlook, we're delighted to report, is far brighter for most than the pessimists would have us believe. Consider these points:

We definitely will not have to close down the patent office. Tough design problems still need to be solved, but there is a good chance that designers will be working with chips containing 1 billion (!) transistors. Between now and 2000, the industry will have likely made it through two more dislocations as intense as the one we're suffering now: the first will be the emergence of sophisticated computer-aided design tools that will cause a round of restructuring in the early 1990s, when it becomes possible for system designers to develop circuits with their own private desktop CAD systems. A second tremor will hit, probably in the late 1990s, when production geometries drop below half a micron, a trend that most likely will require radical new solutions in processing, materials, and perhaps even a new transistor structure.

We believe that by 2000 the industry will divide into two camps: The commodity business may even look like what the naysayers have been predicting for the entire industry, and the made-in-America segment may not be all that large; but the semicustom camp should be just as exciting in technology change, new products, market growth, and new company startups as this industry has ever experienced. Some market watchers even believe the semicustom business will be a far larger market than the commodity side will represent in 2000.

But if the chip industry is to grow and prosper as we expect, it cannot be fettered by artificial means. Open world markets are vital, and every nation must open its market to everyone. To do otherwise would invite no-win trade wars. We continue to be the optimist. By 2000, chip makers will have made the electronics industry the biggest, most important business of all. **ROBERT W. HENKEL**

National
Semiconductor



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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

Raster Graphics Processor (RGP). A fully programmable, high-performance microprocessor engine specially tuned for graphics applications. Samples available Third Quarter, 1987.

Bitblt Processing Unit (BPU). A 20-MHz data chip that controls data movements within its dedicated memory plane and between it and other memory planes in a multi-color system. Available now.

Video Clock Generator (VCG). A timing and control generator providing all of the synchronization signals needed by a graphics system, with a pin-programmable pixel frequency of up to 225 MHz. Available now.

Video Shift Register (VSR). A parallel-to-serial shift register capable of serial output shift rates up to 225 MHz. Available now.

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:

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

National Semiconductor

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MEETINGS

Seminar on Marketing Intelligence for Industrial Products and Services, Delta Planning Group Inc. (1001 E. Touhy Ave., Suite 91, Des Plaines, Ill. 60018), Hotel Sofitel, Chicago, April 20-21.

35th Annual National Relay Conference, National Association of Relay Manufacturers (P.O. Box 1505, Elkhart, Ind. 46515), Oklahoma State University, Stillwater, Okla., April 20-22.

4th Annual Conference on Copper Thick Film Technology, International Society for Hybrid Microelectronics (P.O. Box 2698, 1861 Wiehle Ave., Suite 340, Reston, Va. 22090), Phoenix, Ariz., April 21-22.

MICONEX '87, IEEE Computer Society, *et al.* (512 Bower Blvd., Winnipeg, Manitoba, Canada, R3P 0L8), Winnipeg Convention Centre, Winnipeg, Manitoba, Canada, April 21-23.

Fourth Annual Electrical Overstress Exposition, EOE (2504 N. Tamiami Trail, Nokomis, Fla. 33555), San Jose Convention Center, San Jose, Calif., April 21-23.

Eighteenth Annual Modeling and Simulation Conference, School of Engineering, University of Pittsburgh (348 Benedum Engineering Hall, University of Pittsburgh, Pittsburgh, Pa. 15261), Pittsburgh, Pa., April 23-24.

1987 Annual Systems Conference, Association for Systems Management (24587 Bagley Rd., Cleveland, Ohio 44138), Louisville, Ky., April 26-29.

ROBOTS 11/17th International Symposium on Industrial Robots, Robotics International Society of Manufacturing Engineers (One SME Drive, P.O. Box 930, Dearborn, Mich. 48121), Chicago, April 26-30.

IEEE Instrumentation and Measurement Technology Conference, IEEE Instrumentation and Measurement Society (1700 Westwood Blvd., Los Angeles 90024), Sheraton-Boston Hotel, Boston, April 27-29.

IFIP 6.5 International Working Conference on Message Handling Systems, International Federation for Information Processing (IFIP Secretariat: 3, rue du Marche, Ch-1204 Geneva, Switzerland), Munich, April 27-29.

The 1987 AIIM Show, Association for Information and Image Management (1100 Wayne Ave., Suite 1100, Silver Spring, Md. 20910), Jacob Javits Center, New York, April 27-30.


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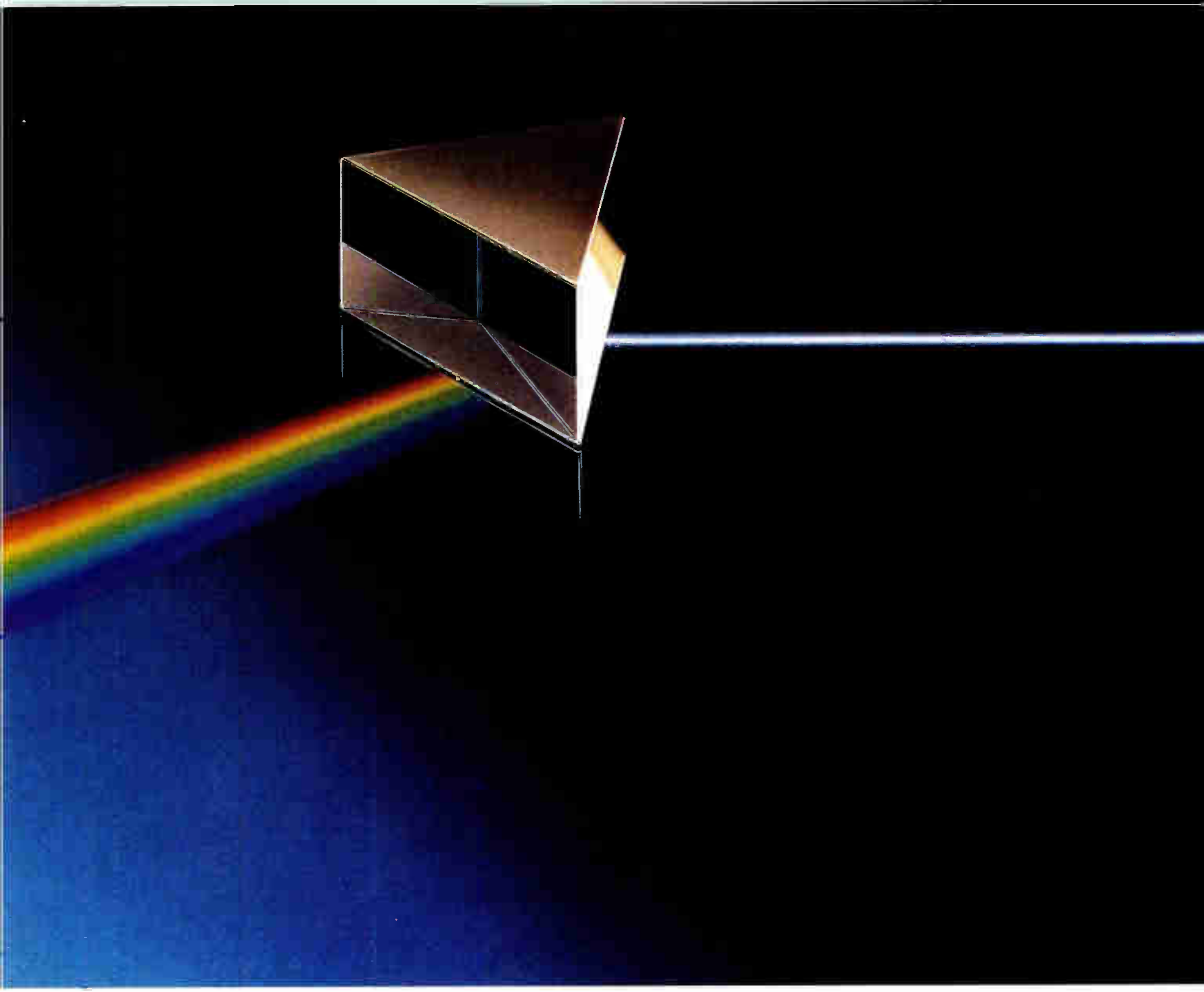
Our Tateyama plant is the newest, most-advanced CMOS VLSI manufacturing base in Japan. Total computerized operation and robot control in Class 1 ultra clean rooms facilitates wafer fabrication to one-micron geometry. Leading-edge design, processing, and testing technologies ensure total reliability.



Response

DRAM

	Product No.	Organization	Access Time Maximum(ns) tRAC	Access Time Maximum(ns) tCAC	Cycle Time Minimum(ns)	Mode
256K	AAA2800 SERIES	256KX1	60/70/80	11/12/13	121/136/151	Static column decode, Page, Nibble, Clocked Serial
1M	AAA1M100 SERIES	1MX1	100/120	20/25	190/220	Static column decode, Page
	AAA1M104 SERIES	256KX4	100/120	20/25	190/220	Static column decode, Page
1M	*AAA1M200 SERIES	1MX1	60/80	15/20	100/130	Static column decode, Page, Nibble
	*AAA1M204 SERIES	256KX4	60/80	15/20	100/130	Static column decode, Page

SRAM

Product No.	Organization	Access Time Maximum(ns)
16K AAA16K4	4KX4	25/35 ns
64K AAA64K1	64KX1	35/45 ns

DRAM MODULE

Product No.	Organization	Access Time(ns)
MM2800 SERIES	256KX8/9	70/80/100

(Products marked * are currently under development.)

For Additional Information, Please Contact:

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Santa Clara, CA 95054, U.S.A
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1. The primary end product (or service performed) at your plant, and the product (or service) that is your own work. (Insert one code for each)

☐ **Plant** ☐ **Own work**

A. Computers, data processing and peripheral equipment, office and business machines
B. Communications, data communications, telecommunications systems and equipment
C. Navigation and guidance, aircraft and missile systems and equipment (oceanography)
D. Test and measurement equipment
E. Consumer products (TV, radio, hi-fi, recorders, home computers, appliances)
Q. Medical systems and equipment
R. Industrial control systems and equipment
G. Semiconductor production equipment (component insertion, coil winding, etc.)
H. Electronic sub-assemblies, components and materials (active and passive components, ICs, discretes, hybrids, power supplies)
I. Other manufacturers using electronic equipment as part of their manufacturing process (machine tools, chemicals, metals, plastics, pharmaceuticals, etc.)
J. Government and military
K. Independent research and development laboratories or consultants
L. Research and development organizations which are part of an educational institution
M. Independent software developers
N. Operators of communications equipment (uti ities, railroads, police, airlines, broadcasters, etc.)
O. Educational: 2-4 year colleges, universities
P. Other (please describe) __________

2. ☐ **Your principal job function: (Insert one code only)**

A. Corporate management (owner, partner, president, VP, etc.)
B. Operating management (general manager, group manager, division head, etc.)
C. Engineering management (project manager, chief engineer, section head, VP of engineering, VP of research and development, VP of quality control, etc.)
D. Software engineering
E. Systems engineering/integration
F. Quality control engineering (reliability and standards)
G. Design engineering
H. Engineering support (lab assistant, etc.)
I. Test engineering (materials, test, evaluation)
J. Field service engineering
K. Research and development (scientist, chemist, physicist, etc.)
L. Manufacturing and production
M. Purchasing and procurement
N. Marketing and sales
O. Professor/instructor at __________
P. Senior student at __________
Q. Graduate student at __________
Z. Other (please describe) __________

3. ☐ **Your principal responsibility: (Insert one code only)**

1. General management
2. Engineering management
3. Engineering
4. Other __________

4. Estimated number of employees at your location: (Check one box only)

☐ 1 to 49 ☐ 50 to 249 ☐ 250 to 999 ☐ 1,000 or more

5. Your engineering function: (Check all that apply)

A. ☐ I design or develop electronic products and systems (hardware and/or software)
B. ☐ I supervise electronic design or development engineering work
C. ☐ I set standards for, evaluate, test and/or support the manufacture of design components, systems and materials
D. ☐ Other function (please describe) __________

6. In your company or organization, do you participate in: (Check all that apply)

A. ☐ Business planning and forecasting
B. ☐ Product planning
C. ☐ Technology planning
D. ☐ No involvement in planning

7. Your involvement in the following stages of product development: (Check all that apply)

A. ☐ Evaluate the need for new products
B. ☐ Develop device specifications
C. ☐ Evaluate suppliers
D. ☐ Review prices and availability
E. ☐ Select Vendors
F. ☐ Approve purchases
G. ☐ Place orders
H. ☐ No involvement

8. ☐ **What is your title? (Insert one code only)**

Operations Management

01. President/Chairman/Owner/Partner
02. Vice President
03. Vice President of Engineering
04. Product Marketing Manager

Engineering Management

11. Technical Director
12. Chief Engineer
13. Principal Engineer
14. Research Director
15. Section Head
16. Project Engineer
17. Senior Engineer
18. Software Manager
19. Senior Test Engineer
20. Senior Field Test Engineer
21. Manufacturing/Production Manager
22. Group Leader
23. Department Head
24. Other Management (please explain) __________

Design or Standards Personnel

31. Systems Engineer
32. Software Engineer
33. Test Engineer
34. Field Test Engineer
35. Manufacturing Engineer
36. Production Engineer
37. Engineer
38. MTS
39. Consultant
40. Scientist
41. Physicist
42. Other Staff (please explain) __________

9. Products that you specify or authorize purchase of: (Check all that apply)

ICs and Semiconductors
01. ☐ Digital ICs
02. ☐ Linear ICs
03. ☐ Microprocessors
04. ☐ Semiconductor memories
05. ☐ Custom/semicustom ICs

Components
11. ☐ Resistors and capacitors
12. ☐ Interconnections
13. ☐ Switches and relays
14. ☐ Optoelectronic components
15. ☐ Readout and display devices
16. ☐ Fiber-optic components
17. ☐ Printed circuits

Equipment
21. ☐ Power supplies
22. ☐ Test and measurement equipment
23. ☐ Automatic test equipment
24. ☐ Field service test equipment
25. ☐ Analog/digital panel meters
26. ☐ Cabinets and enclosures
27. ☐ Semiconductor production equipment
28. ☐ Robotics components/equipment
29. ☐ Microprocessor development systems

Computer-based Systems and equipment
31. ☐ CAE hardware/software
32. ☐ CAD/CAM hardware/software
33. ☐ Minicomputers
34. ☐ Microcomputers
35. ☐ Computer terminals
36. ☐ Computer boards
37. ☐ Disk/tape memories
38. ☐ Graphic displays
39. ☐ Software packages/services
40. ☐ Printers/plotters
41. ☐ Computer peripherals
42. ☐ Modems
43. ☐ Communications equipment
44. ☐ None of the above

10. Your degree of profit accountability: (Check one box only)

A. ☐ I have direct profit responsibility
B. ☐ I share profit responsibility with others
C. ☐ I have no profit responsibility

11. Your level of sign-off or purchase approval authority for your company or organization: (Check one box only)

A. ☐ None
B. ☐ Less than $1,000
C. ☐ $1,001 to $ 5,000
D. ☐ $5,001 to $10,000
E. ☐ $10,001 to $25,000
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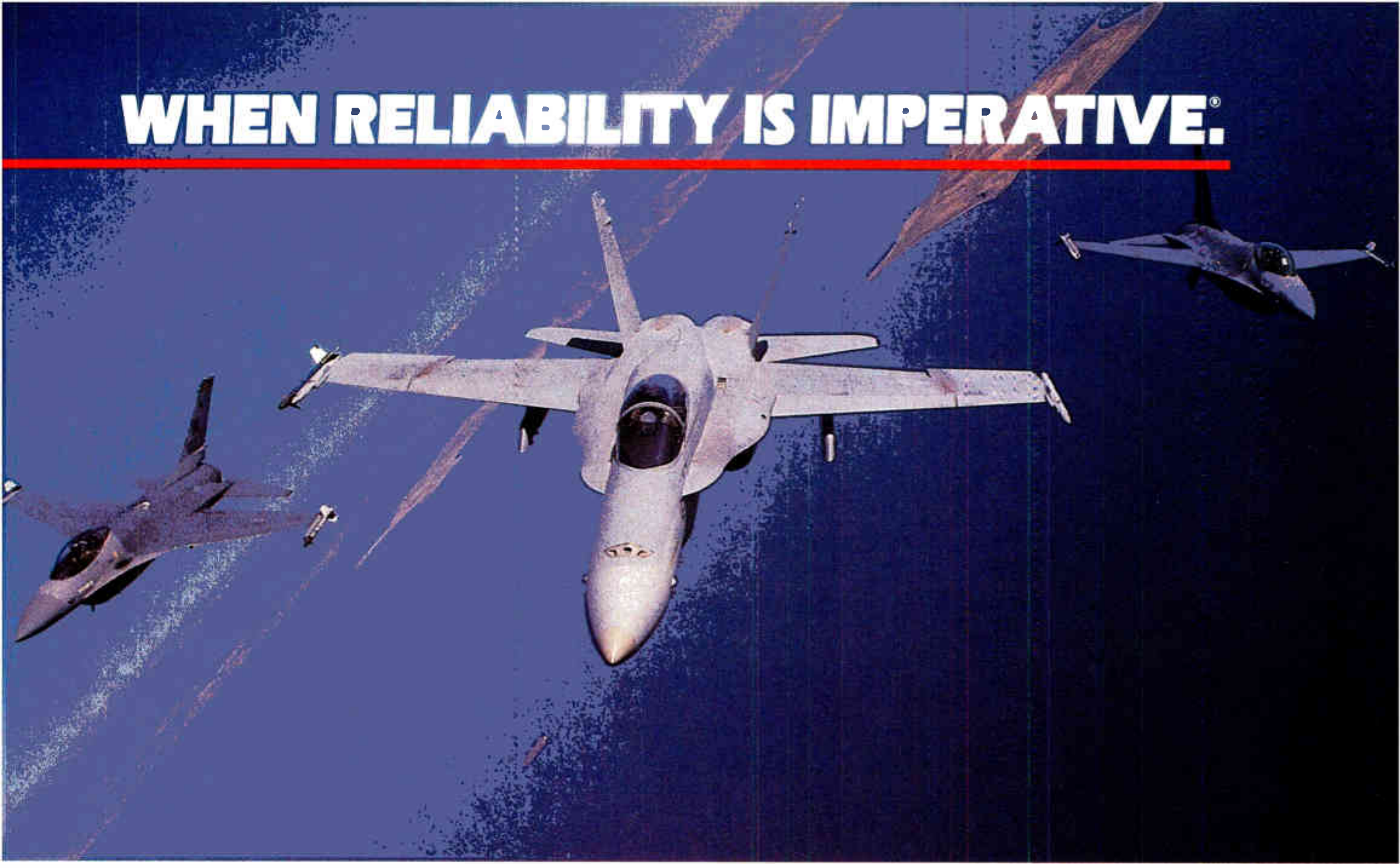

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ELECTRONICS NEWSLETTER

MONOLITHIC MEMORIES ABRUPTLY LEAVES THE GATE-ARRAY BUSINESS...

Monolithic Memories Inc. is abruptly ending its gate-array venture, citing poor prospects for profits, but it sees greener pastures elsewhere. Field-programmable logic may be headed for higher densities, and the Santa Clara, Calif., company believes that's where its future lies. MMI pulled out of the gate-array market after only five months—last fall it promised a series of arrays with up to 6,000 gates [*Electronics*, Oct. 30, 1986, p. 25], but the company's perspective changed when prospects for higher-density field-programmable logic-cell arrays brightened recently. Unlike gate arrays, these chips do not require simulation or final metalization steps. MMI second sources logic cell arrays from Xilinx Inc. of San Jose. The Xilinx chips, although now limited to less than 2,000 gates, are expected to attain much higher densities later this year. □

...JUST AS AT&T CLIMBS ABOARD THE GATE-ARRAY TRAIN

AT&T Co. is slipping into the high-performance semicustom chip business with a line of three gate arrays, all based on the same proprietary, double-level metal, complementary bipolar process. The move is another step in AT&T's strategy to go commercial with parts it is producing successfully for its own use. The top-of-the-line chip is the LA200 UHF array, which will be able to support frequencies of 4.0 GHz in npn transistors and 2.5 GHz for pnp transistors. The LA300/LA301 has a high voltage feature that provides a minimum collector-to-emitter reverse breakdown of 90 V for both transistors. The LA400 provides a frequency of 350 MHz for npn transistors and 300 MHz for pnp transistors. All three arrays consist of uncommitted vertical npn and pnp transistors, capacitors, and diffused and ion-implanted resistors. They are designed on a grid system, to simplify interconnects, and can be produced very quickly—turnaround times are just 4 to 8 weeks. □

BOWING TO MITI PRESSURE, TI WILL CUT MEMORY PRODUCTION IN JAPAN

Texas Instruments Inc. is grudgingly bowing to pressure from Japan's Ministry of International Trade and Industry to join six Japanese chip makers in cutting memory chip production by 13% at its Japanese subsidiary. TI agreed to comply with new quotas set on March 23 by MITI, which singled out TI Japan Ltd. for not responding to first-quarter targets to lower production of dynamic random access memories and erasable programmable read-only memories. Japan hopes reduced production will dry up the gray market and help avert U. S. trade sanctions over alleged dumping of memory chips into Asian markets. TI Japan has contended that as a U.S.-owned company, it should be immune to MITI-mandated production cuts, since "a cut in TI Japan production is inconsistent with the second part of the U.S.-Japan Semiconductor Trade Agreement, which aims to increase the market share of American-based companies." □

NEW PC FROM IBM EXPECTED TO RUN ALL THREE OF ITS GRAPHICS STANDARDS

Makers of color graphics adapter boards expect the clone-killer due momentarily from IBM Corp. to include an analog monitor supporting all software written for IBM's three graphics standards. The monitor reportedly has a 31.5 kHz horizontal scan rate, with three vertical frequencies: 50 Hz (noninterlaced) for the color graphics adapter, 60 Hz for the extended graphics adapter, and 70 Hz for the professional graphics adapter. The fast horizontal frequency allows a double-scan mode that boosts resolution of the CGA boards to 640 by 400 pixels, says Genoa Systems Corp., a San Jose, Calif., company waiting in the wings with graphics boards for the new PC. □

ELECTRONICS NEWSLETTER

TI AND LINEAR TECHNOLOGY JOIN UP TO MAKE IT BIG IN LINEAR ICs

Two U.S. chip makers are out to significantly expand their combined 10% share of the $5 billion worldwide linear IC market. Texas Instruments, which accounts for about $450 million in linear sales, and Linear Technology Corp. (LTC), a five-year-old linear IC maker with $45 million in annual sales, are banding together in a five-year strategic alliance. The deal gives LTC the second source and advanced processing technology it needs to keep growing and to expand into more advanced linear circuitry. And it provides TI access to LTC's line of proprietary linear circuits, as well as to the Milpitas, Calif., company's stable of top analog designers. TI recently labeled linear circuitry as its fifth focused chip thrust [*Electronics*, Mar. 19, 1987, p. 34]. The Dallas company will be able to second-source up to 25% of LTC's products over the next five years, picking 60 devices from LTC's current lineup of 120 products and the 120 that it expects to design during that period. TI will also invest about $1 million for warrants to purchase 735,000 shares of LTC. The two companies will also jointly develop new ICs, in such areas as combined analog-digital circuits and very high-speed parts using TI's 1-μm processes.□

MOSTEK'S NEW STRATEGY FOR 16-BIT MICROCONTROLLERS: STAY FLEXIBLE

Mostek Corp. is revamping the layout of a 16-bit microcontroller first offered in 1983, hoping to make the chip easier to tailor to individual needs. The Dallas company will show the revised MK68HC200 and a new strategy in 16-bit microcontrollers at Electro in New York in April. The 16-bit microcontroller market is just getting started, and Mostek is trying to make its offering the most flexible available, with configurable blocks of memory or input/output circuitry on both sides of the central processing unit. The CPU is compatible with Mostek's original n-channel MK68200, but the new CMOS chip is much faster, with 8-, 10-, and 12.5-MHz internal execution speeds rather than the older part's 6-MHz top speed. Mostek hopes to let customers begin to make custom variations by next year. □

WILL AT&T'S 3B2/600 HELP ITS MINICOMPUTER BUSINESS?

AT&T Co. is moving to strengthen its lackluster computer business, but its minicomputers continue to struggle. "We know very well we have to enhance the high end of our minicomputer line," said Vittorio Cassoni, senior vice president at AT&T's Data Systems Division, before introducing late last month the 3B2/600, a minicomputer two to four times more powerful than its previous top model, the 3B2/400. AT&T also is planning to have a more powerful 3B2 version and a personal computer based on Intel Corp.'s 32-bit 80386 microprocessor before the end of the year. But it remains at best "a third- or second-tier player," says Kenneth Bosomworth, of International Resource Development, Norwalk, Conn. □

A FLAT SATELLITE ANTENNA BOWS THAT CAN BE BUILT INTO A PORTABLE TV

Comsat General Corp. of Washington, D. C., and Japan's Matsushita Electric Works Ltd., Osaka, have jointly developed a flat satellite antenna for the consumer market to replace the parabolic dishes in use today. Flat antennas have previously been used only in military applications. The new antenna uses a multilayer planar array rather than the phased-array system used by the military and operates in the Ku band. It is suitable for both the U. S. fixed satellite service (FSS) and the Japanese and European direct broadcast by satellite (DBS) systems. The new antenna was unveiled in London and will go on sale by the end of the year. Matsushita hints that it plans a version that could be built into portable TVs. □

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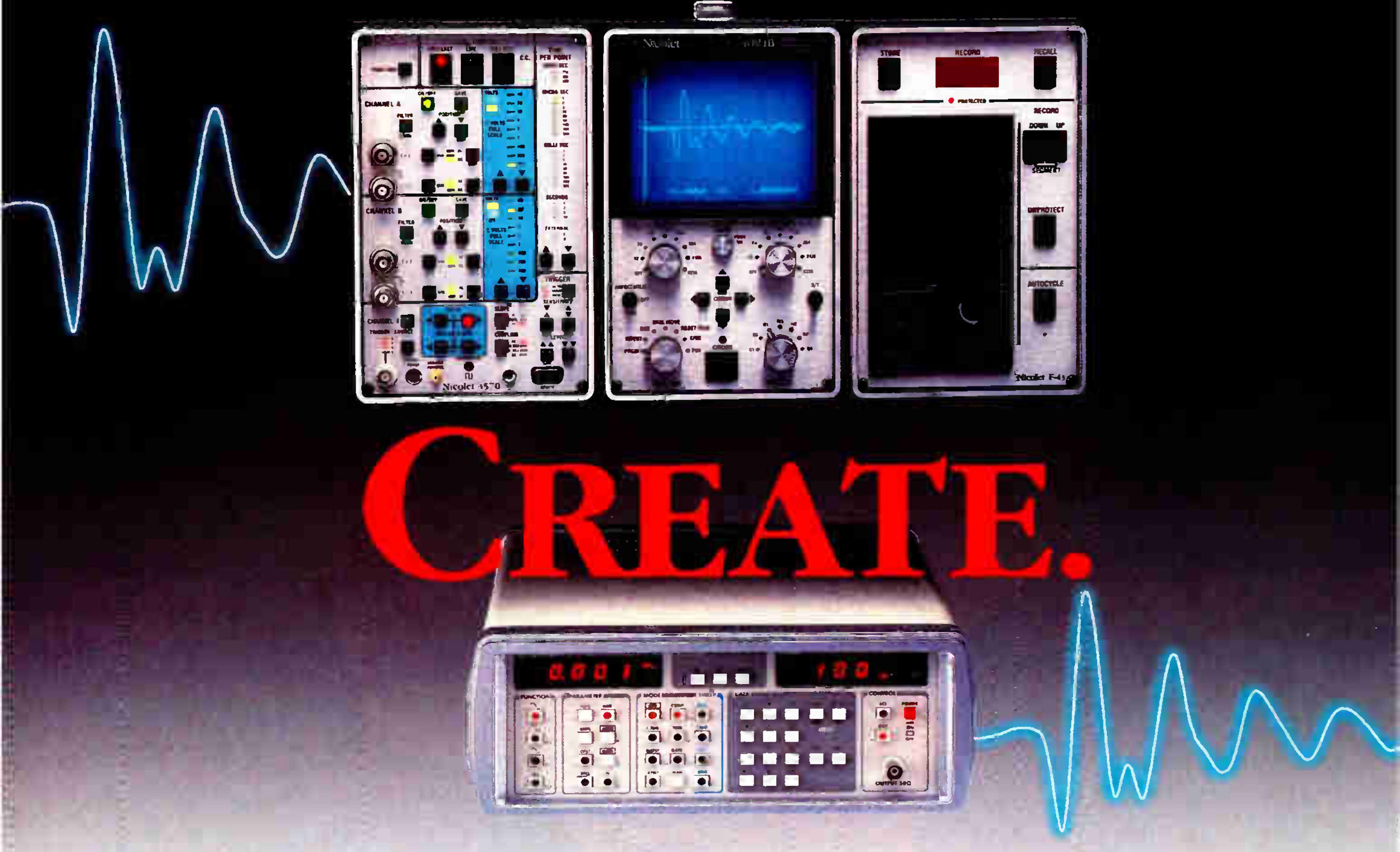

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Electronics

MATSUSHITA ROLLS OUT THE FIRST TRON-BASED PERSONAL COMPUTER

PROTOTYPE SHOWS OFF OPERATING SYSTEM THAT'S JAPAN'S 32-BIT HOPE

TOKYO

Three years after the start of Japan's TRON project to develop a new computer architecture, and at a time when Japanese makers more than ever need their own personal-computer operating system to compete in world markets, Matsushita Electric Industrial Co. has finally unveiled a working model of a TRON-based personal computer. The director of the project, Prof. Ken Sakamura of Tokyo University, envisions the new machine's operating system as no less than an international standard for the 32-bit computer era.

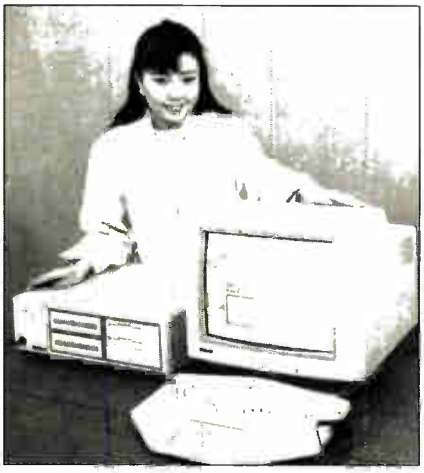
The machine runs under an operating system called BTRON, for business TRON. It is part of an industry-wide TRON effort to give Japanese makers a large chunk of the market for 32-bit computers. The effort lately has taken on a new sense of urgency, since Intel Corp. and Motorola Inc. have refused to sell the designs for their newest 32-bit processors to Fujitsu and Hitachi, which are jointly developing TRON chips. Matsushita, Mitsubishi, and Toshiba are also working on their own projects.

The Matsushita machine is very much a developmental model. It uses an 80286 for a central processing unit, because Matsushita's proprietary 32-bit TRON chip is not yet available. A production model of the machine is not likely to show up for two years.

TRON TRIO. Besides BTRON, Sakamura foresees systems called ITRON (for which NEC and Hitachi already sell software) for robots and test-system controls, and CTRON, for mainframes. Matsushita's announcement comes just before a symposium and demonstrations in Tokyo sponsored by the TRON project.

TRON, for "the real-time operating-system nucleus," includes a chip architecture optimized for fast task switching and a series of operating systems including BTRON [*Electronics*, May 12, 1986, p. 41]. "The machine waits for the operator rather than the other way around, as at present," says Yoshiaki Kushiki, an engineer at Matsushita's Central Research Laboratory in Osaka.

TRON also might be considered a real-time replacement for Unix, with standardized operations for applications programs in the manner of Macintosh—users don't have to learn different operations for various programs based on BTRON specifications. But machine-independent interfaces, and the TRON application data bus for compatibility among application programs, permit the use of various manufacturers' hardware. Also, the TRON application-control language provides a standard command language for data-processing tasks.



KEY DIFFERENCE. A striking feature of the BTRON computer is its ergonomic keyboard.

Since one goal is to make Japanese-language processing as simple as English word processing, Japanese processing and communications are included in the operating system. The file-management system provides real and virtual object modeling rather than the hierarchical model used in Unix, which the developers say is closer to the way people actually handle knowledge.

The computer also uses an ergonomic keyboard, a digitizer input tablet and stylus designed by Sakamura, and an image scanner. Other than the keyboard and a high-resolution windowing display that integrates text, graphics, and pictorial information, Matsushita's prototype looks like an IBM Corp. PC AT clone, with openings for two of the drive windows shrunk to accommodate 3.5-in. floppies.

The bit-mapped display has a resolution of 864 by 648 pixels. This shows only part of the contents of video random-access memory, which contains four planes of 1,024 by 1,024 pixels. Main memory is 2 Mbytes of RAM, and file memory consists of two high-density 3.5-in. floppy disk drives and a 20-Mbyte hard disk. There is also an interface for an optical disk. *–Charles L. Cohen*

COMPANIES

CAN BROOKS MAKE A NEW DEAL FOR FAIRCHILD?

CUPERTINO, CALIF.

Fairchild Semiconductor Corp. is hoping that momentum from parent Schlumberger Ltd.'s investments, which have modernized its plants and its product line, will keep the company moving at current rates long enough for it to find a new backer or to provide the income to support a management-led buyout.

But some industry analysts question whether Fairchild can sustain the heavy debt load that would be required to pay the $250 million believed to be Schlumberger's asking price. Accordingly, the collapse of the deal by which Fujitsu Ltd. would have become an 80% owner for $200 million has left Fairchild president Donald W. Brooks scrambling hard to find backing and keep the Cupertino, Calif., chip maker in one piece.

Bargain hunters are already looking at Fairchild's 32-bit RISC microprocessor, the Clipper, and its profitable high-speed-logic lines, should Schlumberger decide to deal them off piecemeal. The parent company, itself weakened by management changes and a declining oil market, is reportedly eager to be rid of a semiconductor venture that has cost it an estimated $2 billion. Brooks had set up the Fujitsu deal as a way of relieving Schlumberger of a relationship that had become a burden.

Brooks's problem is that, shorn of Fujitsu, Fairchild no longer looks so attractive. "Fairchild has a credibility problem," says Richard Skinner of Integrated Circuit Engineering Corp. in Scottsdale, Ariz. "Schlumberger could pull the plug any day. Some potential customers have held off designing in Fairchild parts because they weren't sure it would be around." Several venture capitalists say the company is not an attractive buy. "It's a second-rank supplier of parts that people designed in a long time ago, plus some sexy products like the Clipper," says one Silicon Valley market researcher.

Brooks insists that all of the alliances that had been arranged with Fujitsu—second-sourcing, foundry relationships, the development of joint products, and a joint cell library—will still be carried out, and that Fairchild will have the same strengths with Fujitsu as a partner as it would have with the Japanese company as a parent. Fujitsu is already making some of the chips in the Clipper set.

BUYOUT FUNDS. None of these substitutes for Fujitsu's deep pockets, but "there are substantial funds for a management buyout," Brooks claims. Debt would be paid off from profitable operations, Brooks says: high-speed logic, in which Fairchild says it's No. 1; standard logic, in which it is No. 3; and the Clipper. Fairchild's February book-bill ratio was the best in two years at 1.2:1, Brooks adds, and the company thinks it can get back in the black this year. Eventually, he says, the firm will make a public stock offering.

Brooks almost had Fairchild safely under Fujitsu's wing when the deal broke down. Whether Fairchild was hit by the crossfire in a trade war, held hostage by the Department of Defense, sabotaged by jealous competitors, or simply ended up odd man out in a deal that soured between Fujitsu and Schlumberger, isn't yet clear. Every explanation has its adherents, with the trade dispute getting the most votes. Commerce Secretary Malcolm Baldrige had strongly opposed the merger as the dispute over gray market operations in Japanese chips threatens to boil over into a full-fledged tariff war.

All the alliances with Fujitsu will be carried out, Brooks emphasizes

But Brooks says the pressure that finally halted the deal was not the product of any coherent national policy. "This is an 'event,' not a policy," he says, "and Fairchild was victimized by it." Brooks says he thought the Fujitsu deal had been torpedoed by his competitors, who had "kindled a fire" over the national security issue, and by the Commerce Department, which was using it as a weapon against the Japanese. "We continue to believe that the acquisition would have been advantageous for the constructive resolution of the U.S.-Japan trade issue and would have resulted in more jobs in the United States and more sales in Japan," he says.

Fujitsu management itself hasn't said what it thinks. But Shoichi Saba, chairman of the Electronic Industries Association of Japan and chairman of Toshiba Corp., says he doesn't think that trade problems directly killed the deal. Instead, he blames perceived security problems.

Brooks gets widespread praise from industry analysts for bringing Fairchild back from the brink. Yet they are not as sanguine about his chances of beating the double whammy of the heavy debt that would result from a buyout and a slow-growth industry still plagued by a recession.

"Brooks is a feisty guy, and you've got to give him credit for trying," says one West Coast analyst who follows Fairchild. "He cares for his people and his company. But I don't think he bought any insurance on the Fujitsu deal." *–Clifford Barney*

AVIONICS

SUPER COCKPIT: LET THE BIDDING BEGIN

DAYTON, OHIO

Military contractors are flocking to Wright-Patterson Air Force Base to get their first detailed look at an Air Force program worth $100 million to $120 million. Called the Super Cockpit, its goal is the development by 1996 of a prototype cockpit system that will eliminate conventional instrumentation from an airplane by placing the pilot in a computer-generated world of his own. About 300 contractors were expected at the end-of-the-month industry briefing.

Super Cockpit will integrate a plethora of leading-edge technologies into a flight-testable version of the system. It will unfold in three phases, with initial contracts on the 10-to-12-year effort to be awarded in December. The program will spin out products along the way, says Thomas A. Furness, chief of the Visual Display Systems Branch at the Wright-Patterson Aerospace Medical Research Laboratory in Dayton.

Key to the Super Cockpit technology is a specially designed helmet whose faceplate presents the pilot with a three-dimensional panoramic representation in color of the view outside his plane, based on data from on-board sensors and terrain data maps. Current research versions of the helmet are based on two tiny, 1-in.-diameter cathode ray tubes with associated optics, but future versions may use more advanced imaging systems such as holography. In daylight, the displayed scene will appear superimposed over the actual scene. It will substitute for the actual world at night and in bad weather.

ALL-SEEING. Pilot's helmet would provide three-dimensional view of the world.

Taking both sight and sound cues from an artificially intelligent electronic copilot, the pilot will interact with the display—setting up weapons and firing them, for example—by voice activated commands, by moving his eyes, or by using head and hand gestures. Actuators in the pilot's gloves will enable him to reach out and "touch" a virtual switch or control panel. "He'll have a three-dimensional world that's presented to his touch, even though it's a virtual image, meaning it's not really there but appears to be," Furness says.

HELPING. All the while, the Super Cockpit's electronic copilot, what the Air Force calls a pilot-intent inference engine, will monitor the pilot's workload, helping out by dynamically clustering appropriate display information when and where he needs it and providing speech synthesized three-dimensional di-

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rectional warnings of enemy threats. The electronic copilot will also monitor the pilot's physiological state to prevent crashes caused by G-induced loss of consciousness or other pilot disability.

Super Cockpit is one of 70 technologies identified as key to Air Force operational needs in the next century by the Air Force Systems Command's Project Forecast II study, which was completed last year. With advanced developmental funding to be provided by the System Command's human systems division, the Super Cockpit umbrella will provide a developmental focus for "virtual cockpit" research already under way at the Aerospace Medical Research Lab and elsewhere for five years, Furness says. About $50 million has already been spent under joint funding from the Air Force, Army, Navy, and the National Aeronautics and Space Administration [*Electronics*, April 1, 1985, p. 34]. The Super Cockpit effort is also expected to be given additional funding from them to add to the Air Force's total.

BY 1994. Phase I will pick up on contract work already under way and is aimed at a short-term product for the Air Force Advanced Tactical Fighter and B-1B bomber. Objectives include a monochrome helmet display system with a limited set of virtual-scene software, a fire-control system aimed by a turn of the head, and a night-vision goggle display. The goal is to have Phase I technology ready for transition to full-scale development during fiscal year 1990. That means the system could go into production planes by about fiscal 1994.

Phases II and III will produce successively more elaborate versions. The goal is to have a Phase II Super Cockpit ready for transition to full-scale development in the period fiscal 1992-94, and the full-blown Phase III system to be ready by fiscal 1996 or later, Furness says. His lab plans to award initial contracts to develop key Phase II and III component technologies in December of this year and in April 1988. One or more contracts will also be awarded by about May or June 1988 to further refine the concept. *–Wesley R. Iversen*

SUPERCOMPUTING

ELXSI'S MINISUPER GOES REAL TIME

SAN JOSE, CALIF.

Elxsi believes it has found an unoccupied niche in real-time computing and is moving fast to be the first to fill it. The San Jose, Calif., minisupercomputer maker is mounting a major campaign to make its System 6400 the leader in the brand-new market of real-time supercomputing.

Elxsi expects the niche to provide 40% of its sales

Providing more power to the real-time realm is an idea whose time has been approaching. Elxsi is joined in that endeavor by the vendors of a couple of other powerful multiprocessor machines with real-time capabilities. One is the new NP1 minisupercomputer from Gould Computer Systems of Fort Lauderdale, Fla. (see p. 113); the other is the Flex/32 parallel computer offered by Flexible Computer Corp. of Dallas.

But Elxsi has decided to get out in front of the parade and focus on real time as one of its major marketing thrusts—it will even call the 6400 a real-time supercomputer. "We expect to see 40% of our sales coming from real-time customers soon, especially within the aerospace industry," says company president Peter Appleton-Jones.

Elxsi's approach is to tailor a real-time operating system for the 6400, which will likely make it the first to apply supercomputer power in situations where it's mandatory that the computer respond to rapidly changing conditions as they happen. The 6400 is a 64-bit multiprocessor minisupercomputer that purrs along at 120 million instructions per second that has been available for three years. And it is particularly well suited for real-time jobs.

To qualify as a real-time computer, a system must be able to guarantee a fast response time. But a supercomputer or mainframe's big operating system can take too much time for overhead functions, preventing real-time response. "Users want the benefits of a modern operating system during programming but want to shove it out of the way to run the real-time jobs," says Robert Olson, Elxsi's vice president for software.

So most real-time programs either use a special operating system or go directly to the hardware. The Elxsi system does both. "One of the nice features [of the 6400] is that you can push the operating system aside and the user program talks directly to the hardware without losing the advantages of user protection," says one user, Bill Wilson, manager of software and systems technology at Martin-Marietta Inc.'s real-time simulation lab.

In addition to its flexible operating system, the 6400 can guarantee response times from 150 to 250 μs. A context switch from one task to another takes just 8 μs. "Most other big computers—the mainframes and the supercomputers—can't guarantee these times because they are oriented toward, and are too busy worrying about, [central-processing-unit] management," says Olson.

THREE WAYS. The programming advantages of the Unix operating system are available on the 6400, so real-time programming is easy. Unix is offered in the AT&T System V and the Berkeley 4.2 BSD versions. VAX VMS is also available. All three run on top of Elxsi's message-based virtual machine system foundation. It is constructed of multiple asynchronous processes, which allows distribution of operating-system tasks to all available processors. This is a boon in real-time jobs with complex scheduling demands.

The hardware and system software of the 6400 is also designed to make it easy to interface a variety of foreign devices. "The operating system is designed to let users plop these [devices] in without having to know how the operating system works or to make changes to it," says Olson. *–Tom Manuel*

DEC PRESSES ATTACK WITH THE FACTORY LINE

Digital Equipment Corp., flying high in several sectors of the computer industry, is now trying to duplicate that success in industrial computing. It has done well selling small minicomputers—first PDP-8s and then PDP-11s—into the factory, but now it is bringing its successful VAX line and networking to bear on the industrial market.

DEC's eight new industrial computer systems, unveiled March 24, include five machines based on MicroVAX II and three new PDP-11 machines. Two of the VAXes and one of the PDPs are sealed units for use in very harsh environments. By extending the VAX architecture and networking to manufacturing, the Maynard, Mass., company stands a good chance of gaining a strong position in computer-integrated manufacturing.

But it may not be smooth sailing. "The whole manufacturing market has not grown as fast as planned—it promises to be a huge market in the long run, but in the short run it's off to a slow start," says Michael Geran, analyst at E. F. Hutton in New York. "And the market is not as homogeneous as people think. There will be a lot of guys playing in it." *–Tom Manuel*

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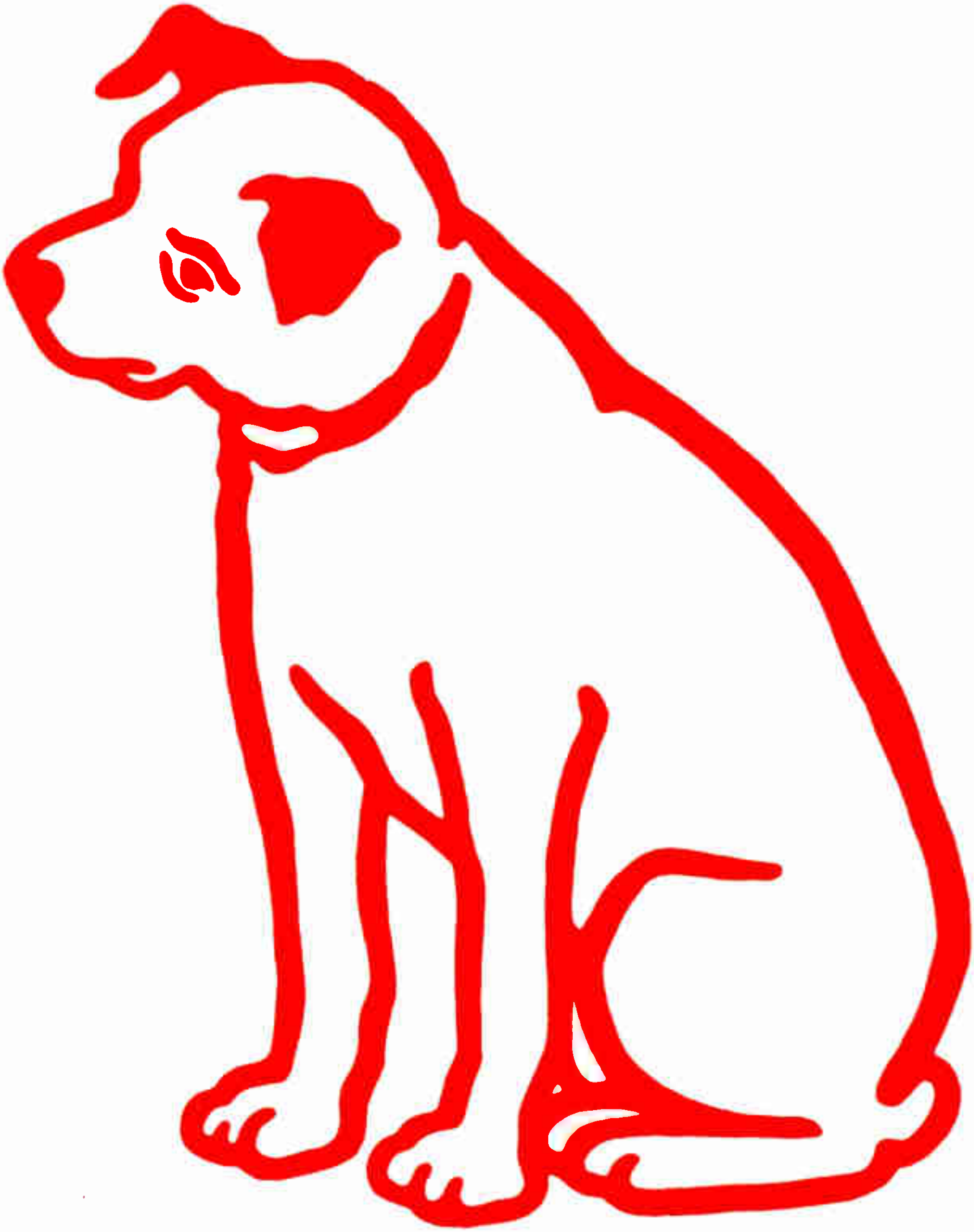

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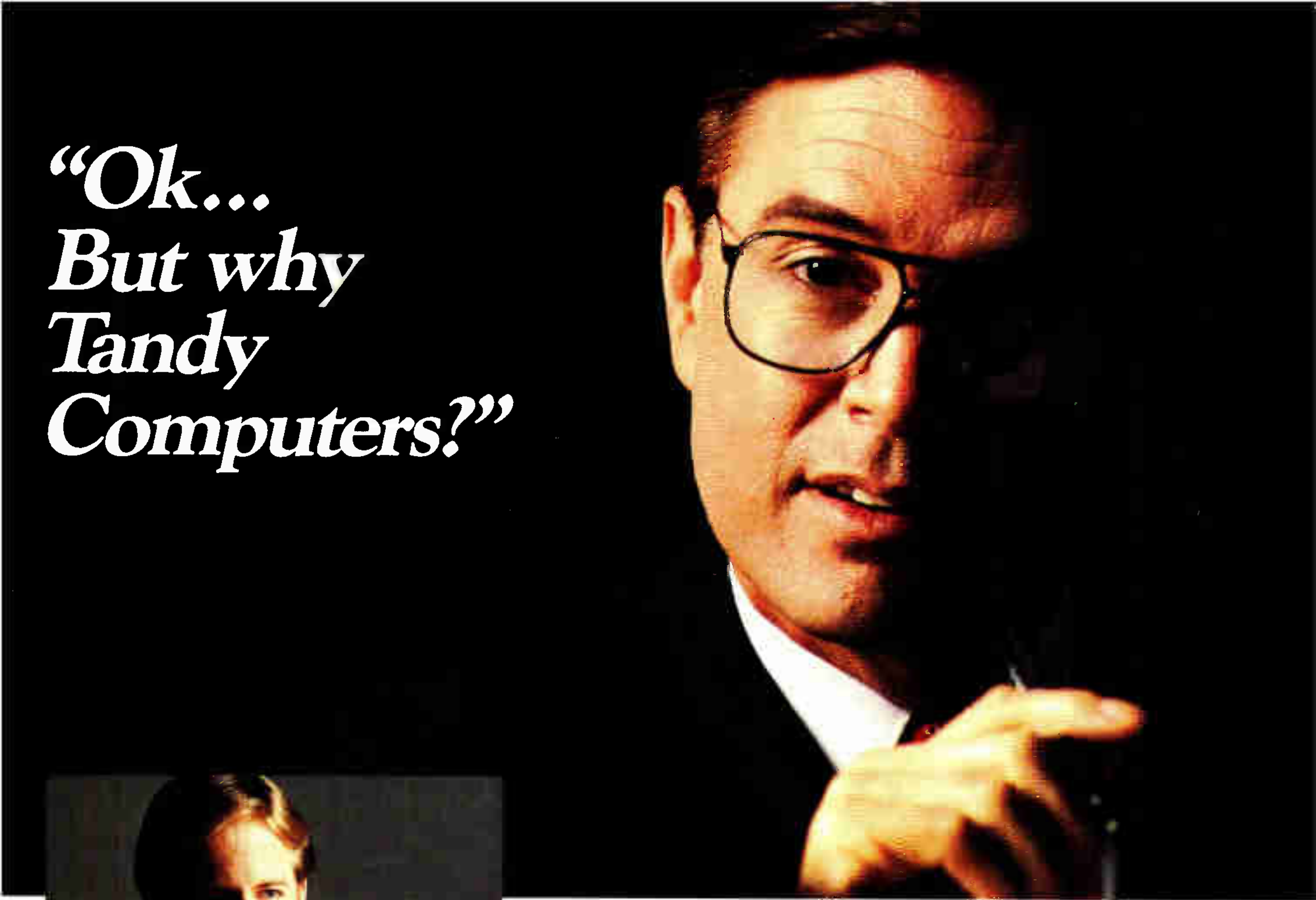
Excerpted from an exclusive article in the August 7, 1986 issue.

McGraw-Hill **Electronics**

THE LEADER IN NEW TECHNOLOGY COVERAGE



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Circle 43 on reader service card

3COM FIELDS ITS OWN 'NETSTATION'

SANTA CLARA, CALIF.

One of the creators of Ethernet has developed a work station designed to occupy a new niche in the office-computing market. Robert Metcalfe, who is now chairman and senior vice president of engineering at 3Com Corp. in Santa Clara, Calif., figures the time is ripe for such machines. "The market size and standards now favor the use of 'netstations' optimized for local-area-network-based work-group computing," he says.

The figures seem to bear him out. The San Jose, Calif., market research firm Dataquest Inc. estimates that between 1985 and 1990, the market for work-group computing systems based on personal-computer LANs will grow at a compound annual rate of 48%. Metcalfe places the market of network users at $2.5 billion by 1991, and says he intends to grab 10% of that. Also, he says, 12 million personal computers are in use in offices today, with 8% to 10% of them networked. And that percentage is growing.

NEW DIRECTION. So 3Com, a LAN company, is making the big jump into what is a new market for the company: office work stations. Its product is called 3Station, a work station designed from the start as a node for operation on an Ethernet network with features that improve networked operations. It is an IBM PC AT-compatible computer with 1 Mbyte of random-access memory and a built-in Ethernet adapter, an extended graphics adapter, and extended I/O-port capability. The computers themselves are made by 3Com.

METCALFE: "The market favors the use of 'netstations' for LAN-based work-group computing."

Whereas most networked personal computers can handle only a single Ethernet packet at a time, the new system has a multiple-packet buffer, which permits it to handle four receive and transmit packets. In addition, because of its dedicated nature, it can use more of its 1 Mbyte of RAM than conventionally networked units—including 33% to 43% more for applications running under Microsoft Windows. A single printed-circuit board with five application-specific integrated circuits from California Devices Inc. of Milpitas, Calif., contains the same logic that resides on several add-on boards in the PC AT.

Also, no problem is anticipated with availability of software, says Metcalfe. With the market trend toward programs that access and share a data base, software writers everywhere are busy turning out the material that the 3Station needs, he says.

Metcalfe, who was one of the developers of Ethernet while he was at Xerox Palo Alto Research Center in Palo Alto, Calif., before he founded 3Com, says, "Our studies showed that users wanted printer and modem capability at their work stations, so we incorporated expanded I/O-port capability, but we built mass storage as a networked resource." As a result, the system's selling price, $1,895 per station, exclusive of disk drive and monitor, costs about 60% less than a PC AT and 40% less than most PC-compatible computers.

3Com's highly automated manufacturing facility in Sunnyvale, Calif., which is now producing 1,000 3Stations a month while running under dedicated tooling, is prepared to turn out 20,000 a month when the marketing effort begins to generate sales in volume. Metcalfe says that shipments are scheduled to begin May 15. *—Jonah McLeod*

SEMICONDUCTOR MARKETS

KOREA AIMS FOR THE TOP IN VLSI BY 1991

SEOUL

In South Korea, people in the industry call it the Blue House Project, after the official residence of President Chun Doo Hwan, whose advisers convinced him two years ago that the only way to crack the world semiconductor market would be to orchestrate a massive development project involving every important Korean company in the business.

That's just what is happening now, and the goal is to position Korean chip makers as major players in the world industry by 1991 (see p. 78). The impetus came from the president, and the muscle for the program—called the VLSI Project—is coming from commitments by three of the largest Korean conglomerates. They are all enrolled in a three-year, $53 million crash effort sponsored by the semiconductor group of the government-backed Korean Electronics and Telecommunications Research Institute, which began operations last fall.

"The goals, by U.S. standards, are totally unreasonable," says Chang-Soo Kim, senior managing director of GoldStar Ltd.'s semiconductor business. But in the three years since he left his position as consulting engineer with Digital Equipment Corp. to return to his native land, Kim says, he has seen so many "unreasonable" objectives achieved that he believes the Koreans can meet them.

The project has three thrusts. The primary one, involving GoldStar, Hyundai, and Samsung, is to develop by 1989 a 4-Mbit dynamic read-only memory using 0.8-μm design rules, with mass production starting in 1990. The second objective, in which Daewoo and Korean Electronics Co. will join the other three, is to develop IC design-automation technology, application-specific ICs with 1-μm design rules, integrated systems digital network ICs, and 32- and 64-bit microprocessors—all by 1991.

Finally, the Koreans intend to develop all the support industries and technologies needed for complete semiconductor manufacturing by 1990, followed by the production of gallium arsenide and other compound-formula chips by 1991. That portion of the work enlists Anam, GoldStar, Korsil, Mikyung, Poongsan, and Samsung.

4 MBITS BY 1988. The coordinator of VLSI Project research is Min-ho Kang of the Ministry of Science & Technology. He says that despite a late start, he expects that a Korean-developed 4-Mbit DRAM design will be completed by the end of 1988. "I expect that some of the goals in the other sections of the project will be narrowed somewhat," says Kang, who describes those two sections as a "wish list" for which project teams have yet to be selected.

The project leaders have figured a

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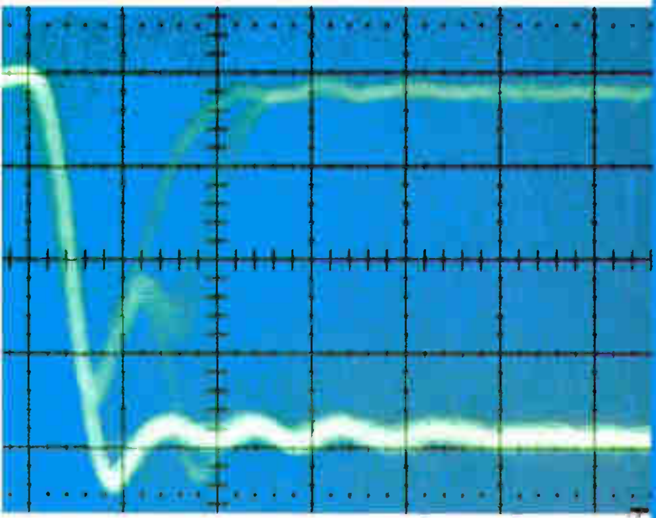

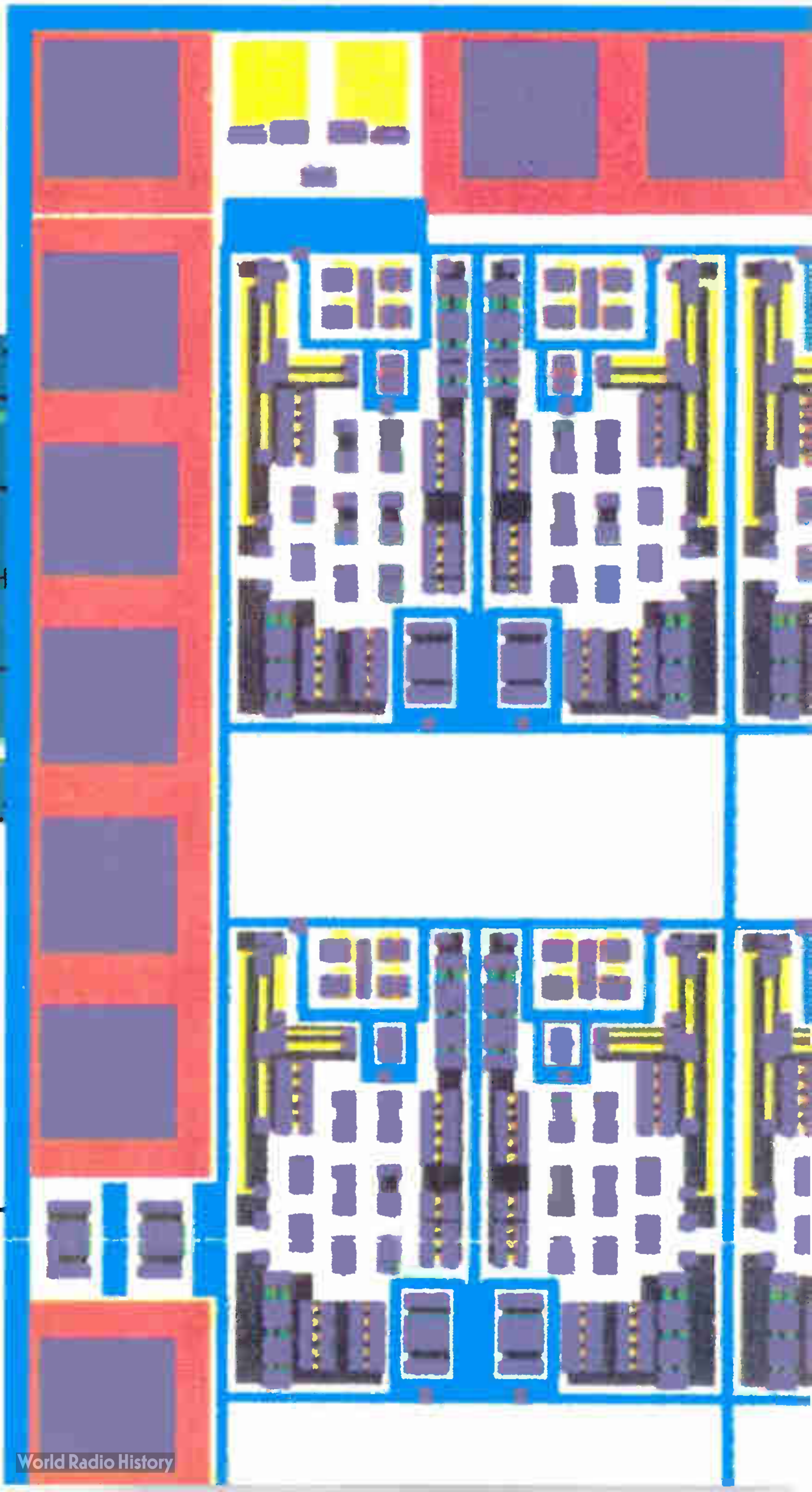

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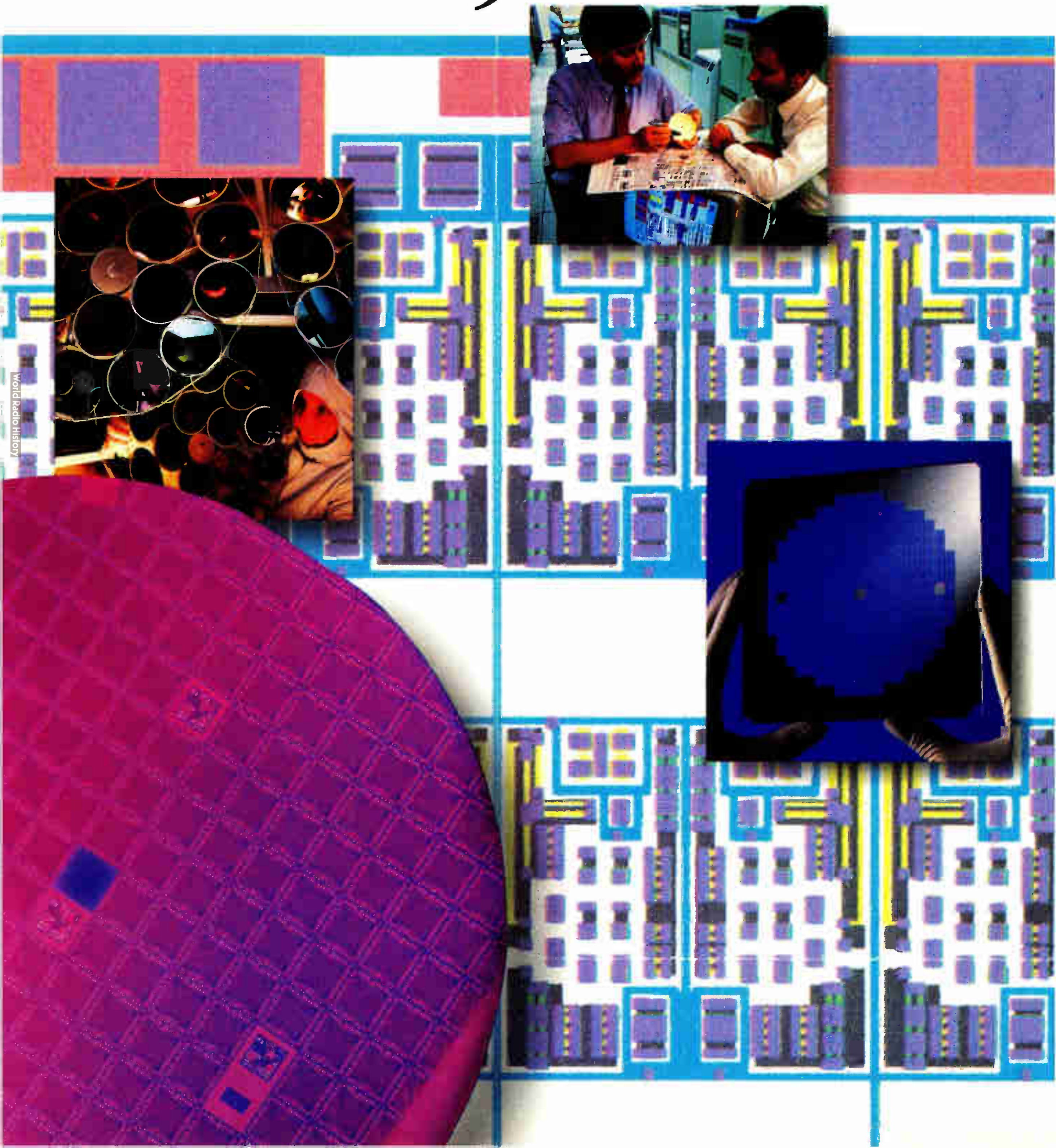

yours.

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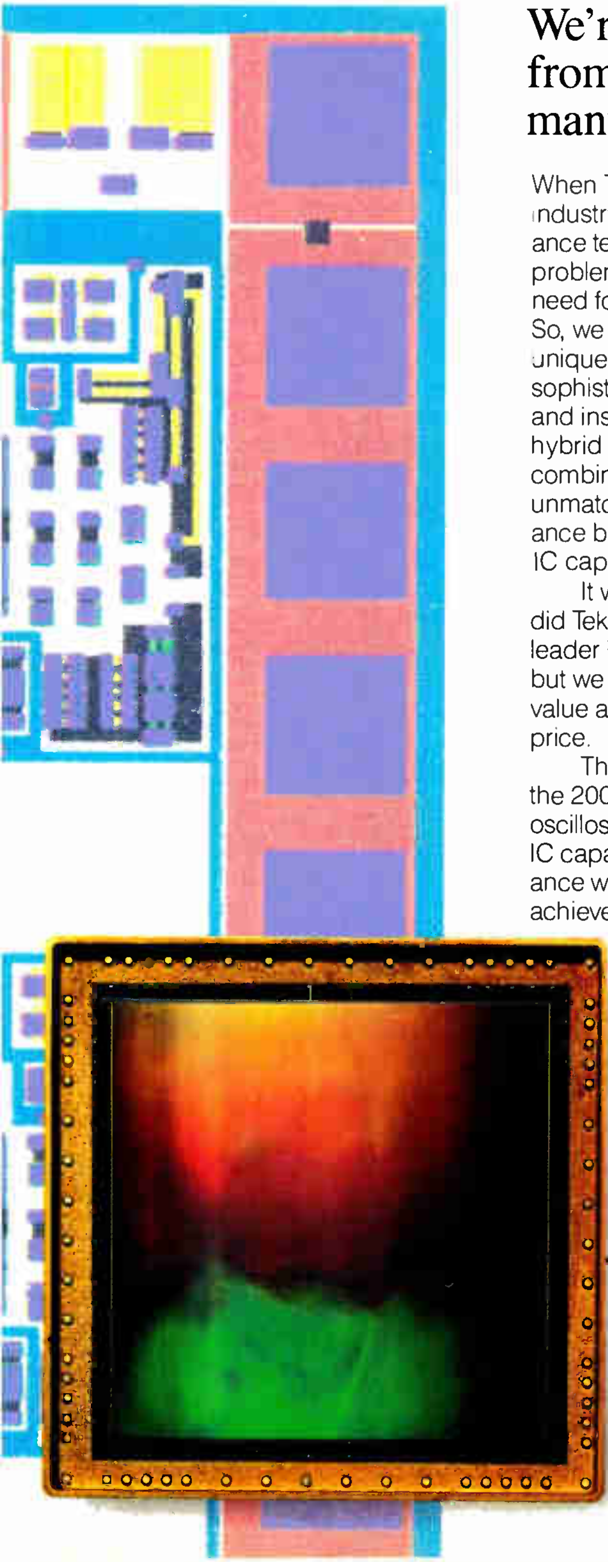

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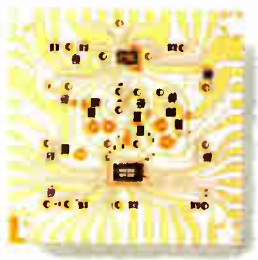

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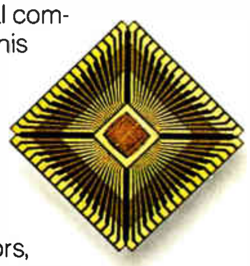

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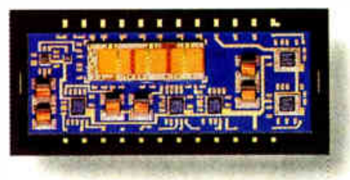

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way to work around the age-old problem of cooperative research and development: how can competitive private manufacturers be expected to cooperate? "We have given the three major manufacturers clear engineering goals, but they are working separately, in their own labs, to achieve them," explains Kang. It seems to be working, as Kang expects to meet the major intermediate goal of the DRAM work: an engineering sample by March 1988. What helped there, he says, is that "the companies had begun work on their own nearly a year before the project was announced."

The major incentive for each private maker is that those companies that meet the intermediate project objectives as well as the final goal get continued financing from the government. "When you have a carrot dangling in front of you, you go for it," says GoldStar executive Kim. The "carrot" in this case is low-interest government loans accounting for nearly half the project, offered with a five-year grace period, followed by repayment over the subsequent five years, at interest rates about 1% below usual commercial loan figures.

KIM: "The program's goals, by U. S. standards, are totally unreasonable."

But Kang points out that if the Koreans can meet the technological challenge, there remains a basic reality: "Even if we develop this product and go beyond it, will the market needs justify the costs?" he asks. "We still think the best approach, long-term, is to seek alliances. Anyone who tries to go it alone in this business is following a very dangerous path." *–Michael Berger McGraw-Hill World News*

SUPERCONDUCTORS

SUPERCONDUCTIVITY DRIVE GETS HOTTER EVERY DAY

NEW YORK

The frenzied drive to develop superconducting materials capable of operating at temperatures 70 K warmer than anyone thought possible just a few months ago has astounded the international physics community and redefined superconductor technology. Barriers once considered insurmountable crumble day by day, and scientists are now reporting on a variety of copper-oxide materials that become superconductors at temperatures ranging from 90 K to 125 K, and they hint that 200 K may be within reach.

Scientists hint 200 K may be within reach

More exciting than mere temperature records, however, are the advances scientists are making in processing these materials for use in wire, magnets, and even computer chips. Researchers at IBM Corp.'s Thomas J. Watson Research Center have produced thin films of yttrium barium copper oxide that remain superconductive up to 87 K. At AT&T Bell Laboratories, scientists have produced moldable strips of the material mixed with an organic binder; it can be shaped and later baked to harden the material and allow it to become superconductive.

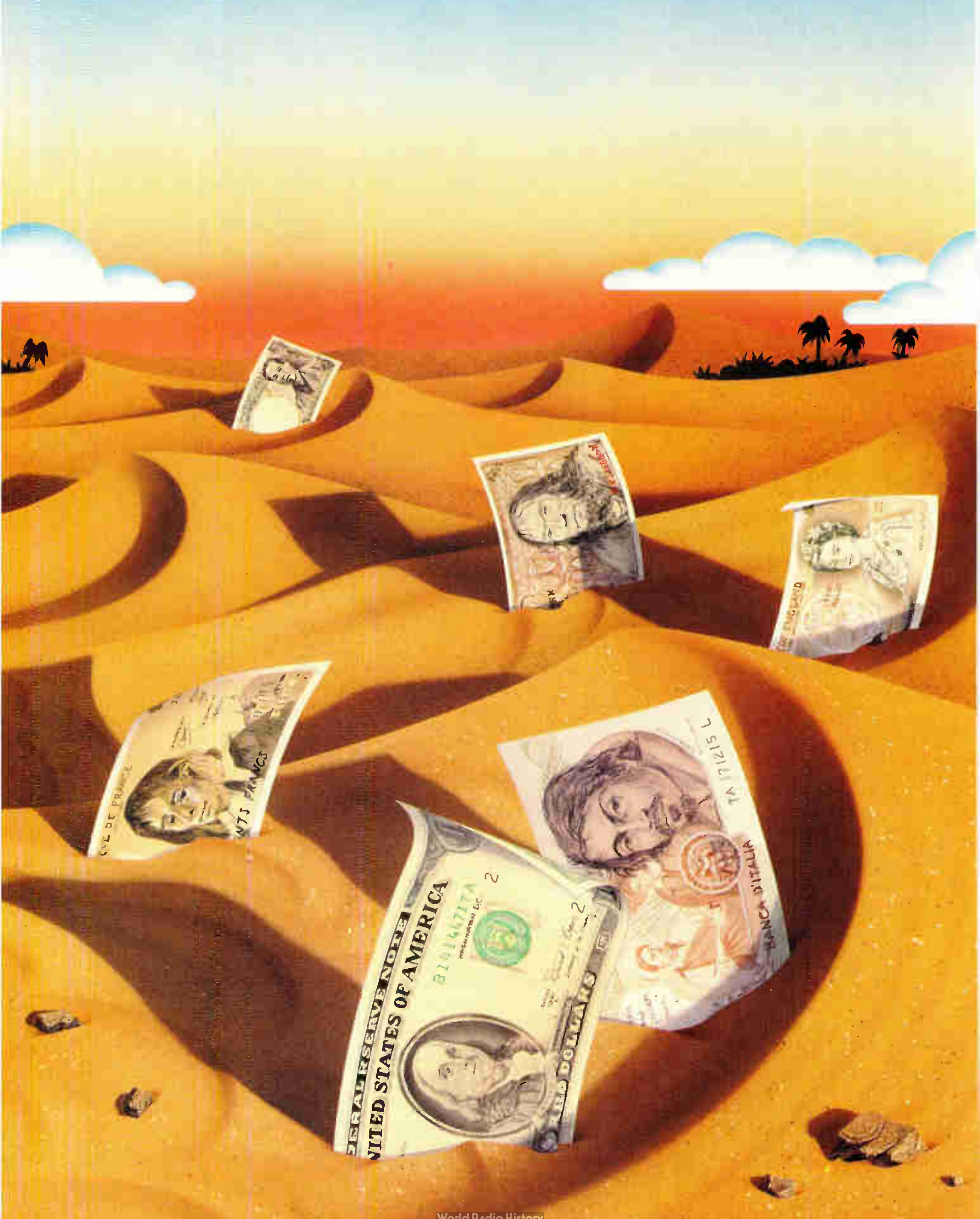
Meanwhile, University of Tokyo researchers report that they have produced superconductors in thin-film form and as drawn wires. And at Stanford University, researchers are using an electron-beam evaporator to produce thin films of lanthanum strontium copper oxide that are superconductive up to about 40 K.

"It wasn't so long ago that we were all stuck around 23 K," says M. Brian Maple of the University of California at San Diego. He was chairman of a panel on superconductivity at last month's meeting of the American Physical Society that drew 2,000 people—many watching TV monitors in the corridors—and went on from 7:30 p.m. until 3:15 the next morning.

For the electronics industry, perhaps the most promising reports came from Stanford and IBM. "We've produced both planar and point-contact tunnel junctions," says Theodore Geballe, a professor of applied physics. "Films have direct application to electronics, and tunneling is essential to understanding the microscopic materials."

The potential applications for these new superconductors, which have critical magnetic fields—up to 300 kilogauss—far greater than today's most

The Hidden Costs...



commonly used superconductor, niobium nitride, are far-reaching. IBM is initially considering them to interconnect devices on chips and perhaps on printed-circuit boards. It also has begun work on prototypes of devices using the new materials, says Praveen Chaudhari, vice president for science at the Watson Center in Yorktown Heights, N. Y.

But Chaudhari warns, "It's not 100% clear right away whether these materials can be used in devices. It's easy to make a device and show that the device works. What you want to do is make something that does something useful." He says the next step is to try to integrate superconducting devices with current silicon and packaging technologies.

Not everyone is convinced that building devices and making thin films is the best way to maintain the momentum of recent months. Maple, for one, suggests that producing and studying the materials in bulk may yield greater understanding about their molecular structure and how they could be improved. "We're at a point now where you can go ahead and make film, but I'm not sure that's the most productive route," he says.

IBM is working on prototypes of devices with new materials

Maple says the key to further research will be whether scientists can find ways to increase current density. Despite all the progress in temperature and magnetism, work in that vital area—the maximum amount of current/cm^2 that a material can support—lags. The new materials' current densities are only a tenth to a hundredth that of niobium nitride.

Nevertheless, the search for more materials with ever-higher threshold temperatures continues. Bell Labs has produced 10 distinct materials that can superconduct above 90 K, says Robert Cava, one of several researchers there who have been working almost around the clock on this project since late last year [*Electronics*, Jan. 22, 1987, p. 37]. "We can make in a reliable and reproducible manner materials that superconduct the whole way through," he says. "These materials are all ceramic, and they can be made using the same techniques as other ceramics. They can be made well by many people."

Where will it end? C. W. Chu of the University of Houston says, "I don't think 90 K is going to be the limit. We'll see 125, 140, maybe even 240 K." Indeed, Chu says the superconductors could be used now without special cooling systems—deployed on satellites in outer space. *–Tobias Naegele*

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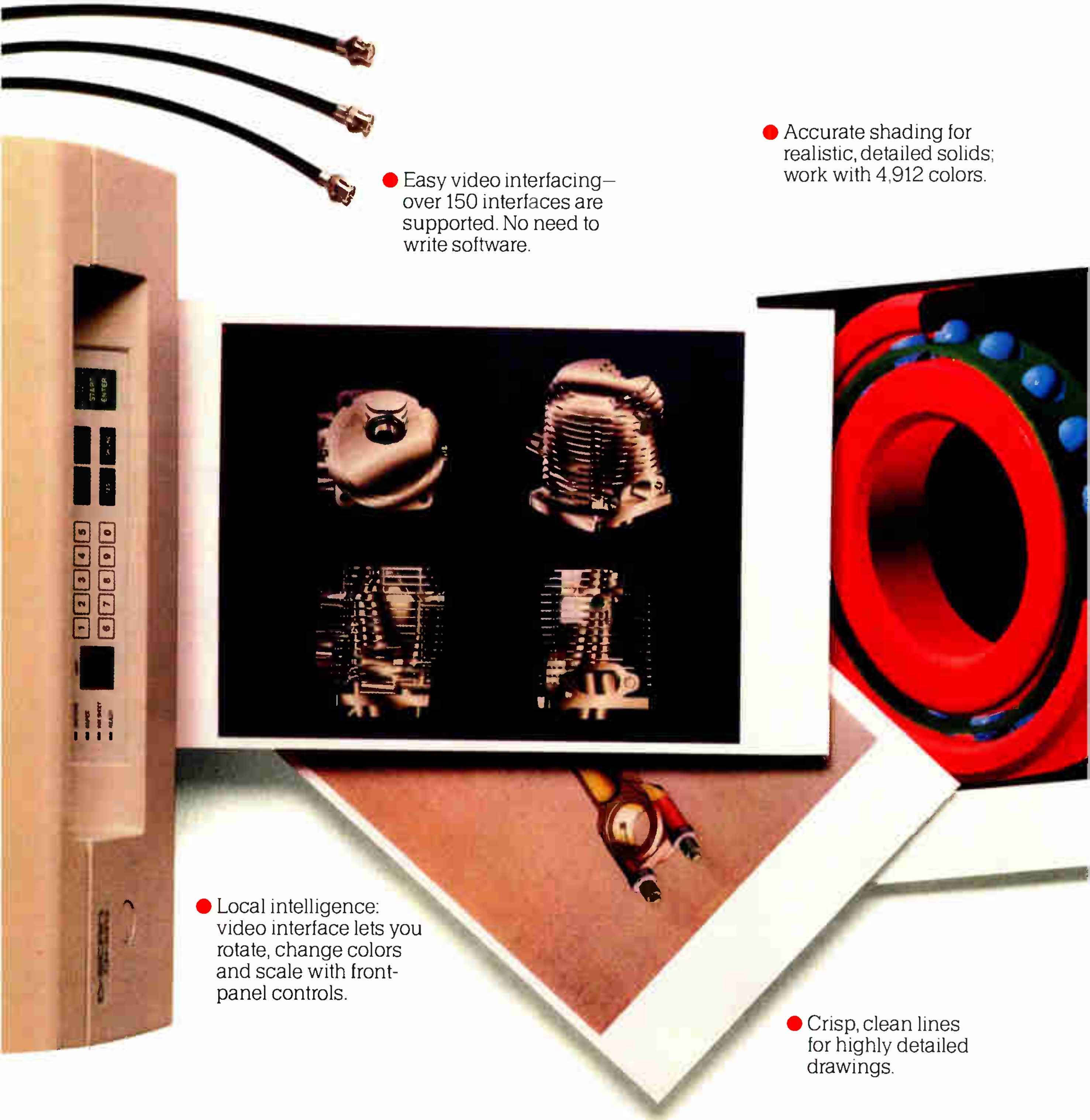

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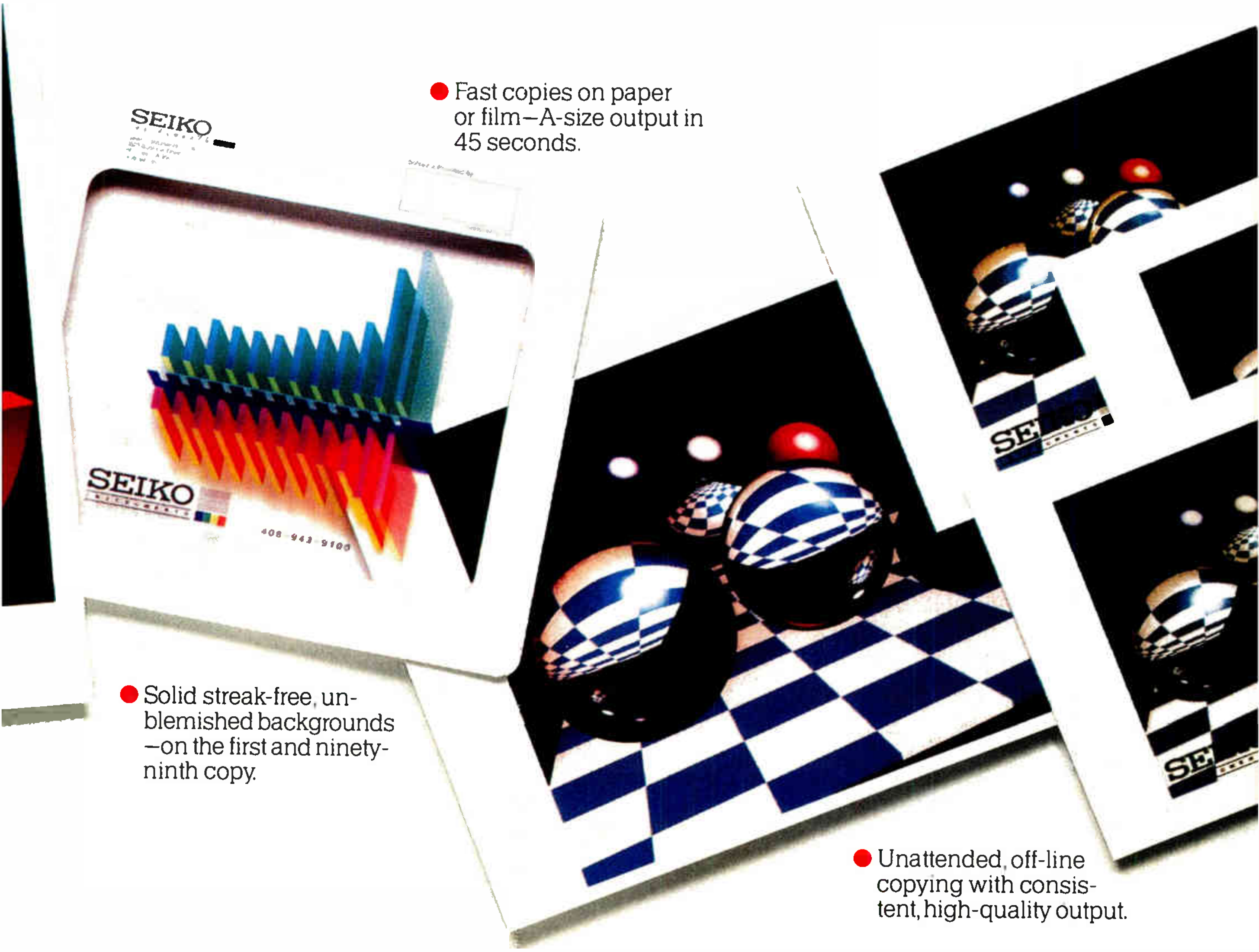

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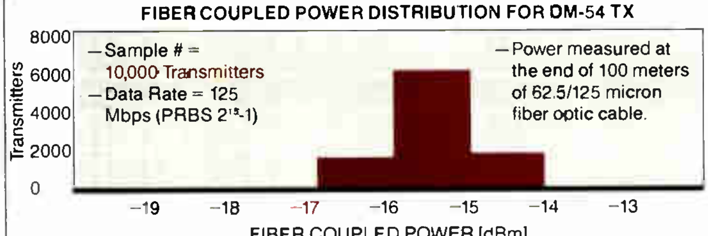

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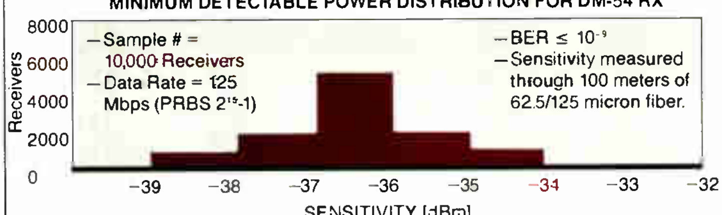

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INTERNATIONAL NEWSLETTER

HOW THREE PLUS FOUR EQUALS TWO IN EUROPE'S CHIP BUSINESS

A major change in the European semiconductor industry is in the works. Thomson Semiconducteurs of France, the Continent's third biggest chip maker, and SGS Microelettronica of Italy, No. 4, are planning to merge their nonmilitary semiconductor businesses into one company. The new firm, as yet unnamed, will be the world's 12th largest semiconductor house and will displace Siemens AG of Munich as Europe's second largest chip maker, behind Philips, of the Netherlands. Thomson, which owns Mostek, of Dallas, now boasts a 1.8% share of the world's commercial semiconductor market and employs about 10,000 people. SGS has a 1.4% share and 8,500 employees. Thomson CSF, the parent company to Thomson Semiconducteurs, says the pact should be signed within weeks, but the deal won't be final until the French and Italian governments approve the merger. □

NOW, A COPYRIGHT FIGHT BETWEEN TWO JAPANESE PC MAKERS

Japanese computer makers are keeping their eyes on Japan's first copyright infringement battle between rival Japanese computer firms over compatible personal computers. NEC Corp., of Tokyo, claims that Seiko Epson Corp.'s new PC-286 personal computers, which are compatible with Japan's best-selling personal computer, the NEC PC-9801, violate NEC's software copyrights. The claim is tinged with irony, because NEC is in the midst of a copyright infringement suit in the U. S. brought by Intel Corp. of Santa Clara, Calif. Seiko Epson, of Suwa, tried to avoid a confrontation by lending NEC a PC-286 for examination. But when NEC said parts of the BIOS operating system and other basic software in the Seiko Epson machines infringed on its copyrights, Seiko Epson refused to delay the April release of the PC-286, despite NEC's warnings that it would likely file suit to block sale of the equipment. Instead, Seiko Epson is seeking to appease NEC by trying to change portions of the software in the few weeks before sales actually start. Seiko Epson claims its original BIOS and Basic software do not infringe on NEC's rights and insists that an infringement suit is unreasonable, since systems software is not explicitly protected by Japanese copyright law. □

THE EC WANTS TO MAKE TELECOM BIDDING A COMMUNITY AFFAIR

The European Commission wants to liberalize over-the-border contract-bidding and equipment-ordering policies for the telecommunications industries of its 12 member nations. Currently, bidding by Common Market countries is limited—in some cases to just 10%—by the governments of the member countries, but now the EC wants to change things. The terminal-equipment market sector, which includes new communications services, will be opened to bidding by all members. The regulations covering traditional terminals, such as Telex machines, call for a rise from the current 10% limit to 40% by 1988 and will reach 100% sometime between 1990 and 1992. □

PHILIPS BUYS 12% OF FLUKE IN STRATEGIC ALLIANCE

A strategic alliance linking John Fluke Manufacturing Co. of Everett, Wash., and Philips Test & Measurement of Eindhoven, the Netherlands, should boost Fluke into competition with market leaders Hewlett-Packard and Tektronix. Under the agreement, which is not yet final, the two will pool their sales and support resources and jointly develop their next generation of T&M equipment. Philips, which will buy a minority 10% share of Fluke, will take control of Fluke's European business, and Fluke will take over Philips Test & Measurement operations in the U. S. Also, Fluke will market Philips' equipment in China, Hong Kong, and Japan. □

INTERNATIONAL NEWSLETTER

NEC TO SHIP ISDN GEAR TO REGIONAL BELL OPERATING COMPANIES

NEC Corp. is breaking into the integrated services digital network market with shipments of its ISDN Adjunct Switching System to four of the seven Regional Bell Operating Companies in the U. S.: Bell Atlantic, NYNEX, Pacific Telesis, and U. S. West. The Tokyo company's system adds digital data-switching capabilities to analog switches. The RBOCs have a large investment in analog switches that are not yet fully depreciated, NEC says, and the company is betting that the BOCs will add digital capabilities to analog switches rather than invest in new equipment. NEC will ship a total of eight systems to the four companies for their experimental ISDN services. ☐

AT&T SAYS IT'S STILL IN THE RUNNING TO ACQUIRE FRANCE'S CGCT

AT&T Co. hasn't given up on its effort to buy a piece of Compagnie Générale des Constructions Téléphoniques, the French telecommunications equipment maker that is being sold back into private hands by the government. In partnership with Philips, of the Netherlands, AT&T is bidding for a piece of CGCT and has so far been stymied in its efforts. But according to James Olson, AT&T's chairman and chief executive officer, "We're still very much in the running." At a recent meeting with reporters, Olson called the struggle for CGCT "foremost among the frustrations we've encountered in our effort to crack the French market." AT&T's chief rival in the battle is West Germany's Siemens AG, which has been rumored to be on the inside track in the competition [*Electronics*, Oct. 16, 1986, p. 154]. "The Germans have been working the political wheels to swing the decision Siemens' way," Olson says; but he warns that any effort by West Germany and other European countries to exclude U. S. firms from competition in Europe is "just going to add fuel to the fire of protectionism in the U. S." ☐

WEST GERMAN STARTUP GETS THE BUS OUT OF PARALLEL PROCESSING

Parsytec GmbH, an 18-month-old West German startup, has developed a parallel-processing computer architecture that eliminates the need for a data bus, offering virtually unlimited expansion capabilities. Instead of conventional microprocessors, the company built the system around Inmos Ltd.'s transputer, which uses communications channels integrated at the chip level instead of a bus. The concept is the key to Parsytec's Megaframe system, which will be shown at the Hannover Fair from April 1 to 8. Several German companies are evaluating the system, which typically comes as an extended single Eurocard board with four transputers and 256 Kbytes of random-access memory. Each board can execute up to 40 million Whetstone instructions per second. Conventional systems often require three similarly sized modules for the same performance, the company says. ☐

WESTERNERS CAN NOW DEAL DIRECTLY WITH THEIR SOVIET CUSTOMERS

The restructuring of trade practices in the Soviet Union by Mikhail Gorbachev, the Soviet premier, may soon have an effect on Western electronics companies. Western exhibitors will be able to negotiate directly with Soviet customers at trade shows in Moscow and Leningrad in November—the first time such transactions have been permitted, according to fair organizer Nowea International, of Düsseldorf, West Germany. Regitech, the Leningrad show, will feature electronic measuring and control equipment; the Moscow event, called Nowtech, will focus on new materials and technology for surface treatment. In past years, companies had to market their wares through Soviet foreign trade organizations, a bureaucratic exercise that slowed the selling process and sometimes failed to consider the needs of the end user. ☐

INTERNATIONAL WEEK

UK IC BOOK-TO-BILL GOES UP AGAIN

For the third straight month, the UK book-to-bill ratio for integrated circuits has remained above parity, according to the Electronics Component Industry Federation, which also predicts a 15% to 20% increase in growth for the year. The ratio for February was 1.23, January 1.20, and December 1.16. The federation's members predict similar increases for 1988. Its data accounts for 75% of UK semiconductor sales.

TERMINALS LOOKING GOOD IN GERMANY

West Germany's market for computer terminals, with an annual growth rate of almost 40% in recent years, will remain at a high level for the rest of the decade, according to a study by Infratest GmbH, a Munich market-research firm. The number of terminals in West Germany doubled from 500,000 in 1982 to 1 million in 1985 and rose 50% by the beginning of this year to 1.5 million. By 1990, Infratest says, the number should top 2 million.

ERICSSON WINS BUNDESPOST DEAL

Ericsson Group's Information Systems Division, Stockholm, has been awarded a $40 million contract to supply personal computers to Bundespost, the West German telecommunications and postal administration. The contract includes 6,000 upgraded WS 286 AT-compatible personal computers and Alfastop terminals.

GEC SYSTEM TO LINK CHINA, HONG KONG

More than $2 million worth of optical-terminal and repeater equipment and digital multiplexers will be supplied and installed by GEC Telecommunications Ltd. of Coventry, UK, for an optical-fiber system between Hong Kong and Guangdong, China. The two contracts, from Cable & Wireless in Hong Kong and the Guangdong Posts and Telecommunications Administrative Bureau, call for 7,860 circuits on a link that will carry telephone, telex, and telegraph, as well as 64-Kbit/s data.

NTT's PHONE IS LIGHTWEIGHT . . .

Nippon Telegraph & Telephone Corp. will introduce a lightweight portable cellular phone in Japan by summer. The Movable Phone, which weighs only 700 grams, will be replacing NTT's Shoulder Phone, which weighs 2,900 grams. The Movable Phone has a removable rechargeable battery, which provides users with 40-minute continuous communication or 6 hours of call waiting. The service areas at first will be the same as the Shoulder Phone; about 6,800 Shoulder Phones are in use in 500 cities in Japan, an NTT spokesman says. NTT will rent the new model for $151 a month.

. . . AND ITS PAGER ADDS DISPLAY

Nippon Telegraph & Telephone Corp. will offer an updated Pocket Bell pager with a liquid-crystal display of up to 12 characters to display telephone numbers and simple messages based on number codes. The Tokyo company expects to start service of Display Pocket Bell this summer in the 638 Japanese cities now served by the existing Pocket Bell. NTT says that about 2.35 million Pocket Bells are in use in Japan. The LCD version will rent for $21 a month, a $2 increase.

E. GERMANS WORK ON 256-KBIT DRAM

The East German chip makers are trying to catch up to their counterparts in the West [*Electronics*, March 19, 1987, p. 53]. They are going all out with high-density dynamic random-access memories, although they lag behind by several years. With production of 64-Kbit DRAMs under way at VEB Kombinat Mikroelektronik, the state-owned combine in Erfurt is also developing 256-Kbit versions for production this year or in early 1988. And industry leaders at the East German Spring Fair in Leipzig said 1-Mbit DRAMs will be in production before the end of the decade.

TOSHIBA SETS UP E-BEAM COMPANY

Toshiba Corp. is setting up a company in Tokyo to produce electron-beam products primarily for the semiconductor industry. The company, Akashi Beam Technology Corp., will be jointly capitalized by Toshiba and Akashi Seisakusho Ltd., Tokyo, a leading Japanese electron microscope manufacturer. The company will develop, manufacture, and market scanning electron microscopes, transmission electron microscopes, semiconductor linewidth measurement systems, electron-beam circuit-test systems, and electron-beam lithography systems. Sales of $33 million are expected in the first year.

INTERACTIVE CABLE TV GOES LIVE IN UK

The world's first fully interactive cable TV goes live in the UK this year. System 8, from British Cable Services Ltd., will be controlled by applications software from computer services company Scicon Ltd. of Milton Keynes, UK. It will carry 30 channels and will eventually reach 200,000 homes. The first phase will begin in Guildford in August.

SIEMENS, YUGOSLAV FIRM SIGN PACT

Siemens has established a joint venture with the Yugoslav medical electronics service firm Meditehna, the first joint venture the Munich company has entered in Yugoslavia and the first service-oriented pact in the East Bloc. Each company will initially put up about half a million dollars to train Yugoslav personnel to service medical electronics equipment made by Siemens—necessary because of its strong presence in Yugoslavia's medical-systems market. Siemens has installed about $150 million worth of such equipment there, and its annual medical-systems business in Yugoslavia is between $15 million and $20 million.

COMPUTER SALES UP 38% IN GREECE

The market in Greece for computers, software, and peripherals jumped by 38% overall last year, from $73 million in 1985 to $101 million in 1986, according to a report by market watchers Strategic International Ltd. of Athens. The microcomputer market showed the biggest increase at 74%, after rising from $23 million in 1985 to $40 million in 1986. Minicomputers rose 33% from $15 million in 1985 to $20 million and mainframes fell slightly from $7 million in 1985 to $6 million in 1986. Demand for peripherals was up by 18% from $17 million to $20 million and software was up 27% from $11 million to $15 million in 1986.

PERSONAL FAX SELLS FOR $843 IN JAPAN

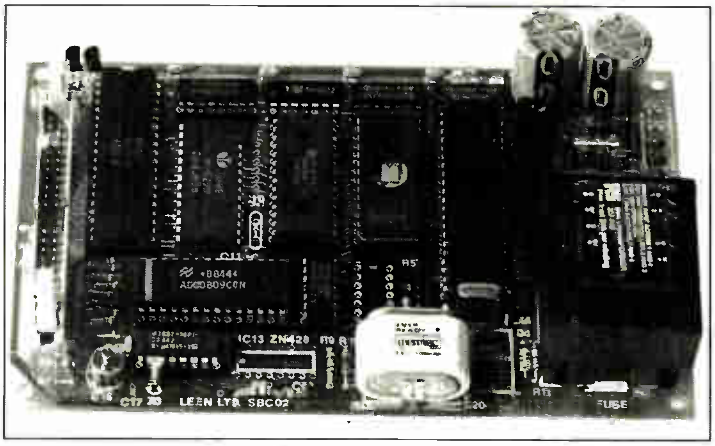
Nippon Telegraph & Telephone Corp. will market its NTTFAX-20, Japan's cheapest Group III letter-size personal facsimile, for $843. Like other Japanese personal facsimile machines, it includes a telephone handset and can make copies. The price is 13.5% cheaper than NEC Corp.'s $974 NEFAX-5 model, which went on sale in January and had been the cheapest machine available.

INTERNATIONAL PRODUCTS

COMPUTER ON A CARD RESISTS FACTORY-FLOOR VIBRATION

SINGLE EUROCARD INCLUDES POWER SUPPLY AND DATA CONVERTERS

A microprocessor, power supply, and analog-to-digital and digital-to-analog converters have been packed on a single Eurocard board to provide a vibration-resistant system for the factory floor. Built by the London Energy and Employment Network (LEEN) for data-acquisition and industrial-control applications, the single-board computer is sturdier and therefore more reliable than current systems that use three separate boards to house the same components, according to Yemi James, marketing manager at LEEN, a government-supported company.



BACKUP. A rechargeable nickel-cadmium battery on the LEEN6809 connects directly to main power lines and backs up 8 or 32 Kbytes of SRAM.

FEWER CONNECTIONS. Using three boards would require as many as 50 extra connections to the host's backplane—which means 50 places where vibration could cause a problem. Besides eliminating a number of potential trouble spots, the single-board configuration takes up less room than three-board systems.

Built around Motorola Corp.'s 8-bit 6809 microprocessor, the LEEN6809 comes with either 8 or 32 Kbytes of static random-access memory backed up by a rechargeable nickel-cadmium battery that connects directly to 240-V power lines. The battery has a 100-mAh capacity and a typical discharge current of 10 µA at 15°C. It also backs up the board's M3002 real-time clock.

The product is aimed at industrial processes where an analog measurement needs to be taken and acted on automatically. One application would be monitoring temperature and switching boilers and pumps on and off, the company says.

The ADC is a Ferranti Ltd. ADC0809CCN with eight input channels and 8-bit resolution. It is error-free to within 1 least-significant bit between 0° and 70°C. Input range is 0 to 2.5 V, and conversion time is 100 µs. Inputs are from 40-pin insulation displacement connector via 1-KΩ series resistors.

The DAC is a Ferranti ZN428E-8 with 8-bit resolution and a linearity error of ±0.5 LSB at 25°C. The differential nonlinearity error is the same. Full-scale output with all bits on is 2.55 V at 25°C. Output is connected to a 40-pin insulation displacement connector.

The clock keeps time from seconds to tens of years, automatically accounts for leap years, has an alarm facility, and produces data in binary-coded-decimal format. Clock speed is 1 MHz.

A 6551 Asynchronous Communications Interface Adaptor serial I/O port with unbuffered TTL levels is included with the LEEN6809. Its integral baud clock runs from 50 to 19,200 baud. The 6522 Versatile Interface Adaptor parallel I/O port comprises two 8-bit bidirectional ports with handshake lines, and two 16-bit programmable timer/counters. Signals travel along the edge of the board over a 40-way insulation displacement connector.

There are two Omron G6C-2117P-5 relays controlled by the parallel port. They can switch up to 7 A at 240 V, have single-pole changeover contacts, and feature 100-ms operate-and-release times.

The microprocessor's clock crystal can be replaced with a stable oscillator module and there is a spare 16-pin dual in-line package position for user modifications.

The boards have electronically programmable read-only memory sockets that can accommodate as much as 32 Kbytes of EPROM.

Available four to six weeks after order, the board with 8 Kbytes of RAM costs £175, and the 32-Kbyte version £195. A board without analog components and power relays costs £150.

–Steve Rogerson

London Energy and Employment Network (LEEN), 99 Midland Road, London NW1 2AH, UK.
Phone 44-1-387-4393 [Circle 500]

ANALYZER OFFERS AUTOMATIC PASS/FAIL

A flutter analyzer from Minato Electronics Inc., aimed at inspection-line applications, offers automatic pass/fail signaling in addition to the conventional functions that measure slight rotational fluctuations in small motors.

The Model 6110 analyzer is a wideband FM demodulator that operates in the 10-Hz to 1-MHz frequency range. Sets of measurement functions can be programmed into the instrument and recalled with the touch of a button. Output terminals are provided so the information can be interfaced with oscilloscopes, recorders, and fast Fourier transform analyzers. Model 6110 costs 385,000 yen. Delivery is within one month of order.

Minato Electronics Inc., 4105 Minami Yamada-cho, Kohoku-ku, Yokohama 223, Japan.
Phone 81-45-591-5611 [Circle 701]

16 MBYTES OF SRAM FIT ON VME CARD

Up to 16 Mbytes of CMOS static random access memory can be put on one VMEbus card from Europel Systems Electronics Ltd. Called the Cosmos-16 family, the boards are available with capacities from 0.5 to 16 Mbytes, and all of them have on-board battery back-up. Each model takes up only one VMEbus slot.

All the cards provide zero-wait-state access on write cycles, and some also provide zero wait on read cycles.

Operating power for the 16-Mbyte model during continuous access is less than 12 W; power drops to 3 MW on standby.

The cards provide full VMEbus specifications, including 16- or 32-bit data width, unaligned data transfers, 16-, 24-, or 32-bit addressing, and read-modify-write cycle support.

Memory can be organized as a single block of 16 Mbytes or as 16 paged 1-Mbyte blocks. Individual blocks can be write protected, nonprivileged-access protected, or totally protected.

All modes of operation and VMEbus addresses can be set up from software-programmable registers or selected from switches on the front panel.

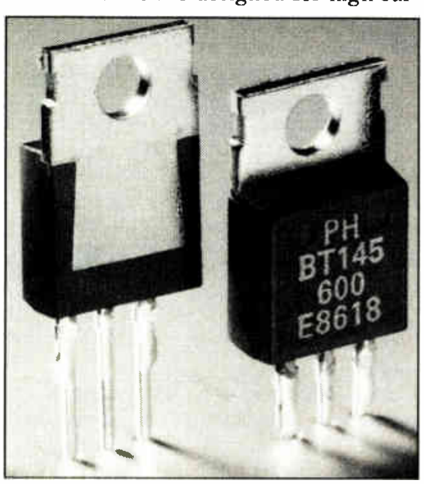
The boards cost from £1,875 for the 0.5-Mbyte unit to £8,000 for the 16-Mbyte model.

Europel Systems Electronics Ltd.,
5 The Vo-Tec Centre, Hambridge Lane,
Newbury, Berks RG14 5TN, UK.
Phone 44-635-31074 [Circle 702]

THYRISTOR PACKAGE CUTS COST BY 75%

The BT145 series of 25-A thyristors from Philips Elcoma come in a TO-220 package, offering a cost-effective replacement to metal-can devices in heavy-duty applications.

Costing about 25% of the price of equivalent metal-can thyristors, the BT145 devices are designed for high-current and single- or three-phase ac motor control in domestic or industrial-control circuits. It targets applications such as heating control, relay and pulse coding, and regulators for power supply circuits without transformers.



The three thyristors have voltage ratings of 500, 600, and 800 V. The gate current needed to trigger the devices is 35 mA at 25°C. The gate-controlled turn-on time is typically 2 μs. The devices are available in volume quantities. Low-volume prices are about $1.20 each in 10,000-unit lots.

Philips Elcoma, P.O. Box 523, 5600 AM Eindhoven, The Netherlands.
Phone 31-40-757005 [Circle 703]

CONTROLLER RUNS MULTIDISKS REAL-TIME

The model 451 high-speed Multibus controller from Xylogics International Ltd., Slough, Berks, uses a software driver to achieve optimal disk-drive performance for real-time multidisk applications in an IEEE-796 environment.

The controller supports 8- to 32-bit microprocessors, including Intel Corp.'s 8086, Motorola Corp.'s 68000, and Zilog Inc.'s Z8000. Running under the Intel iRMX286 time-operating system, the model 451 supports the high-capacity 2.5 Mbytes/s storage module device and Storage Module Drive compatible disk drives. Commands are issued by creating peripheral commands in an input/output parameter block in memory, and chaining them for optimal controller throughout.

The unit costs £1,600, and original equipment manufacturers' discounts are available. Delivery is within 30 days.

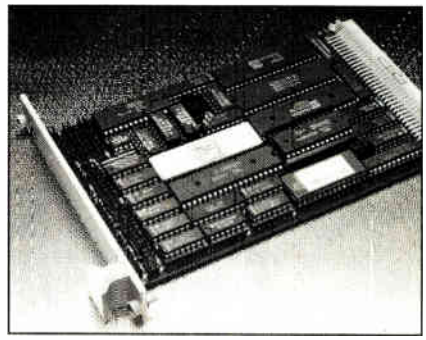
Xylogics International Ltd., 46-48 High St., Slough, Berks SL1 1EN, UK.
Phone 753-78921 [Circle 705]

STORAGE CONTROLLER FITS ON EUROCARD

PEP Modular Computers GmbH has introduced an intelligent mass storage controller for the VMEbus on a single-height 100-by-160-mm Eurocard. The design objective for the VMSC controller was to accommodate all system mass-storage control functions on a single module with no compromise in functionality.

Two Winchester drives and four floppy drives, or three floppy drives and one tape drive, can be interfaced simultaneously.

Intelligent firmware used in conjunction with Zilog Inc.'s Z80-based hardware provides a high level of programming convenience with a powerful instruction set, automatic media-format recognition, and blocking/deblocking functions. Buffering and a direct hardware interface to the VMEbus optimize throughput. Unit price for the VMSC is 1,750 DM. Delivery takes four weeks.



PEP Modular Computers GmbH, AM Klosterwald 4 D-8950, Kaufbeuren, West Germany.
Phone 49-8341-8974 [Circle 706]

MULTIMETER OFFERS LOW-COST ACCURACY

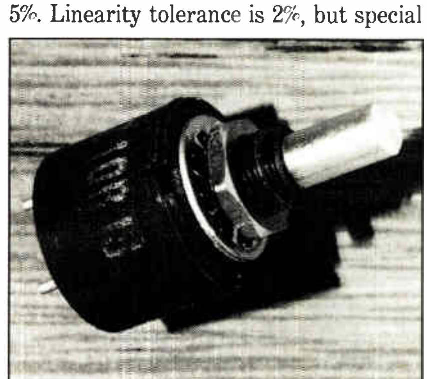
The 6½ digit multimeter Model 6000 tabletop unit offers long-term accuracy for dc voltage and resistance measurements of 0.005%. The accuracy is now achieved only with more expensive digital multimeters, says Perma GmbH, developer of the 6000. The meter can be used for seven measuring functions, including temperature and 2- and 4-pole resistance measurements. Temperature is shown in Celsius, Fahrenheit, or Kelvin. Available from stock, the basic unit, with an IEEE interface, sells for about 2,600 DM.

Prema GmbH, Robert-Koch-Str. 10, D-6500 Mainz 42, West Germany.
Phone 49-6131-50620 [Circle 704]

POTENTIOMETER HAS WELDED CONNECTIONS

Welded rather than crimped terminal connections give the model M2 wirewound potentiometer from Argo Electronic Components Ltd. two advantages: they completely eliminate the "hop-on, hop-off" resistances associated with crimped connection, and they provide a fully homogeneous joint.

The M2 is available in resistances from 5 Ω to 50 k-Ω with a tolerance of 5%. Linearity tolerance is 2%, but special



versions are available at 1%. Power rating at 70°C is 2 W.

Proof voltage from shaft to track is 1 kV dc with an insulation resistance of 500 MΩ. Rotation is 290° ±5°. Unsealed torque is 1 to 5 oz/in., and end torque is 10 lbs/in.

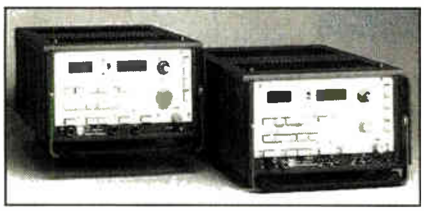
It is available in a printed-circuit-board configured with 0.2-in. terminal spacing or a panel-mounting configuration, the latter with an aluminium-alloy shaft. Price varies with resistance and tolerance ratings, but averages £1.40 each.

Argo Electronic Components Ltd., Electric Ave., Westcliff-on-Sea, Essex SS0 9NW, UK.
Phone 44-702-343355 [Circle 707]

METER CHECKS PCM NOISE AND DISTORTION

The low-frequency level meter from Wandel & Goltermann GmbH handles noise measurements with integrated weighting filters and measures quantizing distortion on pulse-code-modulation systems. It also includes the usual level, gain, and loss measurements, and comes in a compact, battery-operated package. Applications targeted by the PMG include monitoring and servicing phone, audio, and data-transmission systems.

The usable frequency range of the receive section is 20 Hz to 110 KHz. The send frequency ranges from 20 Hz to 64



KHz, and resolution of the frequency display is 10 Hz. Below 20 KHz, the resolution is 1 Hz. Standard output impedances are 600 and 1,200 Ω.

The meter is available now. Price depends on the importing country.

Wandel & Goltermann GmbH, P.O. Box 45, D-7412 Eningen, West Germany.
Phone 49-7121-860 [Circle 708]

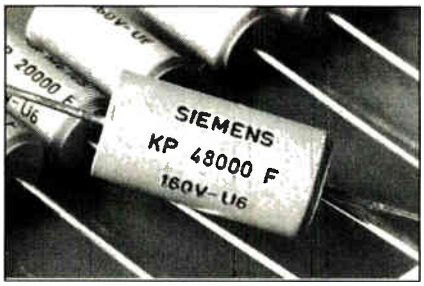
160-V CAPACITORS SUIT LONG NETWORKS

Siemens has raised the nominal voltage of its B33074 communications capacitors from 100 to 160 V, which suits them for the complicated telephone networks and long lines in the U.S. and Canada. Continuous limit current can reach 1 A.

The capacitance of these low-flammability, plastic-encapsulated, polypropylene devices ranges from 100 pF to 48 nF. At the 48-nF rating, the cylindrical devices measure 9.7 by 19 mm. Like their predecessors, they feature low-loss, high-capacitance stability and a negative temperature coefficient, with an operating range of -40°C to +85°C.

Up to 1,250 taped capacitors can be fed into the automatic-placement equipment from one reel for mounting on digital pc boards. Leads 30-mm long, which project from each end of the capacitor, are then inserted into the board.

The price depends on capacitance value; a 10-nF version costs .45 DM in



10,000-unit lots. Delivery takes 10 weeks.

Siemens AG, Postfach 103, D-8000, Munich 1, West Germany.
Phone 49-89-23-40 [Circle 709]

PHILIPS LEDs HIT UP TO 200 MILLICANDLES

Luminous-flux, hyper-red light-emitting diodes from Philips have intensities up to 200 millicandles at a wavelength of 650 nanometers with drive currents of 10 mA. The device range, designated Hyper-red LED, is aimed at two broad market segments: one comprising standard display panels, information boards, moving advertisements, and electronic games; the other, low-power applications as in battery warning lights or indicators in portable equipment.

With its new LED range, the company is offering a choice of light output from 0.7 to 200 millicandles, drive currents of 2 mA or 10 mA, beamwidths from 20° to 110°, and a variety of encapsulations.

The LEDs are single-heterojunction gallium-aluminum-arsenide devices that use a single-step liquid-phase process.

Prices depend on the type, quantity, and the importing country. Average selling price is from 0.225 to 2.275 guilders per piece in volume quantities. Delivery from receipt of order takes from six to eight weeks. Samples are available from stock.

Philips Elcoma, P.O. Box 523, 5600 AM Eindhoven, The Netherlands.
Phone 31-40-757005 [Circle 710]

FACTORY COMPUTERS RUN AT 16 TO 20 MHz

The Eurocom 5 family of central processing unit modules from Elteo GmbH is aimed at industrial VME applications where speed and processing power is critical in system design.

Available in different configurations, the Eurocom 5 boards carry the Motorola MC68020 16- or 20-MHz processor, a random-access memory, a programmable VMEbus interrupt handler for multiprocessing applications, and two asynchronous RS-232-C serial communication lines.

The boards also have an interface for mass-storage I/O, a 24-bit multipurpose and task interrupt timer, a battery-backed clock, a system controller with a bus arbitration module, and a local extension bus to customize the Eurocom 5 with dedicated intelligent peripheral interface I/O modules.

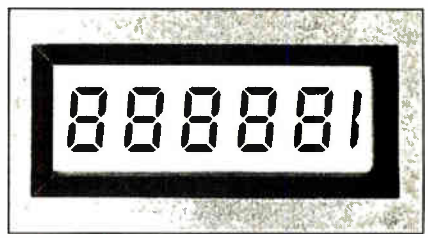
The family is available now. The basic version, the Eurocom 5-100, which runs at 16 MHz, will cost 6,800 DM.

Eltec Elektronik GmbH, Galileo-Galilei-Str. 11, D-6500 Mainz 42, West Germany.
Phone 49-6131-50630 [Circle 712]

LCD CAN BE READ FROM A WIDE ANGLE

The multipurpose 5½-digit liquid crystal display EA2032 from Electronic Assembly GmbH is a low-power, plug-in module featuring a high-contrast display with 6-mm-high digits that can be read from almost any angle. It can be used as an event counter or an hours-of-operation counter.

The module measures 40-by-22-by-12.5 mm. Pins are arranged so the module



can be plugged into a 28-pole integrated-circuit receptacle. Working off a supply from 2.8 to 5.5 V, the module consumes 1 μA. A 3-V lithium battery will provide years of uninterrupted operation. Available now, the EA2032 costs $1.70 DM apiece in lots of 100.

Electronic Assembly GmbH, Luitpoldstr. 12, D-8034 Germering, West Germany.
Phone 49-89-846088 [Circle 711]

TEMPERATURE UNIT OFFERS WIDE RANGE

The PM216 temperature sensor for IEEE-488/IEC625 instrument buses from Philips GmbH's Test and Measuring Division operates over the -200°C to +85°C range and features integrated temperature measurements and limit warnings.

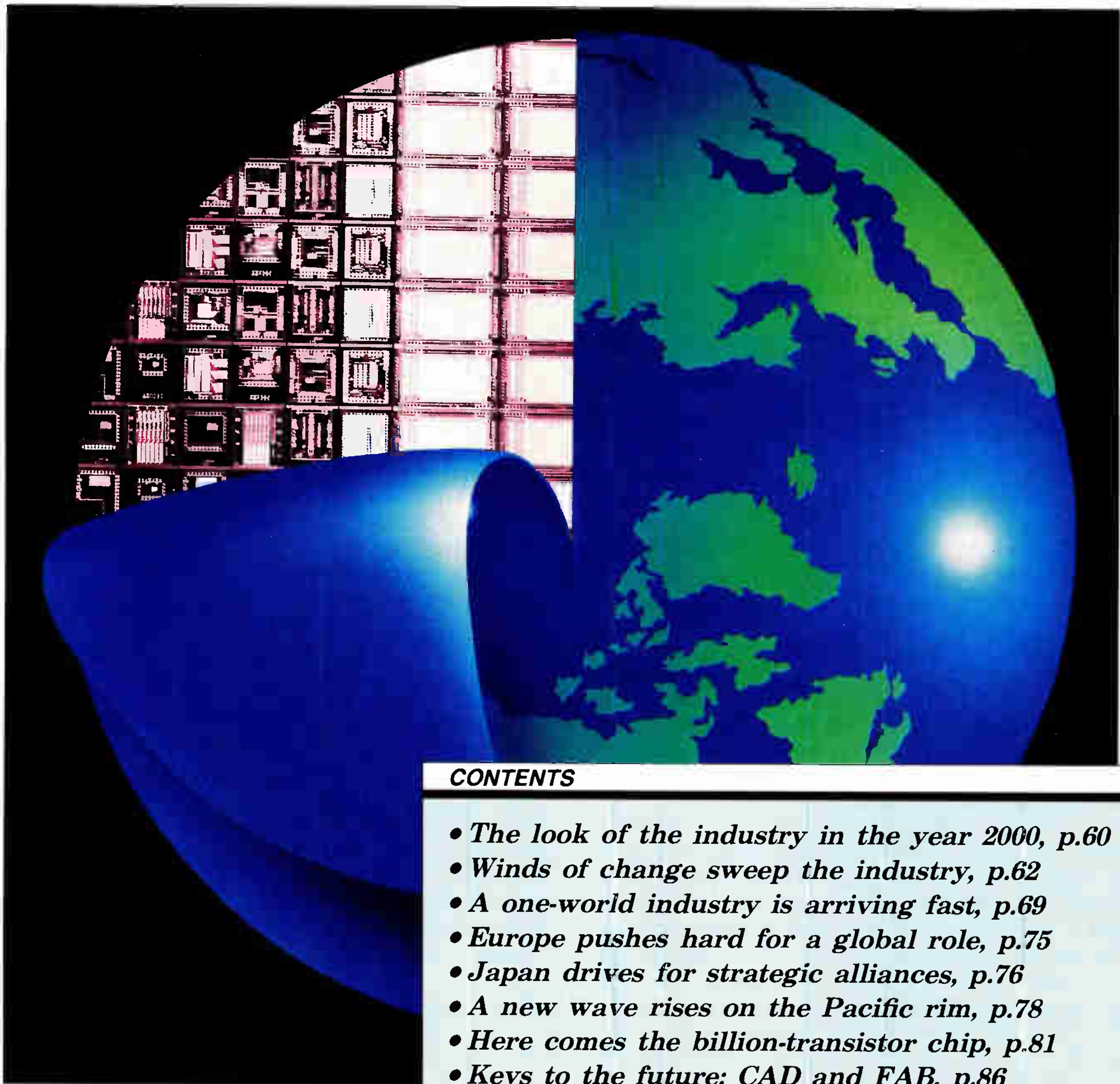
The sensor's results can be compared with preprogrammed limits. Available from stock, it costs 1,500 Dutch guilders.

Philips Test and Measuring Div., 5600 MD Eindhoven, The Netherlands.
Phone 31-40-788620 [Circle 713]

SPECIAL ISSUE

THE CHIP MAKERS: WHERE THEY'RE HEADING

Global alliances, systems on chips, and desktop design will pull a struggling industry into the 21st century



CONTENTS

THE LOOK OF THE INDUSTRY IN 2000

It will be completely redefined in terms of structure, participants, and in the way that products are designed, manufactured, and marketed

by Samuel Weber

It has never been easy to predict where the chip makers are heading. But long-term technology trends still foretell the most. With much of the technology that will be in place by the turn of the century already in various stages of development, the picture for the year 2000 emerges. By then, the industry will be completely redefined in terms of its structure, the participants, and, most important, the way products are designed, manufactured, and marketed.

The semiconductor world will be divided into two camps, each with its own distinctive set of market characteristics. One will produce high-volume commodity parts, and the other the many forms of semicustom chips, including system-, customer-, and application-specific integrated circuits, as well as other parts targeted at low-volume market niches. The commodity side of the industry, which will be in the hands of a relatively few players, will focus more on low-cost manufacturing than on interaction with customers. The semicustom side will represent a completely different way of doing business, with especially close customer relationships and high levels of service and support. On this side, the year 2000 will see a free-for-all with every type of chip maker—from the giant commodity producers to the tiny design house—still in the fray.

SEMICUSTOM VS. COMMODITY

Some industry observers see the semicustom side of the business becoming overwhelmingly dominant by 2000, and commodity parts very nearly disappearing, as higher levels of integration and easy customization of chips lead to a world populated by highly individualized systems on chips. Even memories are beginning to be application-specific in nature, they point out. The noncommodity side of the marketplace is already flexing its muscles: Pasquale Pistorio, the chairman and CEO of SGS Microelettronica of Agrate, Italy, argues that while commodities now represent 80% of all parts shipped, they account for only 50% of the dollars. He predicts these high-volume products will continue to lose market share all through the 1990s.

Not everyone agrees with Pistorio's scenario. Charles H. Phipps, a former TI marketing vice president who is now a consultant, claims that "generic" products—any part that makes it to high-volume sales without requiring extensive sales support—will account for 70% of IC dollar volume and will still provide 60% of sales by the mid-1990s. As a result, he argues, merchant houses will retain a strong role.

But all agree that even if the noncommodity side of the industry does not push the high-volume vendors out of the market, it will be a force to be reckoned with, creating its own market environment. With the advent of powerful design tools for ASICs and other semicustom chips, the design prerogative, once firmly in the hands of the chip maker, will have shifted to the systems designer by the end of the century. In addition to intimate vendor-customer relationships during the design cycle, fast turnaround and ongoing dedication to customer service will be far more important than the ability to turn out millions of low-cost chips.

By the year 2000, innovative design and architecture will have superseded process and manufacturing as the keys to product success, an industry environment that will continue to spawn young, spirited companies whose strength lies in the development of unique proprietary products without the burden of costly fabrication facilities. These fast-moving design specialists will flourish alongside a group of specialists of the opposite type: companies specializing in leading-edge process technologies with applications in niche markets.

Straddling the fence between semicustom and commodity markets will be a number of powerful vertically integrated companies. With their deep pockets, design staffs, production capabilities, and extensive research and development facilities, this type of company may hold the ultimate edge in the battle for survival.

Meanwhile, technology in 2000 will be continuing its inexorable drive into submicron geometries, bringing the promise of generations of faster, denser chips holding a billion devices. The ramifications of such functional power on a chip are barely imaginable for both IC maker and system designer. New device structures and design tools will have been developed for them; voltage levels will have been reduced; and longstanding architectural approaches will by then have been abandoned. The process technologies required may es-

THE JAPANESE CROWD INTO THE TOP 10 MERCHANT IC MAKERS

	1966	1976	1986 (Estimate)	1996 (Forecast)
1.	Fairchild	TI	NEC	IBM
2.	Texas Instruments	Fairchild	TI	NEC
3.	Motorola	Philips/Signetics	Fujitsu	Fujitsu
4.	Signetics	National	Hitachi	Hitachi
5.	Westinghouse	Intel	Motorola	Toshiba
6.	Sylvania	Motorola	Toshiba	TI
7.	Raytheon	NEC	Philips	Matsushita
8.	RCA	GI	National	Mitsubishi
9.	Philco	RCA	Intel	Samsung
10.	General Instrument	Rockwell	Matsushita	Siemens

SOURCE: INTEGRATED CIRCUIT ENGINEERING CORP.

calate the cost of fabrication facilities to levels that only a few organizations can afford.

As chip makers move raggedly toward the 21st Century, the semiconductor landscape will continue to change radically—as it has every decade (see chart). Looming is yet another shakeup in the lineup of the Top 10 merchant suppliers, capped by a succession of Japanese megacompanies. Only if IBM Corp. turns merchant in the next decade, as now seems likely, will a U. S. chip maker lead the list, and only one company, Texas Instruments Inc., can boast of having appeared on the list for 20 years. With the predicted decline in commodity markets, some observers doubt the industry can support as many as 10 merchants by the year 2000.

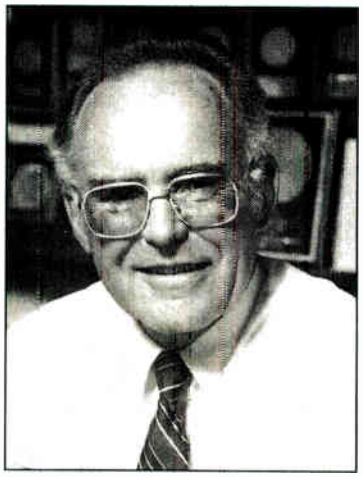
Underlying this turn-of-the-century industry superstructure will be a fast-developing vast and complex network of international alliances in the form of mergers, acquisitions, and technological partnerships. These alliances are being forged out of the realization that no one company can go it alone in exploiting the protean semiconductor technology. Ties will be formed between all companies of all stripes, crossing international borders to complement one another's strengths, bolster gaps in proprietary product lines, and provide manufacturing capacity.

Furthermore, such international alliances will help the IC makers penetrate overseas markets. Not just the U. S. and Japan will be active in these alliances in 2000. European chip makers, traditionally laggards, are already showing new determination to close the technological and marketing gaps. And new forces are gathering in Asia as the Pacific Rim nations emerge as both consumers and suppliers of ICs.

One thing is certain. After all the upheaval and turmoil, though the semiconductor industry may look different and its participants may change by the year 2000, it will emerge as the single most important industry the world has ever seen.

MOORE VS. MEAD: IS SILICON VALLEY OBSOLETE?

Is the semiconductor industry consolidating the integrated-circuit revolution, or is it on the verge of another one? It is now consolidating, in the face of overcapacity and worldwide competition, says Gordon E. Moore, who helped create Silicon Valley as the cofounder of two of its most important companies, Fairchild Semiconductor Corp. and Intel Corp. But to Carver Mead, who with Lynn Conway co-invented the design methodology that threatens to undermine the type of company Moore has built, the fun has only begun.



GORDON E. MOORE

Change is the only really constant factor in the semiconductor industry, says Moore, Intel's chairman. But he insists that the selling of standard products based on sophisticated processes will remain the industry's fundamental way of doing business. "The world lives on mostly standard products," Moore says. Standard microprocessors (like Intel's iAPX 386 and the members of Motorola's 68000 family) can live indefinitely because of the large bodies of software they have accreted. Even application-specific ICs, Moore says, will be built mostly around standard blocks tailored to special needs.

No industry figure has foreseen the technical changes that are now remaking the industry more clearly than Mead, the California Institute of Technology scientist who pioneered in hierarchical IC design, simulation, and compilation. The ability to design complete systems cheaply and easily on a chip and have the ICs fabricated at a silicon foundry makes it possible for anyone with minimal training to express almost any system-level idea, he says.

The result, Mead says, is that "the chip is software. The medium is not the value; information is the value." And Silicon Valley, which sets great store on producing chips, is obsolete. "We're in the service business, not manufacturing," he asserts.

Mead contends that the design revolution has only begun, and the traditional semiconductor houses don't understand it. Foundries, he says, are printing presses, and designers are writers; and prices are coming down rapidly enough for silicon writers to publish their ideas as systems. The Mosis project at the University of Southern California, for example, allows designers to deliver a specification tape and get a prototype and five chips for $400. "Any high school kid with an American Express card can do it, and it costs no more than software," Mead says.

Moore admits to being surprised at the success of the design-only semiconductor houses, such as Brooktree Corp. and Weitek Corp., that embody Mead's ideas. However, he thinks there is room for only a few of these companies. "There are too many players in the business right now," Moore says. "We are well beyond the range of maximum efficiency. The 1990s will see many fewer company formations and a new wave of consolidation."

Mead recognizes the need for large IC makers but insists they will not be on the leading edge. That will be the place of the design houses that can stay a step or two ahead of firms that are tied to fabrication-line investments.

Beyond the design revolution, says Mead, lies still another change that is even more significant, a change to radically new circuit architectures. He is working on one possible type, neural networks—silicon hardware that imitates the way the brain works.

–Clifford Barney and Larry Waller

CARVER MEAD

WINDS OF CHANGE SWEEP THE INDUSTRY

Chip makers must get through two major technology dislocations before 2000: desktop design and maybe even a new transistor structure

by Clifford Barney

A massive restructuring is now sweeping through the worldwide semiconductor industry, causing as profound and dramatic a series of changes as the business has ever experienced in its short but tumultuous history. Buffeted by the need to keep up with rapidly-changing technology on the one hand and a host of dangerous economic and political forces popping up on the other, many chip makers face what amounts to a do-or-die struggle. As a result, the industry will look vastly different by the year 2000; and along the way, chip makers will have to make it through at least two severe dislocations.

By the early 1990s, the emergence of highly sophisticated computer-aided-design tools will cause further restructuring when it becomes possible for nearly every potential user to develop his or her own circuit and then farm out the design to a foundry to fabricate. Then, by the late 1990s, the industry may have to face a restructuring at least as significant as the shift of the main integration vehicle from bipolar to MOS in the late 1960s. Indeed, if the increases in circuit complexity are to go on, it may be necessary to shift not only to a totally new transistor structure, but to new materials.

The basic factor that chip makers must face up to is that as chips grow more highly integrated, they look more and more like systems than components. The upshot is that the long-established importance of standard chip products erodes, and semicustom or application-specific integrated circuits become more and more important. Although standard commodity chips still account for well over half of the units shipped, they generate only about half of the industry's revenue, by some estimates. More and more, the money is in semicustom parts and ASICs.

It is commonly believed within the U. S. industry that the Japanese drive for major market share is the major factor behind the wrenching changes that it is going through. That drive obviously is having strong short-term effects, but the technology itself is behind the more fundamental, long-term shifts that can already be seen. With standard products losing their dominance, the merchant IC companies will decline—unless they capitalize on the snowballing ASIC trend. But to do that, they must forge the kind of relationship with customers that ASIC houses pioneered: very close ties emphasizing large amounts of service.

The design process also must change radically, with more of the design being done by the customer with CAD tools, and with the design task focused more and more narrowly on spe-

THE NEW SHAPE OF THE MERCHANT IC INDUSTRY

Standard IC makers

Advanced Micro Devices
Cherry Semiconductor
Intel
Eurosil electronic
Exar
Fairchild Semiconductor
General Instrument
Inmos
International Rectifier
Matra-Harris
Micron Technology
Monolithic Memories
Motorola Semiconductor Products Sector
National Semiconductor
SGS Microelettronica
Siliconix
Sprague
Standard Microsystems
Texas Instruments
Western Digital
Zilog

Vertically integrated companies

AT&T
Ford Microelectronics
GE/RCA/Intersil
GM/Hughes Electronics
Gould
GTE Microcircuits
Harris
Honeywell
ITT Semiconductor
Mitel
NCR
Philips/Signetics
Plessey
Raytheon
Rockwell International
Siemens
Telefunken electronic
Thompson Components-Mostek
TRW
All major Japanese and Korean semiconductor producers

Design houses

Digital:
Altera
Brooktree
Dallas Semiconductor
Lattice Semiconductor
Chips & Technologies
Cirrus Logic
Faraday
Integrated Device Technology
Logic Devices
MOS Electronics
Vitelic
Weitek
Xilinx
Zoran

Linear:
Anadigics
Analog Devices
Burr-Brown
Crystal Semiconductor
Linear Technology
Maxim
Micro Linear
Precision Monolithics
Silicon Systems

Process specialists

Bipolar Integrated Technology
Catalyst Semiconductor
Cypress Semiconductor
Exel Microelectronics
Gazelle Microcircuits
GigaBit Logic
Hypres
Inova Microelectronics
International Microelectronic Products
Micro Power Systems
Mosaic Systems
Orbit Semiconductor
Performance Semiconductor
Seeq Technology
Sierra Semiconductor
TriQuint
Vitesse Electronics
Xicor

Semicustom houses

Actel
Applied Microcircuits
California Devices
Ferranti
Integrated Logic Systems
International Microcircuits
LSI Logic
Micam Associates
Micro Linear
Solid State Scientific
VLSI Technology
Waferscale
Zymos

NOTE: In this representative listing, a number of companies fit in more than one category. They are placed under the heading of their most important business.

cific systems or niches within the marketplace.

Because of these new imperatives, a landscape once dominated by a few manufacturers that pioneered in the technology can now be seen as a spectrum of many types of chip makers—at least in the U. S.—with companies clustered in four main areas (see chart, opposite): the traditional merchant IC houses, the vertically integrated conglomerates with captive semiconductor operations, ASIC specialty houses, and the group of niche specialists who either focus on an area of design expertise or on a targeted process expertise. The members of each of these four groups each bring their own brand of strengths to the new ball game, and they each face a unique set of challenges.

- The traditional merchant IC houses such as Advanced Micro Devices Inc. and Intel Corp. have much experience in process technology and chip design, but they must turn those strengths in a new direction. The sagging standard-IC business is still keeping them alive, but they must learn to react quickly to target chips for niches, and to build closer customer relationships around a semicustom-chip capability.
- The vertically integrated companies, among them the giant Japanese and European chip makers and such U. S. concerns as NCR Corp., have the healthiest financial foundations to build upon of any of the four groups. They also boast vital internal synergies, such as their own systems-design expertise, to draw upon for building systems on chips. But they must find ways to move faster and in more directions if they are to beat nimble niche specialists to small but lucrative new markets.
- The semicustom manufacturers are young companies set up with the new realities of technology in mind. Emphasizing quick-turnaround ASICs based on gate arrays and standard cells and designed with sophisticated CAD tools, they are in a position to quickly make effective use of growing levels of chip integration. The challenges such companies as LSI Logic Corp. and VLSI Technology Inc. face are, first, keeping their design tools abreast of the capabilities of process technology, and, second, keeping their own process technology on the leading edge without traditional process-driving parts like dynamic random-access memories.
- The design or process specialists sprouting all over the U. S. have identified niches where their expertise can provide full solutions for systems customers. Examples of design specialists are Brooktree Corp., which designs chips for graphics subsystems, and Weitek Corp., which designs mathematics accelerators. These two companies have dispensed entirely with wafer-fab operations to focus all their resources on design. One example of a process specialist is Cypress Semiconductor Corp., which makes high-speed memory and logic for niche markets on its 1.2-μm fab line. These small companies move quickly and have very close relationships with customers: they give them exactly what they need without a big wait. But they must stay on their toes, because the industry giants around them can and do pick up on their targeted niches and design competing parts.

The lines between these groups are not always

NOW NATIONAL AIMS TO BE A DESIGN LEADER

Merchant chip makers have a choice: change strategies or go the way of the dinosaur. National Semiconductor Corp. built its reputation as a sometimes-abrasive low-cost maker of jellybean integrated circuits with no time for handholding with buyers. But now the Santa Clara, Calif., company has rewritten its corporate mission to focus on design leadership, advanced technology, and service, service, service. "We never say no to a customer," says James M. Smaha, executive vice president of the Semiconductor Group. "We are dogmatic about it."

The change in philosophy stems from a series of meetings that founder and chairman Charles E. Sporck launched in the early 1980s with key customers. The goal was to find out what direction their business was taking and where their technology was going. The answers—into more highly integrated systems built in CMOS—made National decide to take a new direction.

"Technical advances were forcing us to get closer to our customers and integrate our products to provide systems solutions," says Smaha. "We had to become a design leader as well as a volume manufacturer."

JAMES M. SMAHA

National has now moved heavily into CMOS, based on a single process that can be used for all products. It emphasizes development of proprietary products, which now account for 45% of its portfolio, compared with 20% five years ago. These products are entered into National's library of standard cells for use in application-specific ICs or for the development of further standard products.

National has also enthusiastically embraced the idea of alliances and partnerships, signing a total of seven last year. These include an important link to General Motors Corp., whose Delco subsidiary has licensed National's surface-mount technology.

Probably its most crucial alliance is with Xerox Corp., with which National has a long-term agreement for the development of ASICs. Xerox provides the systems expertise and National the know-how in chip design, the CMOS process, manufacturing, and packaging. The year-old alliance is working well, Smaha says. Xerox has supplied cells for National's library, and National will supply the bulk of Xerox's semicustom ICs.

As the technology migrates to more highly integrated products, Smaha foresees ICs becoming pervasive in all areas of society. "It is the kernel to the economic success of any country," he says. Whole nations, as well as companies, are competing today for industrial power. Therefore, he concludes, there will always be a place for the merchant semiconductor company—providing, of course, that it takes good care of its customers. *–Clifford Barney* clearly drawn. Intel and National Semiconductor Corp., for example, have ASIC operations and are expanding their systems activities. The semiconductor arms of Motorola Inc. and Texas Instruments Inc. have always been more or less autonomous segments of vertically integrated systems houses. And NCR is a leader in the standard-cell ASIC field.

Companies in all of these groups are struggling to stay on board the fast-moving roller coaster of technology (see p. 81). And they must deal with an array of limiting economic and political factors that will determine the new shape of the industry. Among the foremost is the increasing cost and more rapid obsolescence of capital equipment. Automated submicron fab lines cost upwards of $100 million and may have a useful life of only two or three years. By the late 1990s, calculates market researcher Dataquest Inc. of San Jose, Calif., a fab line will have to produce $650 million in annual revenue to justify itself.

Another key development is the shift of the bulk of IC production and consumption to Japan and the Far East. U. S. companies have tried a variety of methods to win greater entry into Japan—from alliances of every stripe (see p. 69) to a trade dispute of major proportions. Their inability to gain entry in any large measure, or to stem Asian dominance of U. S. commodity markets, has profoundly affected the strategy of the U. S. merchant chip makers.

Because they are effectively shut out of the Japanese market, these companies are turning to making advanced niche products with higher selling prices, notes Gene Norrett, head of Dataquest's semiconductor service. "Commodity products are gone," he says. "Japanese companies will maintain their closed market at home and sacrifice chip profits to support their vertically integrated structures. U. S. companies will make high-end chips like digital signal processors and sell them to each other."

The alliances are one aspect of a consolidation that is picking up speed. Another aspect is the increasing importance of joint projects, such as Sematech, the proposed manufacturing consortium. Beyond that, mergers and acquisitions are expected to reshape the industry. Advanced Micro Devices' chief executive officer W. J. Sanders expects only five or six merchant houses to remain independent, and many analysts think he is on the high side. "Merchant semiconductor companies can't survive," maintains Matthew Crugnale, head of marketing consultants Crugnale & Associates of Mountain View, Calif. "The U. S. industry will become embedded in big systems houses."

It is in this context that the traditional IC merchants are trying to survive and the newer technology-driven companies are attempting to gain a foothold. Most executives at mainstream companies agree that the trend toward higher integration is a major challenge to makers of standard ICs, because the more integrated the chip, the more system-specific or application-specific it must therefore be. They acknowledge that their companies are slower than the specialty houses to react to the trend. But they say they are attempting to develop focused

LSI LOGIC RIDES THE ASIC WAVE

There's a revolution shaking the world of computer-aided design, executives at LSI Logic Corp. are fond of saying, and it is giving designers far greater flexibility in implementing their designs. This change also benefits those chip makers specializing in application-specific integrated circuits, as LSI Logic does.

"We're talking about an extremely fluid environment for the design engineer," says Wilfred Corrigan, chairman of the San Jose, Calif., company. "He has the ability to process enormously complex silicon and to do it in a short time frame in most any configuration he wants. That is a radically different design environment than in the past."

The CAD-tool revolution results from two very different forces, says Rob Walker, senior vice president and chief technical officer. Chips made with the latest high-density CMOS are so complex that they require new models, routers, and tools capable of simulating the entire system. And developments in tool technology are leading to an era when a chip-design file can be used to produce either gate arrays, standard-cell parts, or chips laid out by silicon compilers.

LSI Logic dates back to 1980, when software for designing integrated circuits was getting powerful enough to quickly produce designs with complexities of several thousand gates. Corrigan realized that there was an opening for a company that could design a semicustom IC fast and then fabricate it in a matter of weeks, rather than the months or years required by commodity semiconductor vendors.

Such a company would make money on its engineering talents as well as its foundry capacity. But to keep its line busy, it would have to replace the big production runs that support the fab lines of the commodity-chip houses with a large number of jobs from ASIC users.

That meant a different approach to customer support than that offered by a conventional IC manufacturer. Not only does the company have to produce the chips, it also must help the designer lay out and then work with him to ensure that the layout meets design rules. It is essential for an ASIC company to be able to produce working silicon the first time. "We don't get paid unless the silicon works," says Walker.

Staying competitive in the ASIC business means keeping customer support and tools abreast of the new levels of IC complexity—as well as keeping up with the process technology itself. The payoff is that while the rest of the semiconductor industry struggles to reap the benefits of ever-higher levels of integration, LSI Logic just keeps doing what it has been doing, only better. "In one year," says Walker, "we have gone from 8,000 gates maximum to 50,000 gates on a piece of silicon." *–Jonah McLeod*

WILFRED CORRIGAN

strategies—such as starting ASIC divisions—while at the same time maintaining a broad product line.

The big companies acknowledge that commodity products may have turned into a losing game. But they insist that standard products will remain paramount, and that niches can't stay hidden for long. Therefore the merchants are putting top emphasis on developing proprietary standard products, while many of them move cautiously into ASICs.

And where the small newcomers make great claims for their intimate relationships with customers, TI and the other majors can offer one-stop shopping. All of the big merchant IC makers claim their customers want to cut the number of suppliers in order to improve quality and reduce their paperwork. Consequently, systems houses are reducing the number of their suppliers, and the effect on a chip maker who doesn't make the cut is severe.

The majors offer deep product lines. Motorola, for example, is buying dynamic random-access-memory dice from Toshiba and even is getting back into DRAM production itself so that its salespeople can carry a complete portfolio. National also has put top emphasis on the design of standard VLSI chips (see "Now National aims to be a design leader," p. 63).

Getting into ASICs is forcing the majors to rethink their operations. "It's been a problem for big companies, because our minds are imbued with the standard-part mentality," admits Motorola Semiconductor Products Sector general manager James Norling. The big merchant houses haven't been willing to allocate sufficient resources to provide the kind of support ASICs require, Norling says, and in addition big-company bureaucracies defeat the whole point of ASICs: fast turnaround. Motorola therefore has isolated its ASIC operation and has made it into a quasi-independent unit.

While they change directions, the older chip makers may draw on their arsenal of patents to keep the newcomers at bay. Suddenly, "intellectual property" has become of far more than intellectual interest. Encouraged by TI's success in extracting DRAM royalties from Japanese suppliers, the merchants are, in the words of Intel's Moore, "awakening to a new opportunity."

"A lot of new entries don't have a patent position," Moore says bluntly. "Some companies could be shut down. Patents and copyrights will change the ground rules in favor of big, established companies that have developed intellectual property." Rodney Smith, president and CEO of Altera Corp. in Santa Clara, Calif., agrees that intellectual property is the key to future success in the industry—but not just for the big, established companies. "Manufacturing is no longer an art," says Smith, whose company has no fabrication facilities of its own. "The real added value is in architecture, design, and testing."

As the merchant IC houses lumber into place, the ASIC early birds are already jumping ahead with the next generation of tools for design, simulation, and layout. This kind of advanced engineering and the service with which it is supported remain their edge: ASIC companies make it easier for their customers to design complex systems. With these tools and the very nature of their business, the ASIC houses are best able to capitalize on the central problem of increasing integration: as the chips get more complex, they look more and more like the system they implement.

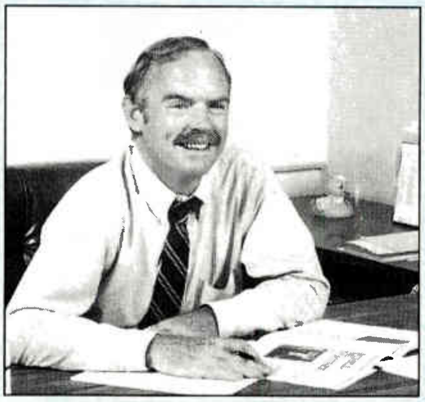
These companies are expanding in two directions. They are spinning off customer designs into standard

BROOKTREE BETS THE BANK ON CHIP DESIGN

Designing chips, not making them, is the key to survival, maintains Brooktree Corp. That's why the six-year-old San Diego company has no fabrication line and doesn't plan to install one.

"Having a fab line is like having your home swimming pool full of pet sharks," says president James A. Bixby. "You end up spending all your time feeding them." As he sees it, Brooktree is not even in the chip business. "We're systems guys; we don't want to make ICs. We don't even know how."

Brooktree's path to success comes from its role as a trailblazing designer of complex integrated circuits that replace entire boards serving as back-end digital processors and data converters in high-level computer graphics. The company, which has only 200 employees, expects sales to surge past $10 million this year. It started delivering its products in late 1985.



JAMES A. BIXBY

By decoupling IC design from in-house wafer fab, Brooktree frees its engineering talent and assets to concentrate on the root problems, says Bixby. The company's prime focus: "correct product definition and design, which amounts to an art and evidently is a very hard thing for the industry to do," he says. First products were a family of digital-to-analog converters, whose speeds have been boosted to 600 MHz, and color-lookup tables made from high-speed random-access memories. Then the two products were integrated into a one-chip type: Ramdacs.

Brooktree can do its production at silicon foundries or on fab lines built by semiconductor houses that these days are happy to provide a choice of the most advanced processes to all comers. Bixby notes he is well aware that the company enjoyed a break in its market timing, "having our first products when these foundries became available."

Skeptics still say the Achilles' heel of companies such as Brooktree is that wafer-fab capacity will disappear when the overall chip business improves, but Bixby brands this a dead issue. "We are customers in good standing ourselves," he says, and adds that foundries have matured into a stable business.

Brooktree is well down the road toward embodying the "silicon publishing" concept proclaimed by Carver A. Mead of the California Institute of Technology nearly a decade ago. "They are the future of the semiconductor industry," Mead says now. *–Larry Waller* products, and they are developing their own complex macrocells, such as LSI Logic's multiplier/accumulator. But the principal strengths of companies like LSI Logic remain in their ability to make use of higher levels of integration quickly, and to provide customers with sophisticated design tools and fast-turnaround service on designs (see "LSI Logic rides the design wave," p. 64).

Even as the ASIC houses distance themselves from the mainstream companies, they are finding competition from the new breed of niche companies. These companies also emphasize service and advanced engineering. Yet because they are specialists in one design area or process technology, they can concentrate their resources. At Weitek and Brooktree, for instance, that area is product definition and design. And because these newcomers do not bear the crushing burden of replacing expensive fab lines, they can spend more money on technical support, sales, and marketing. At Weitek, in Sunnyvale, Calif., there is one applications engineer for every field sales person—whereas large IC merchants may have one engineer for every 16 salesmen.

Having a wafer-fab line requires a company to scramble all the time to keep it operating at capacity, says Brooktree president James A. Bixby. Without a fab line, the San Diego company is free to focus on product definition and design, which Bixby considers the industry's fundamental art (see "Brooktree bets the bank on chip design," p. 65). Success at design innovation grows from close relationships with customers, he says.

But not all of the newer companies avoid owning fab lines, and some of them even specialize in it. For example, Cypress Semiconductor is known for a flexible high-performance process and a fab line implementing it that can multiplex 75 different products, including fast 35-ns programmable read-only memories and 15-ns RAMs (see "For Cypress, niche products are the key," left).

One of the strengths of the small niche companies—a close relationship with the customer—is also a hallmark of vertically integrated systems houses with their own IC operations, such as NCR (see "NCR sees its edge in systems expertise," right), because the customer is very often within the company. And the other big advantage of the verticals—the deep pockets of the parent corporation—is taking on more and more importance.

The Japanese chip makers are the quintessential vertical companies. But unless they change the way they do business, says T. J. Rodgers, president of Cypress, they will not be able to compete in the new markets, which are dominated by niche products and system-specific solutions. U. S. merchants have sufficiently diversified product lines to survive, he says, but the Japanese are too slow-moving and too averse to taking risks to compete in such markets.

That situation may not last. Dataquest reports that the Japanese are turning away from

FOR CYPRESS, NICHE PRODUCTS ARE THE KEY

The future belongs to the niche company, says T. J. Rodgers, the 38-year-old president and chief operating officer of Cypress Semiconductor Corp. And he is betting that his four-year-old San Jose, Calif., chip maker, with its state-of-the-art CMOS process, is in the vanguard.

In the future, the semiconductor market will largely consist of system-specific niches, Rodgers says, where the ability to produce high-performance integrated circuits on a relatively short turnaround time will be more important than the ability to turn out millions of ICs at relatively low cost. "And that is going to make life tough for many of the large commodity-oriented companies—especially the Japanese, who just can't compete in small-volume areas that are technologically fast-moving."

Instead of focusing on commodity markets, which represent hundreds of millions of dollars in sales but razor-thin profit margins for each device type, Cypress aims all of its 70 or so products at niche markets, each of which has potential sales of about $20 million. None of these markets by themselves is large enough to attract a major competitor, but together they represent sales of about $1.4 billion. Even if Cypress captures no more than a small share of each market, that represents a healthy chunk of sales, says Rodgers.

And indeed that has been the case. For while major U. S. and Japanese semiconductor firms are still showing losses on their semiconductor sales, Cypress's sales for the corporate year ending in December increased almost 200% over 1985, to $50.9 million. Expectations by industry analysts are that sales for 1987 will exceed $80 million.

Since its founding, the company has raised $48 million in private capital and $70 million in an initial public offering. Much of this money has gone toward building a fabrication facility for advanced CMOS circuits. Cypress's products fit into four well-known categories—static random-access memories, electrically erasable programmable read-only memories, electrically erasable programmable logic devices, and interface logic circuits—but all are aimed at niches.

An important factor in the success of Cypress, Rodgers says, is its advanced CMOS technology, with which it can build chips that are twice as fast as competing ICs and consume half the power, yet cost about the same. For about two years, Cypress has kept a jump ahead of the competition with a 1.2-μm process. To keep that edge, it has moved to 0.8 μm, and it has delivered samples of five memories using the new process.

Complementing the process is an automated assembly line in San Jose that not only can mount chips in 40 or so different packages, but can perform such assembly in 3½ days, versus 8 to 10 weeks for many competitors. This means, says Rodgers, that Cypress does not have to assemble chips until it has an order. It's this kind of sprinter performance that he sees as the key to the future. *–Bernard C. Cole*

T. J. RODGERS

volume manufacturing and are investing heavily in R&D for leading-edge technologies, such as 16-Mb DRAMs, 32-bit microprocessors, three-dimensional CAD systems, expert systems for designing VLSI circuits, new materials such as gallium arsenide, and bioelectronics. Between 1984 and 1988, Dataquest says, Japanese manufacturers will have opened at least 80 basic research laboratories and spent an awesome $2 billion on them.

Moreover, an increasing number of U. S. startups are trading technology to Japan for capital, manufacturing capacity, and market access. And shifts in low-end manufacturing to other Asian countries are driving Japanese companies into direct competition with the U. S. companies in the market for chips with a higher level of design-value content than such chips as commodity memories have. That's one reason for the increasing attention U. S. companies are giving to the protection of intellectual property, Dataquest says.

Because of their internal synergies and their financial strengths, integrated companies are widely seen as the best equipped to survive in their current form until the year 2000. It is not surprising, then, that traditional U. S. semiconductor manufacturers are looking to emulate these strengths. And there is more than one route to vertical integration.

The now-aborted attempt by Fujitsu Ltd. to take over Fairchild Semiconductor Corp., and Thomson CSF's acquisition of the remains of Mostek Corp., are examples of moves toward the classical vertical model. But vertically integrated IC companies have never done well in the U. S.; they have not been able to integrate the volatile chip operations with the broad interests of the parent companies.

Another path is being blazed by Intel and National Semiconductor. They are turning themselves into a new kind of vertical organization, a systems outgrowth of an IC company.

Even horizontal integration might appear, with large IC houses acquiring smaller ASIC houses and becoming corporate hubs for satellite operations.

Surprisingly, the notion of horizontal integration gets a warm welcome from Weitek president Arthur J. Collmeyer. The business that the merchant IC houses count on—the need for a full line of standard products—will not attract the best designers, he says. New companies "do things first, and they keep the majors honest," says Collmeyer. Therefore it might make sense, he believes, for a TI or an Intel to sponsor "Weitek-like" companies to design chips that the big company could make and distribute.

Another survival strategy is cooperation. The merchant houses have turned to the government, looking to the Department of Defense for help and to Congress for some way of accommodating joint industry projects by bending the antitrust laws. The manufacturing consortium the chip makers have proposed, Sematech, is supposed to put U. S. companies on a par with the Japanese in manufacturing. The big question is whether Sematech can unite an industry that has always prided itself on its diversity.

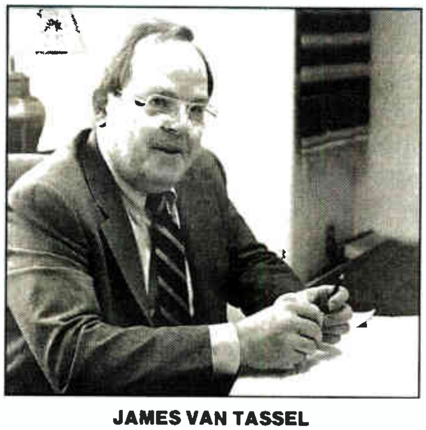
This diversity has always been one of the strengths of the semiconductor industry, and it's likely to help merchant houses, ASIC suppliers, design and process specialists, and vertically integrated giants all live to see the year 2000. There are many strategies for survival, and the companies that successfully carry theirs out may look very different than they do now—but they'll still be around.

NCR SEES ITS EDGE IN SYSTEMS EXPERTISE

The system on a chip will rule the semiconductor world, and no one is better positioned to captain its cause than vertically integrated chip merchants, argues James Van Tassel, vice president of NCR Corp.'s Microelectronics Division. For example, he says, his division can capitalize on NCR's vast bank of systems expertise to win sales on the outside as well as inside the Dayton, Ohio, maker of computer, communications, and point-of-sale systems.

Even today, says Van Tassel, "I think most semiconductor companies are in short supply of good systems-level engineers. We've got about 4,000 of them." And when dense, application-specific integrated circuits—systems on a chip—can be compiled at systems designers' desks, that edge could be important.

Van Tassel's division chalked up about 30% of its estimated $100 million in MOS IC business last year to internal NCR sales. And it leverages its internal designs to attack the merchant market. For example, half of the 44 very large-scale ICs in NCR's new Tower 32/800 computer [*Electronics*, March 5, 1987, p. 25] are ASICs designed by NCR's General Purpose Systems Division. About half a dozen of those chips have general market appeal, and Van Tassel says that most will in time be offered as standard products.



JAMES VAN TASSEL

It's a strategy that NCR has used successfully in the past—in Small Computer Systems Interface chips, for example. "It's one thing we've turned from a weakness into an advantage," says Lowell D. Deckard, NCR Microelectronics assistant vice president of product management. "We don't have the in-house systems expertise, so we depend on [other NCR divisions] for that. And as the computer-aided-design tools get more powerful and are distributed to more people, those systems people become easier and easier, to tap."

Van Tassel is quick to note that his division must compete against outside vendors for NCR business. "One thing you learn in a vertically integrated company is that [other divisions] love to use you as long as you give them good service," he says. But he concedes that his division does have an advantage: "The trend in modern purchasing is partnering and in-depth relationships—and what could be more in-depth than having your customer be part of the same company?" *—Wesley R. Iversen*

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A ONE-WORLD INDUSTRY IS ARRIVING FAST

By the end of the century, an intricate network of alliances will tie together the semiconductor business in one vast, global web

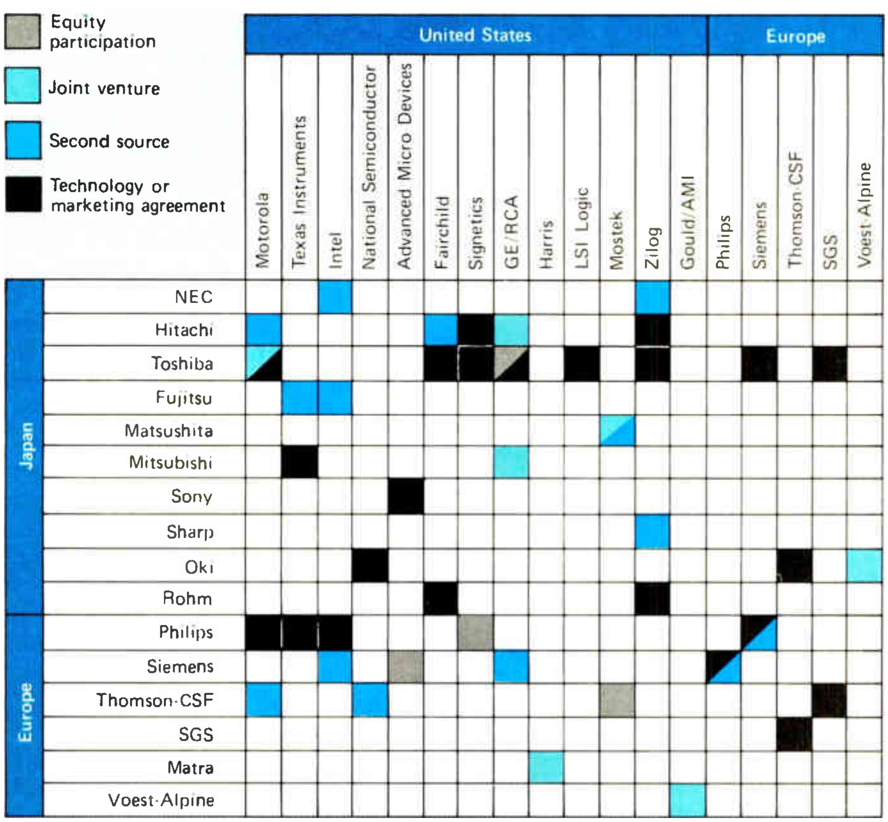
by Arthur Erikson

By the start of the 21st Century, the semiconductor business will be a mature, globe-spanning industry notable for its intricate web of linkages. A plethora of alliances ranging from joint ventures to second-source agreements will link giant companies to one another, giant companies to small, and small companies to one another. Picking the right partners will be crucial to winning—and holding—a place among the elite Top 10 in the business. Togetherness will be the cement of survival as the global industry triples its current output of integrated circuits, despite their soaring levels of complexity. By 2000, its output will be pushing past 60 billion ICs a year.

Pundits reflecting on the industry's evolution probably will single out 1987 as a watershed year. Among other things, 1987 has seen the U. S. government for the first time check Japanese expansion into the country by pressuring Fujitsu Ltd. into calling off a deal that would have given it control over Fairchild Semiconductor Corp. But the rash of less-entangling alliances seems certain to continue. Japanese companies have, over the two previous years, signed more than 100 pacts with international partners—and American and European companies have been just as eager to make a deal as their Japanese counterparts.

Alliances have been forged between big chip houses, between chip houses and systems houses, between companies strong on chip design and those strong in chip production, and between large companies and small (see chart). Companies that couldn't get, or didn't want, a deal that would open a market abroad dealt themselves in with overseas plants. NEC Corp. and Texas Instruments Inc., both companies that have generally shied away from entangling alliances, expanded their production plants abroad. Following the same approach, European chip makers set up shop in the U. S. An American presence gives them access to markets that are large enough to warrant the massive investments necessary to remain on the leading edge of technology.

MAJOR INTERNATIONAL LINKAGES FORM AN INTRICATE PATTERN



SOURCES: DATAQUEST INC., *ELECTRONICS*, INTEGRATED CIRCUIT ENGINEERING CORP.

All of these mergers, cooperation agreements, joint projects, and miscellaneous maneuverings are going to have wide-ranging effects. One of the most obvious will be a significant shuffling of the list of Top 10 semiconductor producers. No one expects IBM Corp. to slip from its No. 1 position, although its presence there is something of an anomaly: the Armonk, N. Y., computer maker so far has produced chips only for itself. Nonetheless, it turns out more chips than any other producer.

Below the top spot, though, things are going to change. It's a fairly safe bet, for example, that semiconductor operations that have been orphaned by the mergers of giant industrial companies—such as the semiconductor division that General Electric Co. put together from some of its own and some of RCA's operations after it took over RCA—will be taken into the camp through acquisitions, either by players already in the Top 10 or by those who are determined to get there.

There'll be shuffling, too, in the lower ranks. Captive suppliers who have made forays into the merchant market will be on the lookout for partners. So will startup niche companies, yet to make anybody's list, who need at the very least foundry facilities. And forms of partnership as yet unconceived undoubtedly will come to pass in the last decade of the 20th Century.

ROOM AT THE TOP?

To win a spot among the Top 10 in the semiconductor business, it's best to be a vertically integrated company that sells massive quantities of chips in the merchant market, says Glen R. Madland, chairman of Integrated Circuit Engineering Corp., a Scottsdale, Ariz., consulting firm. ICE predicts that in the Top 10 for 1996, vertical organizations will predominate. IBM will hold the No. 1 ranking; it could conceivably be a merchant supplier by then, Madland thinks, which would make it a very large vertical supplier indeed.

Four Japanese firms—NEC, Fujitsu, Hitachi, and Toshiba—will trail IBM. Then will come TI, the only company on the list whose semiconductor business is currently bigger than its equipment business. Two more Japanese companies will hold the No. 7 and No. 8 slots—Matsushita Electric Industrial Co. and Mitsubishi Electric Corp. Rounding out the list will be Korea's Samsung Electronics Co. and West Germany's Siemens AG.

Almost anything can happen in a decade in the semiconductor business, so it's easy to quarrel with this forecast. Motorola Inc.'s Semiconductor Sector ranked fourth on ICE's list for 1986; its recent alliance with Toshiba Corp. could well keep it near the top. Philips, the Dutch electrical-electronics giant, and a U. S. subsidiary, Signetics Corp., last year sold some $1.356 billion worth of ICs, reports Dataquest Inc., a Santa Clara, Calif., market research firm. That's nearly three times the IC sales Siemens racked up in 1986, but the Munich company has a horde of cash and could leapfrog Philips by making a major acquisition.

And dark horses could emerge at any time. A main-line semiconductor house could swallow up the merchant semiconductor operations of GE/RCA and catapult itself onto the list. Officials of the company shy away from specifics, but industry insiders are convinced the division's merchant semiconductor operations—except for application-specific integrated circuits and silicon-on-sapphire parts—are up for sale [*Electronics*, Nov. 13, 1986, p. 30]. "Jack Welch [GE chairman and chief executive officer] hates the semiconductor business. He doesn't make any secret of that," says a company official who asked not to be identified. But he adds, "It's not a fire sale. We're not out to dump it."

NORLING: Not even Motorola can be a leader in every market segment.

Some analysts who keep tabs on the industry think that Intel Corp. could get tucked under somebody's wing; the same goes for National Semiconductor Corp. and for Advanced Micro Devices Inc., although AMD should get a solid lift from the pact it has in the works with Japan's Sony Corp.

Then there's always the giant AT&T Co. in the wings. So far its chip subsidiary, AT&T Technology Systems, has found it hard to break into the merchant market with its memory chips and microprocessors. But AT&T has not given up. It has made a move into chip making in Europe through a deal with the Spanish national telephone company. The two expect to have a $200 million CMOS plant on stream in Madrid next year.

Thwarted alliances can affect the movements at the top, too. The deal whereby Fujitsu would have bought a controlling interest in Fairchild from its current owner, Schlumberger Ltd., would surely have rippled the ratings. But it fizzled in the heat of the U. S.-Japanese trade friction and concerns about national defense at the Pentagon.

Fairchild executives are now looking elsewhere for help. Fairchild's chief executive officer and president, Donald W. Brooks, says that the collapse of the Fujitsu plan means that "Fairchild will be forced to globalize on its own." But it will carry out several of the activities already planned with Fujitsu, including joint second-sourcing, joint development of new products, and foundry agreements. Another Fairchild executive added that the two companies would work toward merging their standard-cell libraries.

While Fairchild awaits new developments, Motorola's Semiconductor Products Sector in Phoenix continues to work out the details of a sweeping accord it struck with Toshiba in late November. Through this tie, Motorola will get entrée into Japanese markets and additional means to supply customers through a joint plant at Sendai that should be turning out advanced memories and microprocessors by 1988 [*Electronics*, Dec. 18, 1986, p. 33]. The rationale of the Toshiba deal is synergy, explains James Norling, executive vice president and general manager of the semiconductor sector at Motorola: "No one company can lead in all segments. Motorola is not even close in memories; Toshiba is not into microprocessors."

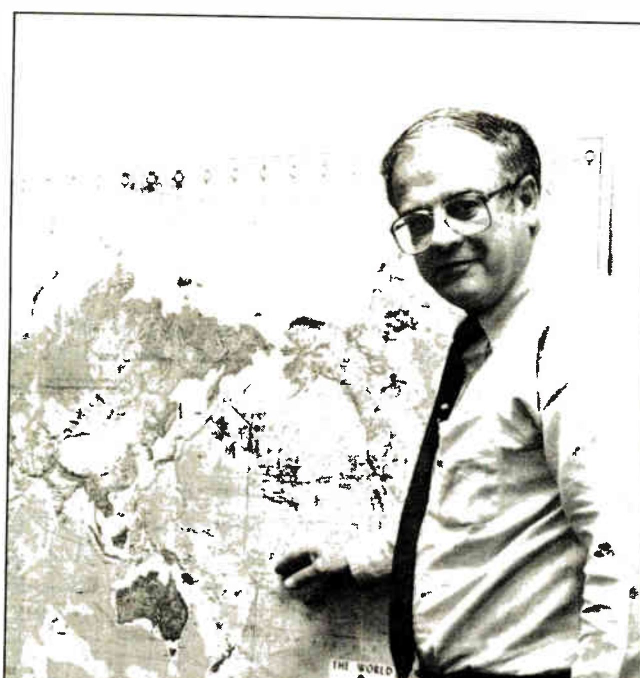
The two may take the next logical step and open a joint-venture plant in the U. S. "The probability is high," Toru Shima, senior manager of Toshiba's Semiconductor Group Business Planning Office, said soon after the pact was announced. Shima cautioned then that there was no schedule for the second round of cooperation. Norling adds that the details are not settled, and there'll be nothing official coming out on them until the questions raised by the Fairchild-Fujitsu imbroglio get answered.

Details have yet to be settled, as well, in a third major pact between industry heavyweights: AMD and Sony Corp. W. J. Sanders, the chief executive of AMD, believes that alliances are the best way to fatten up the product portfolio without overplump budgets for research and development. For example, the Sunnyvale, Calif., company and West Germany's Siemens second-source a few of each other's parts (in addition, Siemens owns some 20% of AMD's stock).

AMD and Sony already have settled on a common CMOS process, and their first joint products will be out by the end of the year. A joint fabrication plant is also a possibility. AMD joined forces with Sony to get into the Japanese market at a time when digital chips are finding their way into all sorts of consumer products. In return, Sony gets access to AMD's marketing savvy in the U. S.

The major pacts between companies in the top tier, such as the Motorola-Toshiba and AMD-Sony deals, are only the most visible part of the search for allies. Underlying them is a global fabric of second-sourcing and technology agreements. The foreign partnerships are a logical extension of the movement offshore that has been going on for at least the past two decades—the first step toward a global industry came when the major semiconductor makers started setting up assembly operations in countries where they could find cheap labor, particularly in South

One result of the flurry of international alliances over the past two years: a half dozen global camps organized around ASIC expertise



PHIPPS: Far East foundries get insights into U. S. technology when they fabricate chips for U. S. circuit-design houses.

Korea, Taiwan, Hong Kong, Malaysia, Singapore, and the Philippines.

Not all of the international alliances are recent developments—a joint venture between Philips and Matsushita Electric Industrial Co., Osaka, for example, dates back to the 1950s. But an overwhelming majority of them have come about in the past three years, with 1986 the banner year, according to Sheridan Tatsuno, who tracks Japanese alliances for Dataquest.

Japanese companies were the most active dealmakers, but far from the only ones. Europe's top chip makers have used international links to keep themselves positioned as major players (see p. 75), although they have not matched the frenzy of the Japanese companies over the past two years (see p. 76). Just emerging are the semiconductor makers in the Pacific Rim countries, who are cautiously seeking partners as they strive to make their mark in world markets (see p. 78).

In Japan, a dozen semiconductor producers signed multiproduct deals with U. S. and European companies. A half-dozen pacts each emerged for memories and microprocessors. And a dozen transpacific deals between ASIC houses were made, including a joint effort among three heavyweights: General Electric, Siemens, and Toshiba, who will cooperate in standard-cell ASIC chips.

But more typically, the ASIC activity consists of small U. S. circuit-design houses pairing up with Japanese semiconductor houses that have a surfeit of state-of-the-art fabrication capacity. Lattice Semiconductor Corp., Portland, Ore., signed on Seiko Epson Ltd., Suwa-gun, for example, to turn out programmable logic and fast 64-Kbit static random-access memories. Similarly, Silicon Systems Inc., Tustin, Calif., tapped Oki Electric Industry Ltd., Tokyo, to fabricate its single-chip modems.

These pacts are doubly beneficial, points out Charles H. Phipps, a former semiconductor vice president at TI, who now works as a consultant. The U. S. companies get the fabrication facilities they need, and the Far East companies put some of their surplus capacity to work. At the same time, they gain insight into North American market trends and access to emerging technology.

Not all circuit-design houses think this is a good thing. Vin Prothro, chairman of Dallas Semiconductor Corp., Dallas, checked out foundries in the Far East and then decided that his company should build its own facility in the U. S. Contracting with an Asian foundry is "a very dangerous situation and in the long term could take the design and technology expertise out of the country," cautions Prothro. He's convinced a Far East foundry would eventually become a volume competitor for any product that catches on.

The flurry of international pacts in ASICs over the past two years has led to the formation of a half-dozen global camps, Dataquest's Tatsuno points out. The flag of LSI Logic Corp. flies above one. Working with the Milpitas, Calif., company are such major players as AMD, General Electric's GE/RCA Solid State Division, Kawasaki Steel, Mitusbishi, Sharp, and Toshiba.

A second camp joins TI and Fujitsu. Among the other tents here are those of Signetics and Harris Corp. Fairchild Semiconductor and VLSI Technology Inc. lead the third camp, Motorola and National are the mainstays of a fourth camp, Gould/AMI bolsters the fifth, Honeywell Inc. and Seiko the sixth. As ASICs take on a larger share of the total semiconductor market, there'll be defections in some camps and new players in others.

Even large companies will continue to form alliances for leveraging R&D outlays and to make second-source deals into the 1990s

At the same time that most of the major semiconductor houses are trying to join their enemies, not beat them, a number of them are also pursuing an alternative approach. They are carrying the battle into the enemy camp. They have learned that to break into overseas markets in a big way, it's essential to have overseas plants. "There's a trend toward localization of production around the world," says H. Gunther Rudenberg, an independent consultant to Arthur D. Little Inc., Cambridge, Mass.

Major U. S. companies such as TI and Motorola set up shop in Europe in the mid-1960s, getting inside the tariff walls to tap markets. That's still the main incentive to build factories in Europe. The obstacles that foreigners must overcome to get into the Japanese market are more formidable than mere tariff walls. The Japanese goverment has promised to open up 20% of its semiconductor markets to outsiders by 1991, as part of the agreement signed with the U. S. Department of Commerce on July 31. But the U. S. companies that figure to do best in Japan are those that have built plants inside the country and staffed them with nationals.

TI led the way into Japan in 1969; it has three semiconductor plants there today. One, at Miho, has become TI's major source for dynamic random-access memories. Motorola tried to follow TI's lead in the early 1970s through a joint venture with Alps Electric Co. In 1980, though, Motorola picked up half of Toko Inc.'s chip-making subsidiary Aizu-Toko Inc. and then bought out Toko's share in 1982 to become the second U. S. chip maker with a plant in Japan. The overseas plants open windows on Japanese manufacturing technology, as well as opening doors to Japanese markets for the foreign companies.

EXLEY: NCR has sized up Far East foundries for possible future alliances.

Alliances overseas and the push toward international facilities are only the latest stage in the trend toward global connections. New variations on the theme will become more and more common in coming years. Increasingly, main-line semiconductor houses are going to forge close ties with niche companies, both at home and abroad. "Today, we are exploring some possible arrangements with smaller IC companies, which might have products that would expand our line in an area that is important to us," says William N. Sick, executive vice president at TI, Dallas. "These companies might need the process capability that we have. Or they might need design automation, or they might need the marketing reach we have as a global competitor."

Such elephant-and-mouse alliances won't crowd out large-company deals, Sick believes. He foresees greater opportunity for cooperation to leverage R&D expenditures than was possible in the past. Alliances might form to tackle areas of common concern, like new forms of lithography or high-speed testers. And he's convinced that second-sourcing pacts will continue to be struck into the late 1990s.

Another lot of new partners could turn up among late-to-market captive suppliers. NCR Corp., Dayton, Ohio, for example, does not now have any international alliances in the chip business. "We haven't pursued them because we're digesting the whale we've already caught," says James Van Tassel, the vice president who heads up NCR's Microelectronics Division, meaning his company's 1985 alliance with Motorola in ASICs. But chairman and president Charles E. Exley Jr. insists that NCR "absolutely" will consider such alliances. "As we look at the semiconductor business, the thing that we need is products.... But what seems to have happened in the Far East is that people felt they needed process and productive capacity, and they've brought a whole lot of it on line without having any products, which makes for a kind of peculiar situation." The future could easily see a link between NCR and Far East manufacturers to fabricate the U. S. company's IC designs.

Another possibility for the year 2000 is international cooperation at wafer level, in the opinion of Lynn Conway, associate dean of engineering and a professor of electrical engineering and computer science at the University of Michigan, Ann Arbor. She foresees an advanced version of the approach now used with Mosis, the MOS Implementation System, with chip designs from several companies fabricated on a single wafer [*Electronics*, March 3, 1986, p. 48]. It's not only politics that makes strange bedfellows.

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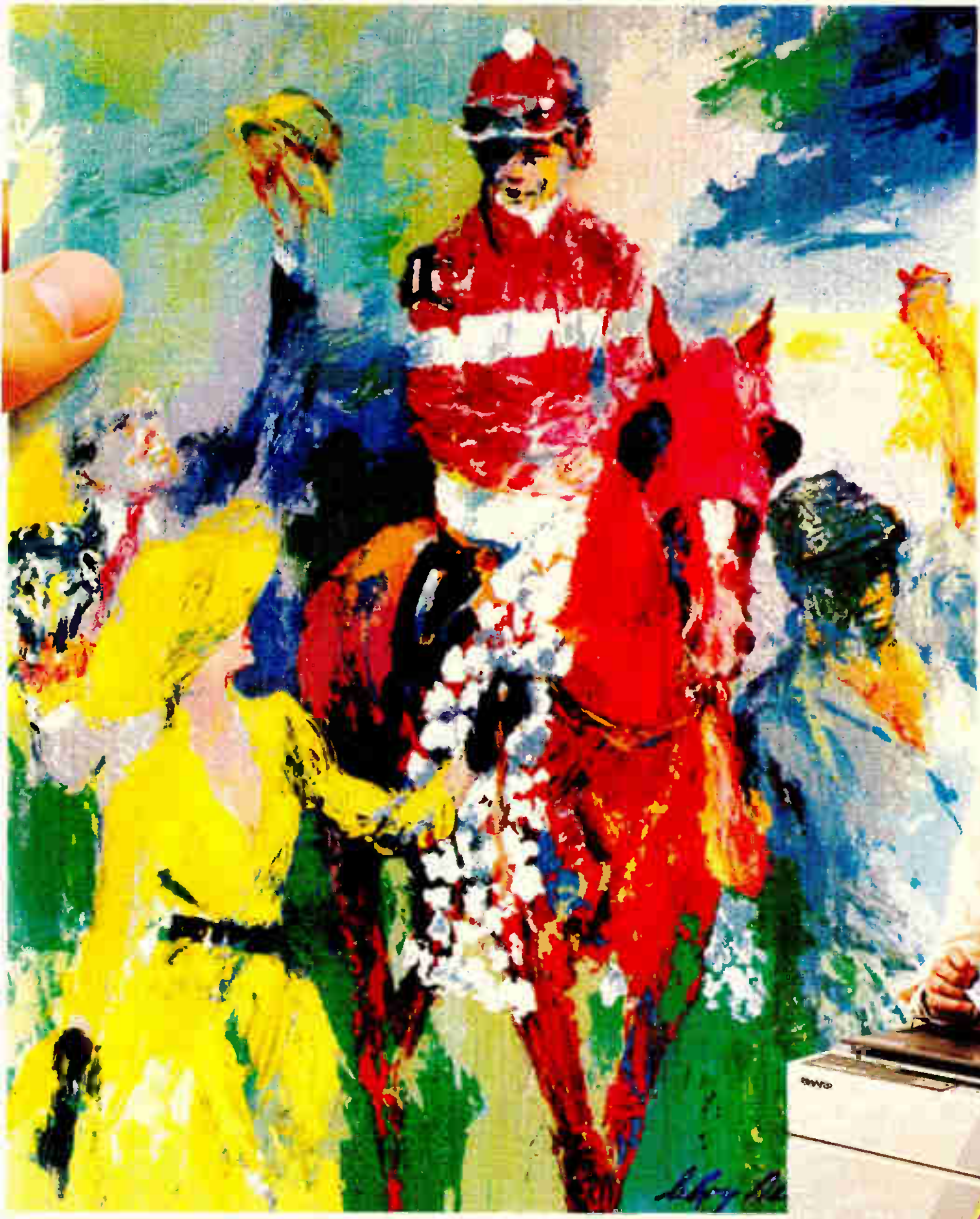

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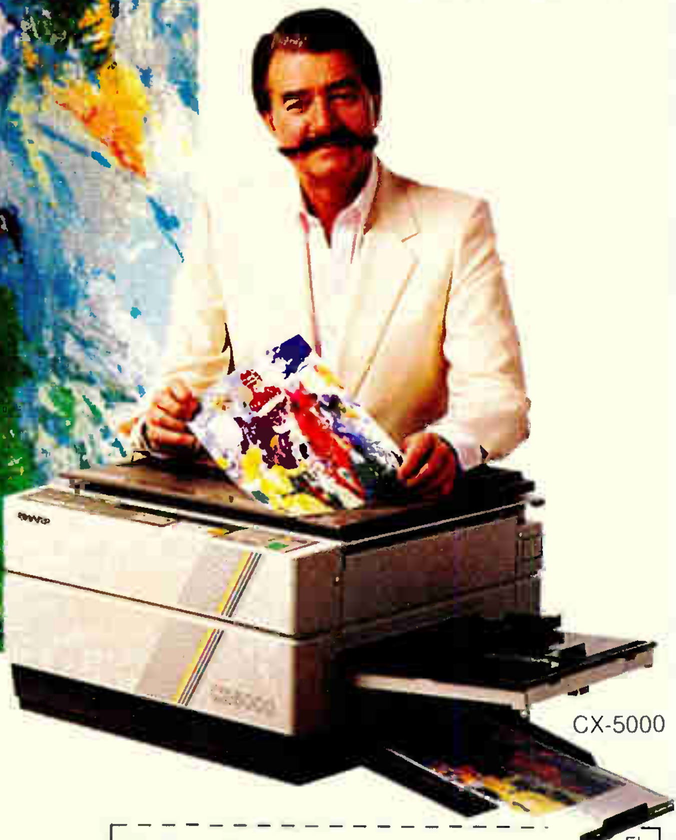

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EUROPE PUSHES HARD FOR GLOBAL ROLE

Unable to get even half the chip business in their own backyard, the Europeans hunt for foreign partners and build plants overseas

by John Gosch

All it takes is a quick look at the market figures to understand why West European chip makers are pushing for a far greater global presence. Semiconductor sales in the region totalled $5.446 billion last year, but the native companies got less than half the business in their own backyard.

That means nothing much has changed since 1980, when the Europeans held a 40% share of a $3.686 billion market, according to the London office of market researcher Dataquest Inc. It is doubtful that the situation can improve in the next several years; there seems scant chance the Europeans can recapture market share from entrenched U. S. companies like Texas Instruments, Motorola, and Intel. Even if they could, they face increasing competition from Japanese heavyweights like NEC, Hitachi, and Toshiba on their home turf.

SURVIVAL TACTICS

To tap the large markets they need to survive, then, companies like Philips, Siemens, Thomson-CSF, and SGS Microelettronica are scurrying to sign on partners from around the world. Says Brian Down, marketing manager for Ferranti Electronics Ltd., Oldham, "If ever there was a time for alliances to be considered, then now is the time. The Japanese have hit the old stomping grounds [Western Europe] of the U. S. The Europeans have to have alliances with each other and with Japan and the U. S."

The Europeans are also working hard to penetrate markets abroad. "European companies have to look at things from a worldwide standpoint," says Jacques Noels, managing director of Thomson's Branche Composants Electroniques, Paris. "There is no magic recipe for this. But we have to extend our markets outside of Europe."

The Europeans, of course, aren't starting from scratch. All the majors have links with American and Japanese companies. There is a skein of intra-European ties, as well. Some of these alliances are limited, aimed at increasing market penetration of a product family. Others call for cooperation in research and development to devise leading-edge parts. Some involve equity participation, which opens the tap to a partner's technology. Although no company will tip its hand, executives at nearly all European semiconductor companies say they have more alliances in mind. "The development of new chip generations will become ever more costly," says Jürgen Knorr, vice president for semiconductor technology, product development, and manufacturing in Siemens AG's Components Group in Munich, "and the problem is best solved by cooperation."

Philips, particularly, is no stranger to world markets and international alliances. The Dutch electronics heavyweight moved into Japan more than three decades ago through a joint venture with Matsushita Electric Industrial Co., Osaka. It staked out a major claim in the U. S. market in 1975 when it bought Signetics Corp.

To fill out its product line, Philips has worked out a product-exchange agreement with Intel Corp. involving 8-bit microcontrollers, such as the 8048 and 8051 and their derivatives. "The agreement has made us the No. 4 company in microcontrollers," says Theo Holtwijk, strategic planning manager at Philips's Electronic Components and Materials Division in Eindhoven. A similar tie-up with Motorola Inc., dating back to 1982, involves 16-bit microprocessors, among other things. Another agreement links Philips to Texas Instruments, Dallas, for development of high-speed advanced CMOS logic (ACL) and semicustom cells.

Siemens, too, has bolstered its position in microprocessors. It has made second-source agreements with Intel and with Advanced Micro Devices Inc., Sunnyvale, Calif.; Siemens also owns what amounts to a bit less than a 20% share of AMD, a connection that is now more than a decade old. A cooperative deal with Toshiba Corp. of Japan, made in 1985 and extended to include General Electric in the U. S. in 1986, has given the West German company a CMOS

MEMORY LINE. Siemens is counting on the Mega project, a joint program with Philips, to keep it a player in leading-edge memories.

cell library for application-specific integrated circuits.

Both Philips and Siemens believe that European companies should form bonds among themselves to counter the thrusts of outsiders, particularly the Japanese. Thomson and SGS Microelettronica, Agrate, Italy, have talks under way that could lead to a Franco-Italian venture that would be second, after Philips, among European chip makers.

However, the cooperation between Philips and Siemens—Europe's two largest electronics producers—is considerably more ambitious. In the biggest cooperative R&D effort on the Continent so far by two semiconductor firms, they have embarked on a $1-billion-plus "Megaproject" [*Electronics*, Oct. 29, 1984, p. 28]. Philips's target is 1-Mbit static random-access memories for low-power consumer applications; Siemens's goal is 4-Mbit dynamic RAMs for data-processing equipment. Both types are scheduled for production in about two years. The design techniques and process technology that come out of the Megaproject will lay the groundwork for the submicron, complex logic chips the two firms expect to build in the 1990s.

JACQUES NOELS

The Europeans do not intend merely to defend their own territory. "We have to extend our manufacturing base outside of Europe," says Noels. Thomson did just that 16 months ago when it bought Mostek Inc. from United Technologies Corp. SGS has built a plant in Phoenix set to go on stream in early 1988 with a 1-μm CMOS process. Philips, of course, established itself when it bought Signetics. More such projects undoubtedly will follow; Noels says, "We have to do what the U. S. did to Europe and what the Japanese are doing." For Europe's chip makers, turnabout is not just fair play—it's an absolute necessity.

SPECIAL SEMICONDUCTOR ISSUE

JAPAN DRIVES FOR STRATEGIC ALLIANCES

Despite Fujitsu-Fairchild failure, by the year 2000, Japanese chip makers will be inextricably woven into the worldwide web of alliances

by Charles L. Cohen

The trend is strong and still growing: Japanese executives expect their companies to forge more and more ties with foreign manufacturers as well as among themselves. By the year 2000, Japanese chip makers will be inextricably woven into the worldwide web of alliances. An indication of both the limitations and the possibilities of such ties are two major alliances with U. S. companies the Japanese attempted to set up last year, one of them broken off, the second successful: Fujitsu's move to purchase 80% of Fairchild ran into a political wall, but Toshiba's less ambitious pact with Motorola proceeds quietly [*Electronics*, Dec. 18, 1986, p. 33].

Also proceeding apace is the now-common Japanese strategy of setting up overseas plants (see chart, opposite). These plants go a long way toward smoothing trade-balance frictions, a major problem for the Japanese chip industry.

"Business is becoming politicized," says Bujirou Kobayashi, managing director at Mitsubishi Electric Corp., Tokyo. "Fujitsu's purchase of Fairchild has been restrained politically while the admittedly more limited pact between Toshiba and Motorola appears to be a plus for both companies." In the future, he says, the perceived risk of making alliances with companies in the U. S. and other countries will be read in the attitudes of politicians.

The Motorola-Toshiba partnership will succeed, predicts Sutezo Hata, senior executive managing director at Hitachi Ltd., Tokyo. "Motorola is seeking increased sales in this very large market," he says. Hitachi itself already has second-source agreements on 8- and 16-bit microprocessors with Motorola. Designs for the chips come from the U. S., and CMOS versions of them are licensed back to Motorola in separate deals. The Motorola package is Hitachi's largest international deal, and Hata says that it worked well enough for 8- and 16-bit systems, but ultimately proved disappointing because it did not include 32-bit chips.

The barrier Motorola erected at 32 bits illustrates one problem that the Japanese find in dealing with Americans: discontinuities. In this case, it was a management decision by Motorola to deny Hitachi rights to its 32-bit processors, but similar kinds of headaches are caused when U. S. companies desert a product line—not an uncommon occurrence—or are acquired, also not a rare occurrence.

Hitachi also has agreements with Zilog on the Z80, Signetics on peripheral chips, and Fairchild on second-sourcing the high-speed CMOS logic line Fairchild calls Fact. Second-source pacts are valuable, Hata

SUTEZO HATA

points out. But in mature markets, other types of deals seem more appropriate.

For example, Mitsubishi has a 10% equity investment in a venture with Westinghouse and GE to sell large power semiconductors made by the three companies in both countries. It gives the Americans marketing channels in Japan that they didn't previously have. Kobayashi says that "we would fail together if we all competed in this mature market."

Other agreements abound, although many are short-term in nature. Fujitsu has ties with Intel on 8- and 16-bit microprocessors and Motorola on 8-bit microprocessors. It has a cross-licensing agreement with TI covering gate-array hardware and software and a deal with Monolithic Memories on gate arrays. Sony had two one-shot deals with Vitelic on memories and is now working out an agreement with AMD. Toshiba licenses Zilog processors in exchange for CMOS processes; Sharp also licenses Zilog processors. Toshiba also has a deal with LSI Logic Corp., Milpitas, Calif., covering gate array design and fabrication.

One unusual arrangement is the one between Texas Instruments Inc. of Dallas and ASCII Corp. of Tokyo. It makes ASCII a value-added reseller of TI's digital signal processors in Japan; added value includes software and system design. TI gets the right to sell overseas the software ASCII develops—reversing the usual flow of software rights.

NEC Corp. finds itself in an uncomfortable position with a former partner it had been forced to accept. NEC had designed what it calls "original" 8- and 16-bit microprocessors but which Intel claims are unauthorized versions of its 8086 family. Intel has sued to establish both that microcode can be copyrighted and that NEC's V-series processors infringe on its rights. The NEC devices sell well in Japan, but the suit is scaring off major U. S. manufacturers. NEC has had agreements with both Intel and Zilog—agreements it made to settle earlier charges of copying microprocessor designs.

Besides striking alliances with foreign companies, setting up plants in other countries remains a major part of Japanese strategy in this internationalized industry. There are two reasons, says NEC senior vice president Tomihiro Matsumura. "Assembly must be performed in low-labor-cost regions," he says. "Despite automation, costs are higher in Japan and equipment cannot be amortized." Also important is transfer of manufacture to consuming nations, for political and trade-balance reasons. Furthermore, "the stronger yen will increase the need for overseas production," says Tadahiro Kamogawa, senior analyst at Yamaichi Research Institute of Securities & Economics Inc., Tokyo.

BUJIROU KOBAYASHI

Hitachi has bigger plans for plants in the U. S. than in Europe, says Hata. "At present, we plan to install a front end in Dallas—although initially we will only customize gate arrays and mask read-only memories—but Munich will remain an assembly facility. Our European market is not large enough to support a front end." His company has little trouble building fabrication facilities in other countries, he says. "The problem is how to build up sales."

One of the most significant obstacles for Japanese companies remains the culture gap between them and their western counterparts. "The limit to growth depends on the extent to which it can break through this barrier," says NEC's Matsumura. "It is not possible to use local personnel 100%. Human relations suffer from misunderstandings. Production doesn't increase to its full potential, and profits don't increase. My generation can't fully cope with the problem. Neither can the next generation."

The biggest problem is management trust, says Hitachi's Hata. "Human relations are more important than conditions. Everything can't be written on paper. Problems include the language barrier and culture, but the Japanese are becoming more international, and barriers are falling. Americans appear to be increasingly thinking of the need for partnerships, and acting accordingly," Hata adds. "The Japanese may understand, but they don't act."

JAPANESE ARE SPRINKLING PLANTS IN U.S. AND EUROPE

Company	Plant location	Product assembled
Fujitsu Microelectronics Inc.	San Diego, Calif.	DRAM, SRAM, EPROM
Fujitsu Ltd.	Tallaght, Ireland	DRAM
Hitachi Semiconductor (America) Inc.	Irving, Texas	DRAM, SRAM
Hitachi Semiconductor (Europe) GmbH	Landhut, West Germany	DRAM, SRAM
Mitsubishi Semiconductor America Inc.	Durham, N. C.	DRAM
NEC Electronics Inc.	Mountain View, Calif.	DRAM, EPROM
	Roseville, Calif.	Fabricates and assembles DRAM, SRAM, ROM, gate arrays, custom microprocessors
	Livingston, Scotland	Microprocessors, DRAM, SRAM
	Ballivor, Ireland	DRAM
Toshiba Semiconductor (USA) Inc.	Sunnyvale, Calif.	DRAM, SRAM, microprocessors
Toshiba Semiconductor (Europe) GmbH	Braunschweig, West Germany	SRAM, gate arrays, microprocessors

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Another big difference between Americans and Japanese, he says, is in the different approaches they take to planning projects. "U. S. companies work on a goal. Japanese spend time on the process. The U. S. [companies] want commitment on results. The Japanese [companies] want understanding without commitment. They are afraid of the risk [of commitment]. We understand the American method, but Japan doesn't work that way."

Growing U. S. covetousness of its intellectual property is also a problem for the Japanese. Japanese chip makers are having a hard time obtaining reasonably priced licenses for designs that they need in order to sell standard systems chips to the U. S. and other export markets. This situation may foster more internal ties among the Japanese. Hitachi and Fujitsu have a deal to develop a 32-bit microprocessor family, peripheral chips, and software. The deal makes better use of scarce resources, enabling development of a greater range of peripherals and software, says Hata. And Hitachi, for one, is hoping that standard operating systems such as AT&T's Unix will make it possible for existing application software to run on proprietary hardware.

SPECIAL SEMICONDUCTOR ISSUE

A NEW WAVE RISES ON THE PACIFIC RIM

Without a doubt, Asian countries will play a much bigger role by the year 2000 in the worldwide semiconductor industry

by Michael Berger and Don Shapiro

South Korea and Taiwan are trying to shoulder their way into the worldwide semiconductor establishment. Lining up behind them, ready to make their own push, are Singapore, Hong Kong, Malaysia, and the Philippines—the countries in what is called the Pacific Rim. Without a doubt, these countries will play a much bigger role by the year 2000 in the worldwide semiconductor industry.

Ironically, the U. S., Japan, and Europe helped the Pacific Rim get its start in electronics. Looking for cheap labor, all of them built facilities there for assembling the chips they produced into packages. In doing so, they made the so-called Four Tigers—Korea, Taiwan, Singapore, and Hong Kong—the world's leaders in the assembly business. By 1990, the Far East's assembly capacity will reach 30 billion units, according to market researchers Dataquest Inc. That's enough to absorb more than 80% of the world's semiconductor production.

But the Asian countries not only learned how to assemble semiconductors in packages; they also learned how to make the semiconductors that go in the packages. Equally important, they learned the value of cooperation in making and selling them.

P. JUNE MIN

South Korea exemplifies the advantages of cooperation. It gains added strength from the vertical integration of the powerful conglomerates that are mounting semiconductor operations.

Taiwan has much in common with Korea. Internal and international cooperation are helping the Taiwanese to establish their electronics industry. The difference is that Taiwan is now about where Korea was five years ago.

Korea itself still has some catching up to do. The country's technology base remains thin. Until a year ago, the Koreans couldn't even produce 256-Kbit dynamic random-access memories in quantity.

Those deficiencies are being overcome rapidly. The leading maker of memory chips, for example, Samsung Semiconductor & Telecommunications Co., now produces close to 3.5 million 256-Kbit DRAMs a month. Overall, semiconductor production grew from $75 million worth of chips in 1983 to $1.47 billion worth last year, according to the Electronics Industries Association of Korea, and is expected to hit $2.25 billion this year. "Within five years, the Koreans will have a strong foothold in world markets," says an executive for a U. S. chip maker.

The Koreans are betting on cooperation to get there. A year ago, the Korean government announced an ambitious project, worth 46 billion won, or about $53 million, to develop a 4-Mbit DRAM by 1989 and go into mass production in 1990. "Two years ago, I would have said this could never succeed," says P. June Min, a former IBM engineer who is senior managing director of Goldstar Semiconductor Ltd. "But we've seen that the only way we're going to succeed is by cooperating, not cutting each other's throats."

The Koreans have the financial staying power to back up their ambitions, thanks to the vertically integrated nature of the conglomerates involved in

SUNG-KYOU PARK

chip-making efforts. "Our group knows that our semiconductor operations cannot possibly pay back the investment," says Goldstar's Min. "But we're supplying our computer, communications, and consumer electronics divisions, which lowers their production costs. So in the end, the group benefits."

Among the Korean companies, industry analysts say, Goldstar is probably the best-positioned. The company avoided the mass-memory market; it is using its alliance with AT&T Co. as a supplier of computer and telecommunications components to build its design skills and enter the application-specific integrated-circuit market worldwide. But if it meets the objective of the 4-Mbit memory project, it also wants to become a mass-memory manufacturer. Min says bluntly: "We intend to be number one, not just in Korea, but in the world."

Samsung, by contrast, has concentrated on the mass-memory market from the beginning. The strategy has paid off so far, but the company has heavy investments to pay back and has only begun to diversify its product base: Non-memory products account for only 10% or so of the company's business today. But Hyeon Gon Kim, Samsung Semiconductor's managing director for administration and planning, says, "Our goal is to increase our non-memory business to 60% of sales within five years."

Samsung has at least established a name for itself, something the Hyundai Electronics Co. is still trying to do, at a cost so far of $100 million. That includes an abortive production-plant project in Silicon Valley. Equipment failures delayed its startup, and then the big market slump of 1985-86 hit. Hyundai finally closed down operations and sold the plant last year. Two lines near Seoul that were opened in 1985 are up and running, turning out limited numbers of static RAMs and electrically-erasable programable read-only memories for Vitelic Corp. of Santa Clara, Calif.

Daewoo Telecom Corp. has had better luck. Its takeover of Zymos Corp., Sunnyvale, Calif., already is paying off, says Sung-Kyou Park, the company's president. "We gave them the financing they needed; they're giving us the sophisticated chips we need for our computer and telecommunications switching products. We're going to be their biggest customer."

The efforts in Korea are mirrored by those in Taiwan. The difference is largely one of scale and the progress made so far; Taiwanese companies have not established as significant a presence. As in Korea, the government provides vital assistance to the industry. The government, for example, set up the Electronics Research and Service Organization, which operates a wafer-fabrication line and provides technical advice to industry.

And, like the Koreans, the Taiwanese semiconductor companies are bolstering government aid with overseas alliances. A silicon foundry, Taiwan Semiconductor Manufacturing Corp., for example, was established earlier this year with funding in part by Philips, the Dutch conglomerate, which took a 27.5% equity position in the company. Two well-known chip-industry executives, James Dykes and Morris Chang, are running the firm [*Electronics*, March 5, 1987, p. 50]. Starting with process technology from Philips, Taiwan Semiconductor is setting up a line to build 2- and 3-μm CMOS chips on 6-in. wafers.

SCHIU SCHE

ROBERT TSAO

But for the most part, Taiwanese chip makers are looking for deals with U. S. companies. For example, United Microelectronics Corp. has acquired a controlling interest in Unicorn Microelectronics Corp., a Santa Clara, Calif., ASIC design house. "We expect that more than 80% of the Unicorn customers will come over to United Microelectronics for wafer fabrication," says Robert Tsao, president of the Taiwanese company. "But that was not our major consideration. The U. S. is the world's largest market, and we want to be there."

Americans can be trying partners. "The profit expectations of American companies are typically much too high," says Schiu Sche, president of Fine Products Microelectronics Corp. By contrast, Japanese companies initially charge much more reasonable fees for their technology.

Another barrier is U. S. sensitivity about a technology drain. "The U. S. exaggerates the seriousness of technology leaking in this region through technical agreements," says Tsao of United Microelectronics. In fact, Taiwanese laws on intellectual property have been tightened in recent years so foreign companies can protect their technology adequately, he says.

But these are problems that Taiwan—and South Korea—are happy to live with so long as they continue to gain access to U. S. technology—and to U. S. markets. By the year 2000, all indications are that they'll be formidable competitors—and that may mean that they'll face the same tense relationships that now exist between the U. S. and Japan.

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HERE COMES THE BILLION-TRANSISTOR IC

A host of design problems remain, but device engineers look for this CMOS chip to be in production by the end of the century

by Bernard C. Cole

A billion transistors on one integrated circuit: that is where the semiconductor industry's drive toward smaller geometries and higher levels of integration will take it by the year 2000. Such is the "conservative" prediction of James Meindl, former professor of electrical engineering and computer science at Stanford University.

Conservative? "Yes," says Meindl, now vice president and provost at Rensselaer Polytechnic Institute, in Troy, N. Y. "As impressive as 1 billion transistors on a single chip sounds, it actually represents a dropping off of the rate of density increase that we in the semiconductor industry have gotten used to." From a 100% increase in density every year through the 1970s, the rate has dropped to 50% to 60% per year during the 1980s and is expected to average no more than 25% to 30% during the 1990s (see chart, below). As the industry moves toward submicron geometries, the going gets tougher—"much tougher," he says.

WHICH WAY TO GO

A whole host of problems converge to make the going tough at the submicron level. Given the vast diversity found in the industry, it's not surprising that many different solutions are being considered. CMOS probably will be the vehicle that will take the industry much of the way to billion-transistor chips, but there is little agreement on the details.

The most prominent problems stem from the fundamental physical limits of the field-effect transistor structure as device geometries shrink to 0.5 μm and lower. Chip makers must deal with such second-order effects as decreased transconductance, punchthrough, and interconnection resistance. These problems should be fairly easily solved in next-generation chips, where the minimum feature will still be between 0.5 and 1 μm. Relatively new isolation techniques, such as trench isolation, will come into play. But below 0.5 μm, a whole new range of solutions will be needed. One possibility that's currently the topic of a hot debate is to move away from the 5-V TTL interface standard that has served the industry for the past 10 years.

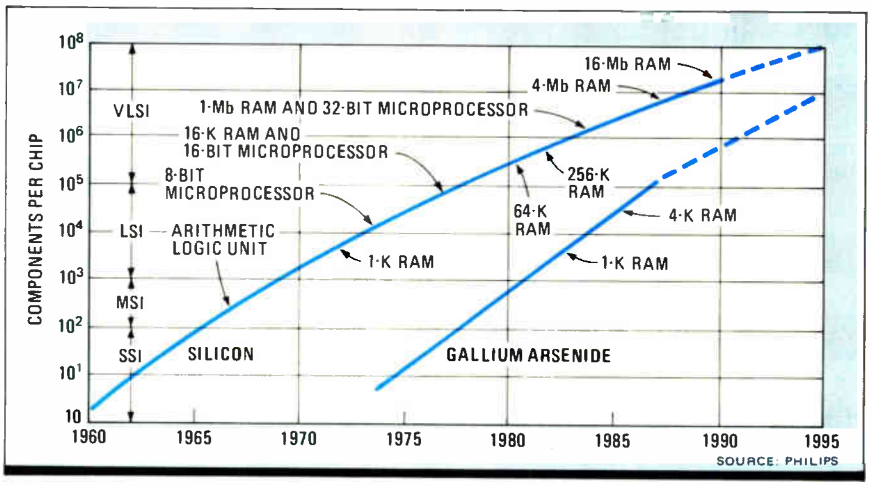
But the point will come, experts agree, where it's no longer possible to shrink geometries any more without rendering the FET inoperable. Conventional transistor structures may well be replaced by such new structures as superlattices and quantum-coupled devices.

Even if all these barriers were to fall like magic, the semiconductor industry would still have some knotty problems to wrestle with. For one, the design of a chip with millions and millions of transistors is far beyond the capabilities of the present generation of automated tools. And to prevent interconnections from taking over too much real estate on such chips, radically new architectures will be needed.

Many experts also wonder how the industry will use these superchips—after all, a billion-transistor chip will have 1,000 times the number of devices on today's most complex ICs. Some industry leaders say that there's no way to put so many devices to good use. Others, however, argue that there are applications out there that can't even be dreamed of until the billion-transistor IC bows.

If CMOS is to be the means by which the industry achieves the billion-transistor IC, says Meindl, some major roadblocks to further development will have to be removed. To get the tighter dimensions, channel doping must be increased—and that decreases the transconductance of the basic transistor, because electron mobility decreases as doping increases. Also, the shortened channel lengths that are needed become vulnerable to punchthrough, unless channel doping is increased, or the voltage decreased, or both. Another problem, Meindl says, is hot-electron emission into the gate oxide, which occurs when electrons in the channel current are accelerated by the large electric field in the drain depletion field of a field-effect transistor operating in the saturation region.

Even more critical as dimensions approach half a



SLOWING. The annual rate of density increases is falling and will run about 25% in the 1990s.

micron are problems that result from the designer's inability to modify certain physical properties of the materials used to fabricate the structures. One such property is conductivity, which has an upper limit that cannot be exceeded—unless the ambient temperature is lowered significantly, which system designers are loath to do. Another is the contact potential, which is not easily modified.

The resulting second-order effects—interconnection resistance, subthreshold turnoff, transconductance degradation, and temperature sensitivity—were not significant at dimensions above 1 μm, but they become more critical as dimensions are reduced, says Meindl. They affect the voltage margins required for reliable circuit functioning, due to fluctuations introduced by increases in parasitic voltage drops and leakage currents. As geometries move closer to half a micron, it is necessary to compensate for these effects by raising the power-supply and threshold voltages within the circuit. The resulting increase in field potential activates another group of effects that reduce the transconductance. Taken together, he says, these effects result in a scaled technology that is less aggressive than predicted by the scaling rules; in fact, they would eventually limit the scaling down of the transistors.

As geometries move down to half a micron, second-order electrical effects that degrade performance will require radical new solutions

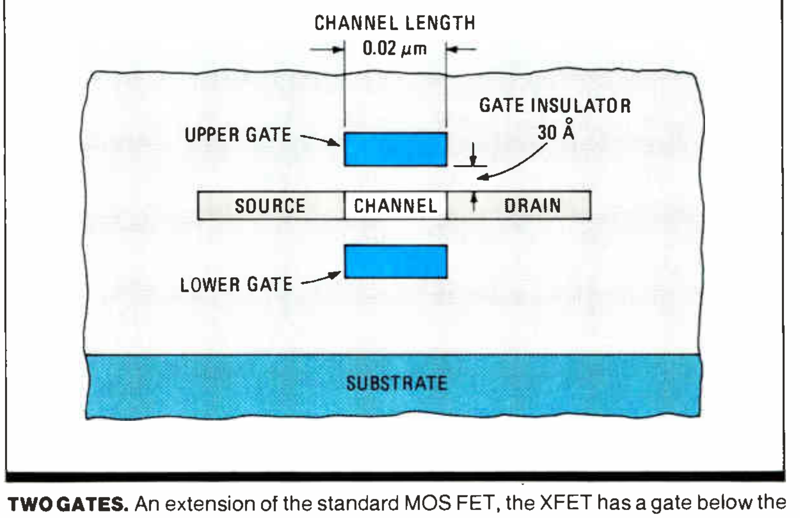
Fortunately, these second-order effects can be minimized, at least in the next generation of VLSI devices. To build 16-to-64-Mb dynamic random-access memories will require pushing CMOS design rules down to about 0.7 or 0.8 μm, says T. J. Rodgers, president and chief executive officer of Cypress Semiconductor Corp., San Jose, Calif. And there are a number of ways to ameliorate second-order effects that do not go much beyond processes that are currently in production at the 1-to-1.5-μm level, he says. "In particular, great attention has to be paid to making sure the contact size, layer-to-layer alignment tolerances, and the metal pitch are correspondingly reduced together with the gate length," he says. Also, it's necessary to modify the conventional local-oxide isolation techniques currently used because the effective width of the transistors and the threshold voltage are controlled by field-implant encroachment into the active device area and the bird's beak phenomenon. "These two factors make device-width control difficult as devices are shrunk to submicron dimensions," says Rodgers. "This is due to increased doping under the field oxide and the bird's beak becoming a significant fraction of the device width."

The next level of integration in DRAMs is a fourfold increase to 256 Mb, and that will require replacing the traditional local-oxide-isolation techniques with something more effective, says Richard Pashley, general manager of Intel Corp.'s electrically erasable memory operations at Folsom, Calif. One alternative, he says, is the use of trench isolation, already being used in some 1- and 4-Mb DRAMs. "One of the main reasons trench isolation is attractive is that it allows significant increases in density without pushing the process to smaller geometries," he says. "Right now it is being used to allow the design of 1- and 4-Mb DRAMs without pushing the process down into the submicron range."

At about 0.6 to 0.7 μm, he says, trench isolation will be essential, not only to reduce the need to go to smaller geometries, but to deal with some of the second-order effects. "In addition to allowing transistors to be moved much closer together, it also minimizes the problem of effective-channel-width control since it eliminates the need for a field implant. Also, due to the fact that the device is surrounded by trenches, the width is well defined, almost by default, and without additional process steps."

Pashley sees the industry going into a holding pattern of sorts at about 0.5 μm as it looks at alternative ways to go to higher density without pushing to smaller device geometries. "Basically the alternatives are to move up or down, to build so-called three-dimensional circuits," he says. "The trend is already starting in DRAMs, as various manufacturers look into using trenched capacitor structures of various sorts to increase DRAM storage charge and either stacking the transistor atop or on one of the sidewalls to reduce cell area." However, the trench technique is limited to DRAMs, says Hans Hausele, deputy director of MOS memory development at Siemens AG's components group in Munich. For static RAMs and logic, he says, it will be necessary to look to stacking transistors.

Another isolation technique that has received intense analysis over the past 10 years is silicon on insulator, such as silicon on sapphire. The problem with SOI, says Rodgers of Cypress, is that most of



TWO GATES. An extension of the standard MOS FET, the XFET has a gate below the channel, which eliminates short-channel effects that plague shrinking MOS FETs.

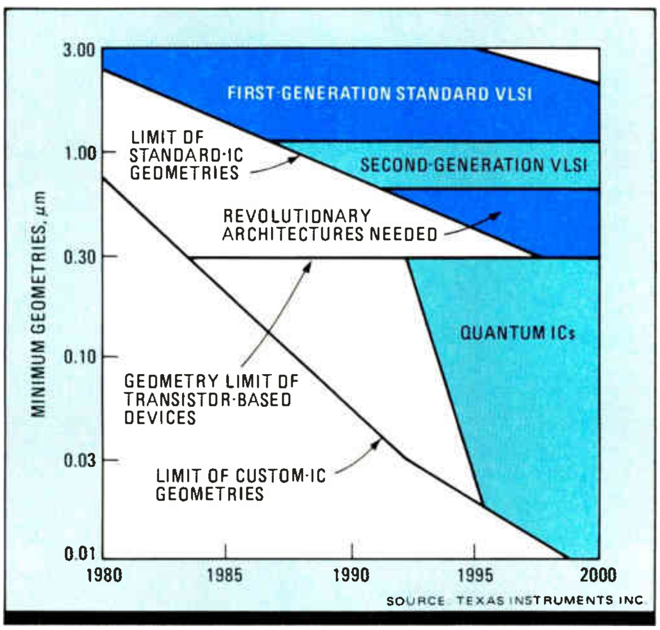
the proposed structures simply are not as good at insulating as bulk silicon. "To put it bluntly, they leak," he says. This means, says Meindl, that while SOI is suitable for SRAMs and logic design that do not depend on capacitive-storage cells, it is clearly not the route to take for DRAMs.

One very serious problem is the industry insistence on staying with the 5-V TTL interface standard, despite the skewing effect this has on how transistors can be scaled down. "When these scaling rules were first developed, it was assumed that the voltage would scale as the devices are scaled," Meindl says. "Without scaling the voltage, all sorts of second-order effects become more serious."

At some point, then, the industry will have to seriously consider a move away from the 5-V standard, says Anthony Ley, vice president of research and engineering at Fairchild Semiconductor Corp.'s Research and Development Center in Palo Alto, Calif. The move will be absolutely essential as device geometries approach 0.5 μm, he says. "Indeed, we may have to readjust not to one shift but to several within the next 10 years as we move to 0.5 μm and below."

Outweighing the inconvenience of shifting to a new interface voltage standard are some very significant benefits, says Siemens' Hausele. "First of all, such fundamental device physics constraints as punchthrough, gate-dielectric breakdown, and hot-electron effects are minimized. But even more important, power dissipation for a given logic function can be reduced a factor of two for each reduction of a volt, enabling complex logic circuits to integrate more functions and to operate at higher speeds."

Memory circuits, though not constrained by power dissipation, will benefit in terms of improved density, performance, and reliability. The tradeoff in memory designs would be that the signals available for sensing will also drop, Hausele says, and that will call for countermeasures such as radically new sense-amplifier designs or a shift to silicides or exotic metals for the interconnection.



SOLUTIONS. Quantum devices may take over when FETs can shrink no more; new architectures will stop interconnections from swamping ICs.

Another way to change the scaling equation is to lower the temperature at which ICs operate, suggests Ushio Kawabe, chief researcher at Hitachi's Central Research Laboratory in Tokyo. The key would be the recently discovered materials that superconduct at relatively high temperatures. "Availability of these materials for device work would greatly increase the practicability of superconducting devices," he points out.

At some point below 0.5 μm, it will be necessary to forsake the traditional transistor structures and to go to new ones, says James Early, scientific advisor at Fairchild Semiconductor, Cupertino, Calif. "Depending on how far we can push the capabilities of silicon, [this changeover] could be as pivotal as the shift from germanium to silicon in the late 1950s," he says. At the least, it will cause a restructuring of the industry equivalent to that which occurred with the shift from bipolar technology to MOS in the late 1960s.

Some optimists believe that the lower limit for optical lithography can be pushed down from 0.5 micron to about 0.1 micron

The question, says Meindl, is at what point the changeover will occur. "Around the beginning of the decade, everyone thought it would be 1 μm," he says. "A few years ago, the transition point moved to about 0.5 μm. Now there are some optimists who believe that that transition point can be pushed down to about 0.1 μm."

What is not clear, says Meindl, is how far the conventional MOS FET structure can be pushed and what kind of device will replace it: a traditional homogeneous transistor structure using a different switching principle, or some sort of heterogeneous layered structure relying on the electrical differences between alternately layered materials of different properties.

Several types of traditional structures that use different properties of the silicon to perform the basic transistor-switching function have attracted recent interest. Among them is the silicon-based complementary metal-semiconductor FET, developed by researchers at Stanford University's Center for Integrated Systems, and the XMOS FET (see figure, p. 82) from the Japanese government's Electrotechnical Laboratory in Tsukuba [*Electronics*, Sept. 9, 1985, p. 14]. Also attracting attention is the cascode FET from AT&T Laboratories in Holmdel, N. J.

Rodgers of Cypress says that if there is a need to replace the traditional MOS transistor, he is voting for the complementary MES FET, in which a Schottky gate rather than an oxide-insulated gate is used to control the flow of majority carriers between the source and drain. In most cases, n-type material is used because of its high electron mobility.

"The limited use of MES FETs in the past, particularly in VLSI circuits, has been due in part to their power requirements as well as to the limited number of circuit configurations possible," Rodgers says. "The complementary MES FET seems to overcome these obstacles. In addition, this structure seems to be immune to many of the second-order effects that plague MOS FETs below 1 μm." In particular, Rodgers says, complementary MES FETs do not require thin oxides and as a result are not susceptible to the problems of obtaining reliable thin gate oxides or to threshold shifts due to hot carriers.

The Japanese lab's dual-gate XMOS FET is an extension of the traditional MOS FET structure built atop a 0.5-μm silicon dioxide layer. It consists of a polysilicon lower gate, a lower gate oxide, an active recrystalized silicon channel region, and a polysilicon upper gate. Researchers at the lab believe that working FETs could be built with 0.02-μm-long channels and 30-Å-thick gate oxides. The new structure not only does away with the short-channel effects that occur at submicron geometries, but also eliminates cross-talk from underlying active layers. Also, the additional bottom gate provides either threshold voltage control or an additional input terminal.

Another sub-0.1-μm structure is the 70-nm cascode MOS FET (CAS FET) from AT&T Laboratories. The usual parasitic drain resistance in the MOS FET is converted into a junction FET that is linked in series with the short-gate MOS FET. AT&T makes use of a symbiotic junction FET formed in the region between the drain contact and the gate. Generally, this region of the channel is a parasitic resistance that degrades the performance of the device. But by properly doping the channel, researchers have found that this region becomes a JFET with the grounded substrate as its gate. Simulations indicate that frequencies as high as 30 GHz are possible with gate lengths of no more than 0.15 μm.

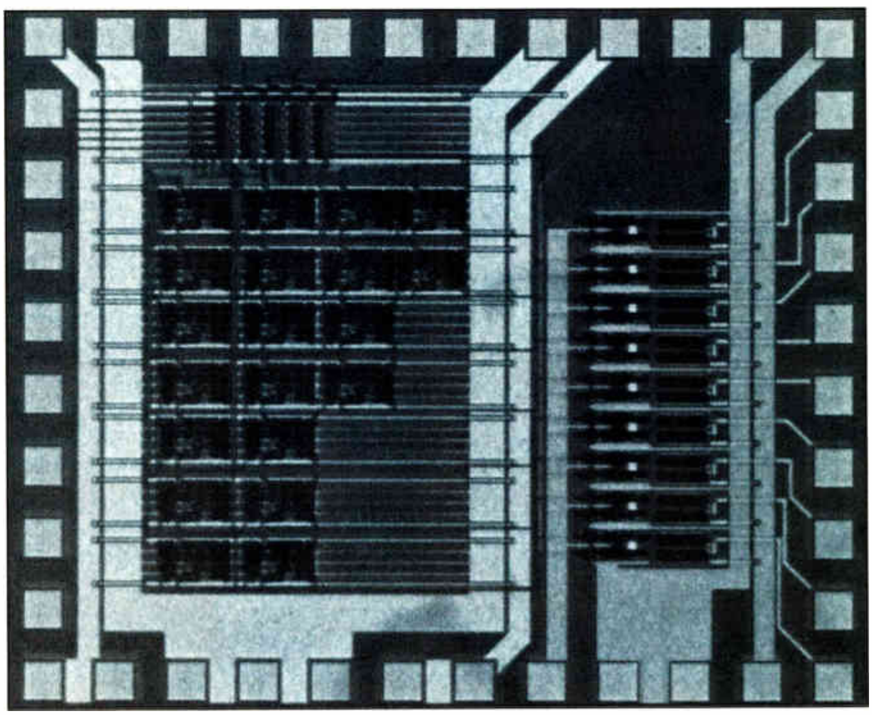
Even with all the ingenuity that device engineers can muster, the traditional transistor structure will play out at about 0.3 μm (see chart, p. 83), says George Heilmeier, senior vice president and chief technical officer at Texas Instruments Inc., Dallas. Some form of heterojunction or superlattice structure could then become the vehicle for further improvements, although it might not be silicon-based. To date, most of the investigation into such devices has involved the construction of superlattice structures consisting of gallium arsenide and aluminum GaAs in alternating layers. One recent example is a modulation-doped FET (MOD FET) from Honeywell Inc. (see photo, right).

However, says Kan L. Wang, professor of electrical engineering at the University of California at Los Angeles, a variety of silicon heterogeneous layered analogues of GaAs structures have been fabricated using molecular-beam epitaxy [*Electronics*, April 28, 1986, p. 37]. One possibility is a CMOS-like heterojunction in which gridded heterojunction layers of alternating doped silicon-germanium are inserted beneath the CMOS structure. Another possibility, Wang says, is a complementary MOD FET using silicon-germanium heterojunctions plus metal-base transistors and permeable-base transistors fabricated from cobalt silicide and nickel silicide layers.

Heilmeier's candidate for replacing homogeneous structures is the quantum-coupled device using heterojunction-based superlattices. One type that is receiving the attention of researchers at TI and other institutions around the world is the electrically controllable surface superlattice (see figure, p. 85). Because it is basically a planar rather than a vertical superlattice structure, it takes advantage of patterned structures on the surface to control quantum potential wells created at the interface between a semiconductor and an insulator or a wider-bandgap semiconductor.

Heilmeier predicts that the first ICs based on quantum coupling will begin to emerge in the marketplace sometime in the early 1990s. "Does that mean transistors will go away?" he asks. "No, it means that there is a different ball game," in which there will be other players besides the traditional bipolar and MOS silicon-based MOS FET structures. The industry has depended on the reduction in costs, greater density, and higher performance for growth, he says. With fundamental physical limits slowing down the density curve as MOS and bipolar technologies reach their fundamental limits in the mid to late 1990s, the present rules of competition based on current technology will change, he believes.

The fundamental limits of current silicon CMOS process technology may be one set of the rules that will slow down the game, but there are other barriers as well, says Nicholas C. Cirillo Jr., department manager



SUPER. Honeywell used MOD FET superlattice devices to build a 1.8-ns 5-by-5-bit multiplier.

for semiconductors at Honeywell's Physical Sciences Center in Bloomington, Minn. The most serious of these is the economic barrier, which he believes will occur at around 0.25 μm, where the investment required may be just too high to justify a push to smaller geometries. "It may not be economically viable to build right to the limits of physics," he says.

Concurring in this view is Bernd Hofflinger, director of the Institute for Microelectronics, Stuttgart, West Germany. "To be sure, physical barriers come into play," he says. "But it is primarily the high costs, which are rising out of proportion with what they achieve, that may keep firms from continuing on the miniaturization path."

However, Wolter G. Gelling, director for semiconductor devices at the Philips Research Laboratories in Eindhoven, the Netherlands, is not sure that rising plant and equipment costs are necessarily a barrier. "Sure, high costs could be a factor if markets stagnate," he says. "But if the semiconductor industry continues to grow, as it is expected to do, why shouldn't companies make enough money to finance a new generation of IC factories?"

Also, a number of practical manufacturing problems may be blocking the road to the billion-transistor chip, points out Ley of Fairchild. "One obvious problem will be the horrendous task of designing a chip with that much functionality, even with the most advanced of design-automation systems, not to mention the tasks of simulation and verification," he says. "The industry is just now getting a handle on these problems at the 1-to-2-μm level. Designing with submicron MOS FETs will require a whole new set of software tools." And if it is necessary to shift to an alternative device structure, says Rensselaer's Meindl, it will be necessary to "reinvent the wheel," with massive investments in new software tools and methodologies.

"Then there are the problems of testing and packaging," says Early. "Even at today's levels of integration, these last are becoming significant bottlenecks."

Still largely unaddressed, says Intel's Pashley, is the interconnection problem: interconnects can consume as much as 80% of the area of a typical VLSI circuit. "Even at today's levels of integration we are talking about the metal interconnect lines on a single chip that in total adds up to several meters," he says. "At the same time as interconnect length and thus resistance is increasing, device size and drive capability is being reduced." As a result, he predicts a shift away from aluminum and such halfway measures as salicides and silicides to lower-resistance exotic metals such as tungsten and molybdenum.

Ultimately, says TI's Heilmeier, the industry will need a new way of looking at architectures to deal with the interconnection problem. "Our roots in IC design go back to the way people designed switching circuits when the elements were relays," he says. "Then the economics were that the switches were expensive and wires were cheap. With VLSI and ULSI, the problem is the reverse: the transistors are cheap and the interconnections are expensive."

What to do with a billion-transistor chip? For one, computers that adapt to the user instead of the other way around, says TI's Heilmeier

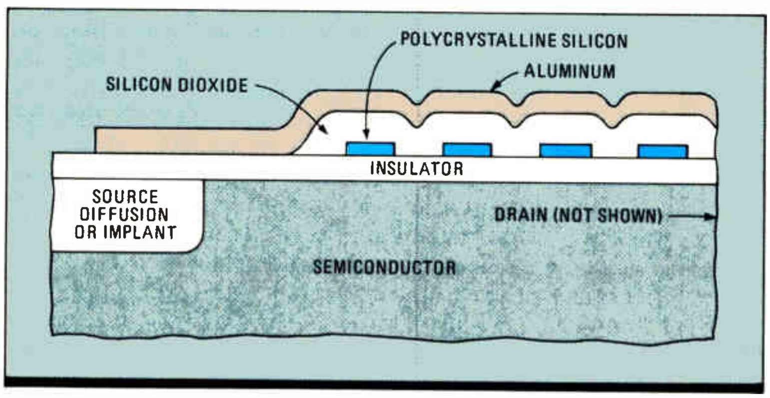
But, says Fairchild's Early, when all is said and done, there is the final problem: what will the semiconductor industry do with all that functionality? "Except for the demand for more and more memory, which seems to be a black hole in the marketplace, gobbling up whatever we give it, are there any applications that will need the amount of functionality on a chip we can give them at even 0.5 μm?" he asks.

In fact, argues John Wallace, president of Ford Microelectronics Inc. in Colorado Springs, Colo., 500,000 transistors on a chip are probably more than enough for most mainstream applications. "What will a million do for you?" he asks.

That's not how Heilmeier sees it. He believes that semiconductor technology will continue to be the enabler for new markets, though the new opportunities will be more system-specific than in the past. For example, he expects to see ICs that will make possible speech understanding, not merely speech recognition. "Some future chips will make image understanding possible," he says. And Heilmeier also believes new ICs will make massively parallel processors available for general-purpose computing.

"Data-base management will be a very ripe area," he says, with intelligent data bases that can alert users of pertinent information as data enters the system and that can automatically browse memory for items of interest in areas specified by the user. Heilmeier also thinks multimillion-transistor ICs will make it possible to merge symbolic processing with numeric computing and will probably result in a combined Lisp and general-purpose processor architecture in the 1990s.

Most of all, he sees the processing power of the billion-transistor chip being focused on the user interface. It will lead to what he calls the transparent computer, which can adapt to its user instead of vice versa. And that will mean the start of a whole new era in computing—and in the IC industry.



PLANAR. Electrically controllable surface superlattices are a kind of quantum-coupled device that TI researchers think may come into use during the 1990s.

KEYS TO THE FUTURE: CAD AND FAB

A revolution in design tools and processing technology will make the billion-transistor chip a reality by the end of the century

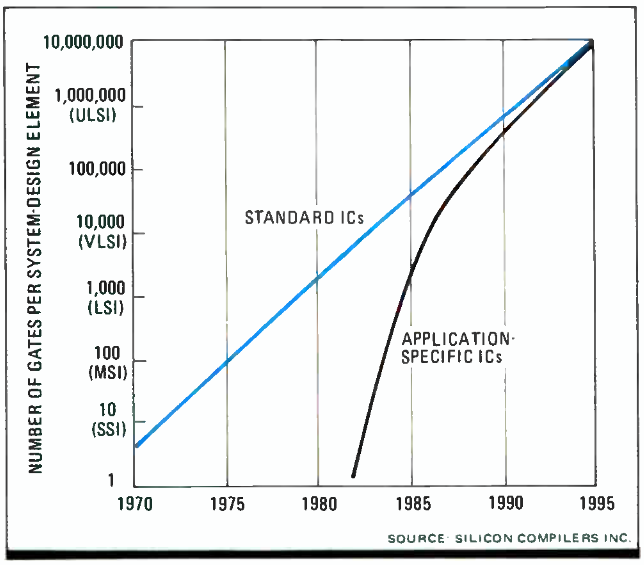
by Jonah McLeod

Building billion-transistor chips will require radical changes in both computer-aided design and integrated-circuit fabrication. But by the year 2000, brand-new generations of CAD tools and fab lines will be in everyday use to handle such super chips. With feature sizes less than 0.5 μm, these chips most likely will be produced with either electron-beam or X-ray lithography. And whole new classes of software tools will greatly speed up and simplify the design process.

New tools will emerge for front-end design capture, the creative part of a design now done manually by designers before they enter it into a work station. Common libraries of components will be built up, making it possible to move designs rapidly from one process technology to another. New simulation tools will arrive to help model the new transistor structures and lay out the topologies that will be required for chips with feature sizes below 1 μm. Layout tools—especially knowledge-based silicon compilers—will radically automate the layout process. Finally, a new segment of the industry will emerge to customize circuits after they have been manufactured.

Processing equipment won't start changing radically until the mid-1990s, when new generations of gear will be needed to reach the vastly greater circuit densities of the billion-transistor chip. For the greater part of the next decade, processing equipment based on optical lithography will remain the workhorse of the industry. Most observers' perception of the point at which line geometries become too small for optical lithography to handle has edged downward over the years. But when this point is reached, electron-beam and X-ray lithography will take over to permit manufacture of devices with line widths as small as 0.1 μm. Processing equipment will also be increasingly automated. Eventually, bare wafers will be loaded at one end of a single piece of equipment, and fully processed wafers will pop out at the other end.

One thing that is changing now is the relative importance of design and process expertise, says Brian Hegarty, vice president and general manager of Honeywell Inc.'s Solid State Electronics Division in Colorado Springs, Colo. "In the past, the driving force in the industry has been process technology," he says. "Today, it is still 80% process technology [and only 20% design-tool technology], but I think it will get to 50-50 or even swing in favor of design-tool technology over the next 10 years." Companies with the best design methodologies will be the stars, Hegarty says, not companies with the best processes.



BIGGER BLOCKS. ASIC designers first had to work at the gate level, but cell libraries and compilers have made the design elements larger.

COST-CUTTING WITH CAD

"The two functions that dictate the cost per gate of a circuit are conception and implementation," says Lowell D. Deckard, assistant vice president for product management at NCR Corp., Dayton, Ohio. Present-day CAD tools help with implementation, he says, and they have cut the cost of designing an application-specific integrated circuit from $40 per transistor down to $6 to $8 per transistor. And by the year 2000, the cost will drop to a few millicents per transistor. Designs are cheaper in part because of the larger design elements becoming available as tools and cell libraries develop (see figure). So the major order of business now is to develop CAD tools that help with the conception phase of design, Deckard says. And that means artificial intelligence. "With the incorporation of AI, CAD tools of the 1990s will allow the user to define a circuit behaviorally and the tool will synthesize the transistor-level design," he says.

In fact, such CAD tools as an "architect's assistant" that help work out the design-synthesis problem are in the offing, says George H. Heilmeier, senior vice president and chief technical officer at Texas Instruments Inc., Dallas. It would look at human decisions and weigh tradeoffs for overall performance, price, and expected yield on the production line. "Today's tools are great once you know what you want to design, but they don't help you with the architectural tradeoffs between power, speed, and cost," he says. "Those kinds of tradeoffs are made very laboriously today."

By 1995, engineers will be doing a lot of VLSI design work at their desks, predicts Lynn Conway, pioneering chip designer and now associate dean of engineering at the University of Michigan in Ann Arbor. "But I don't know if we will see a lot of AI used in design." She expects it to be exploited primarily in simplifying and codifying the quantitative knowledge now applied.

Theo Claasen, director for IC design at Philips Research Laboratories in Eindhoven, the Netherlands, agrees. He says there should be more man-machine interaction, and shies away from the idea of a completely autonomous computer-controlled design process. "The computer should do primarily the tedious work," he notes. "The designer should retain the capability to make design proposals to the machine, evaluate feedback from it, discard certain computer-made suggestions, make counter-proposals, and decide on a final course of design. Such systems should be ready by 1994."

A new level of CAD called "group or collaboration technology is another world that will descend on the workspace fully in the 1990s," predicts Conway. She says that it will help conceptualize a chip before the detailed design process begins. This software is just beginning to emerge at places such as the Xerox Palo Alto Research Center in California and at Michigan. It will enable design teams to work together on such tasks as brainstorming a "quick cut" at a design idea. It will also provide help in remembering technical or market constraints when changes are to be made in a design.

Conway does not think AI will play a big role in actual chip design. "AI will be exploited in some ways," she says, primarily in simplifying and codifying the quantitative knowledge now applied. "I don't know if we will see a lot of AI used in the actual design, since a lot of that has proved to be solvable by procedural and algorithmic methods."

HEGARTY: CAD will drive the industry in the future more than process technology.

One problem that CAD tools already are addressing is the accelerating pace of change in process technology. Previously, a foundry customer designed for a given process technology, knowing he had a sufficient market window using the process. Now, the foundry customer who designs for, say, a 1.5-μm process and takes a year to develop the product finds that a new generation of process technology has arisen while he worked.

To facilitate this process, a number of companies, including VLSI Technology Inc. of San Jose, Calif., have developed portable libraries that can migrate across technologies. "All our current development in standard cells and gate arrays is based on a set of primitive elements that we can port from one technology to another," says Andrew Haynes, ASIC strategic marketing manger. "All our compilers, megacells, and simpler cell families share this commonality, so we can migrate designs across a broader range of technology changes than possible in the past."

To reach the level of 1 billion transistors on a chip will require a major shift in simulators. For one thing, "we will need additional work done in transistor-level simulators that give us a better understanding of transistor parameters than we have now," says James Van Tassel, vice president of NCR's Microelectronics Division. Simulating new structures such as devices built with trench isolation for greater density will require new software capability as well.

In fact, there probably will be whole new generations of simulators, especially circuit and timing simulators. "These tools need to be more closely tied to the silicon," precisely emulating the timing and behavior of the actual circuit, says Rob Walker, vice president and chief engineering officer at LSI Logic Corp. in San Jose, Calif. Designs implemented in 3-μm process technologies experienced gate delays of 3 ns. So if circuit timing was off a few hundred picoseconds, it had little or no impact on circuit operation. Interconnection delays were negligible as well.

"Circuits implemented in 1.5-μm process technologies, however, have gate delays of a few hundred picoseconds. So circuit timing being off a few hundred picoseconds begins to impair circuit operation," says Walker. And in circuits implemented in submicron process technology, the gate-delay problem increases in magnitude. In addition, interconnection delays in the 1.5-μm and submicron processes become a significant or even dominant factor.

Silicon compilers are maturing to the point that the engineer will not have to concern himself with implementation details—but compilers still have a long way to go. "The silicon compilers of today are designer-oriented layout-and-analysis systems rather than being true compilers," says David Hightower, manager of advanced system design at Calma Co., Milpitas, Calif.

But silicon compilation is developing fast (see photo, p. 88). "The phase of silicon compilation that we will enter soon will take care of the details in the design process, such as placement and routing of standard cells," says VLSI Technology's Haynes. "Nonalgorithmic steps in the design are going to be handled by expert systems."

Silicon compilers will be a major force for change, agrees William N. Sick, TI executive vice president, but he thinks that the advent of highly competent silicon compilers will not rock the industry off its foundation. "Manufacturers will declare they have pure silicon compilers. In fact, they will see great advances, but with each step we will be able to compile solutions to a limited class of problems," Sick says. He believes the technology will infiltrate the market—slowly—during the late 1990s.

Floor planning is the next major challenge in compilation tools. A designer producing a floor plan blends his understanding of how data flows on a chip and his understanding of how he wants the chip to come out—the aspect ratio, his understanding of power and ground, and so on. Expert systems using heuristic knowledge from the designer are the only way to automate this task. "If you were to attack the problem with an algorithm that places these parts, you would fail," says Hightower.

New kinds of computer-aided design tools will help the integrated-circuit designer with architectural tradeoffs at the conception stage

As with other CAD tools, artificial intelligence will have a big impact on compilation, says David L. Henderson, strategic marketing manager at Inmos Corp., Colorado Springs, Colo. He expects to see knowledge-based systems—pattern recognition and other software techniques—"that will allow us to build CAD tools that are good enough for specialists to design extremely complex chips, but I still don't see printed-circuit-board designers doing their own ICs with these tools in the 1990s. That is probably another 10-year effort to get silicon compilers to the point where they are available to everyone and still make good use of the silicon."

In fact, silicon compilation is ready to leap into the AI era, argues Dennis Sabo, vice president of marketing at Silicon Compilers Inc. of San Jose, Calif. "The next generation of silicon compilation to expect this year is the first uses of AI, not simply an expert system," he says. These compilers will learn what tactics produce better results and use them in later designs. "Next-generation tools will not need to be fed new rules by the designer; they will learn them," says Sabo.

COMPILED. Leaving many implementation details to a silicon compiler, GE researchers laid out a 35,000-transistor chip in three days.

Automated design tools also will have to address the problem of a new class of parts falling between standard ICs and ASICs. This will call for design software that can tailor chips after they have been manufactured, suggests Vin Prothro, chairman of Dallas Semiconductor Corp. His company's semicustom products are not designed in the same way as gate arrays or standard-cell parts. The customization is added after manufacturing; one form of that could be software either written into the die by laser beam or stored in random-access memory and kept alive by a lithium battery.

Given the near-revolution that will sweep chip design by the year 2000, it's hardly surprising that manufacturing technology also will undergo sweeping change. Manufacturing chips with densities approaching 1 billion devices will require new classes of lithographic equipment and a high degree of automation in all processing gear. By the year 2000, optical lithography finally will have reached its limits. George Rutland, president of Ultratech Stepper, a unit of General Signal located in Santa Clara, Calif., says it will run out of steam by the mid-1990s.

But other industry experts are not so sure of that date. "A few years ago everyone thought optics would be dead at 2-μm line widths," says Alan Wilson, manager of chip lithography at IBM Corp.'s Thomas J. Watson Research Center, Yorktown Heights, N. Y. "Then they said it would be dead at 1 μm, and now we are seeing it below 1 μm. The cutoff for optics has continued to decline."

Any of the major stepper companies make machines that can print a feature 2 to 2.2 times the wavelength of the light in use, says Wilson. One common wavelength is 430 nm, which can print features at roughly 0.86 μm. The excimer laser allows smaller wavelengths to be used—such as 250 nm, offering resolution to 0.5 μm. That's the point—0.5 μm—where the limit of optical lithography will be found, says David Grundy, technical director at Plessey Semiconductor Ltd., Swindon, UK.

That means the vast bulk of silicon will be produced by optical lithography up to at least 1995, says David Hutchital, vice president and general manger of Perkin-Elmer's semiconductor equipment group. But he agrees that 0.5 μm is the end of the line.

It isn't just a matter of the available wavelengths of light, either. "A major limitation is the small depth of focus of high-resolution optical lenses," says Wolfgang Arden, director of the lithography and inspection department at the Microelectronics Technology Center of Siemans AG in Munich. "Further use of optical lithography for features down to 0.5 μm in size will require multiple-level resists or considerable planarization of the chip topology" to overcome that limitation.

Whenever optical lithography does hit an absolute limit, it probably will be replaced by any of three technologies. Each can be used to fabricate chips with features smaller than can be made with optical techniques. They are direct-write electron-beam systems, X-ray lithography, and ion-beam systems.

"E-beam systems have two advantages," says Douglas Dunn, managing director of Plessey Semiconductor. "They get us down to lower feature sizes and they take out some of the initial cost by eliminating the expensive and complex mask steps." The disadvantages of E-beam systems are their high cost and low throughput. The systems, which cost $3 million or $4 million each, can only produce 5 to 8 wafers per hour.

In production, E-beam lithography may be too slow, but it is flexible—it can be quickly altered and changed to allow experimentation, points out IBM's Wilson. As a result, it is a widely used laboratory tool. "We debug with E-beam, and we manufacture with optical techniques," he says.

The advantages E-beam methods have over mask-based technologies are programmability, lower tooling cost, and short turnaround times. "For limited runs, the direct-write E-beam techniques will come to the fore," says Bernd Hofflinger of the Institute for Microelectronics in Stuggart, West Germany. "It is in prototyping ASICs where the E-beam technique will make its mark."

X-ray lithography's advantage is high image resolution, down to 0.1 μm. It can reach that level because of the short wavelength of X-rays, around 1 nm. "It has been shown that we can print ¼-μm line widths with X-ray," Wilson says. IBM has mounted a major X-ray lithography research program.

The biggest problem for X-ray lithography is whether this very expensive technology can win enough industry support, says Wilson. The storage-ring synchrotrons needed to produce the X-rays themselves are extremely costly, but the cost could conceivably be reduced by having a number of companies share a storage ring, he points out. As many as 30 steppers could be hooked up to a single ring, and the machines could produce 30 wafers each per hour. This could vastly reduce the cost of the technology, to about $2 million for each wafer-producing station, he says. Such sharing is already going on at a Japanese research facility.

Making masks for X-ray work is another big problem. "This problem is due to stresses in the mask and to the different expansion coefficients of the extremely thin membrane that carries the X-ray-absorbing material, typically gold or tungsten, and the absorber itself," says Wolter G. Gelling, director for semiconductor devices at Philips Research Laboratories in Eindhoven, the Netherlands. Different rates of expansion can lead to distortions in the patterns produced.

X-ray work is being pursued in Japan and the U. S., but most actively in West Germany (see photo). In a multicompany project sponsored by the German government, chip makers and systems producers have developed the techniques and equipment needed for fabricating their first X-ray exposed devices, albeit for experimental purposes [*Electronics*, Feb. 5, 1987, p. 78].

X-ray lithography will come into play sometime between 1992 and 1997, says IBM's Wilson. Beyond that is ion-beam mask-projection lithography, which "perhaps may be the ultimate solution when we get below 0.2 or 0.1 μm. That might occur after X-ray; around the turn of the century it could be in vogue."

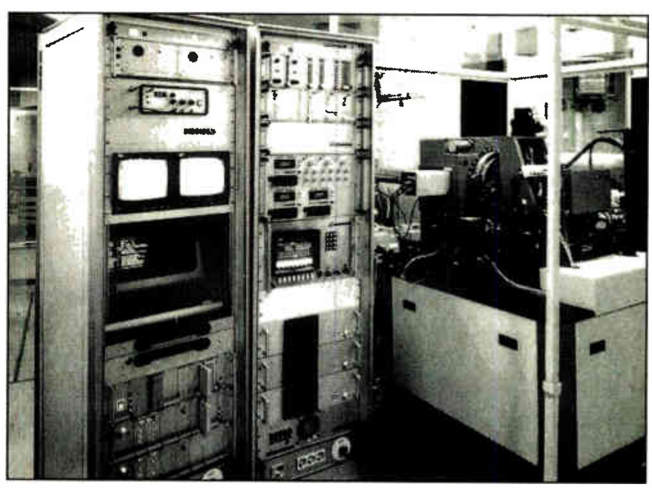
Before then, however, "there are many years of research still to be done," Wilson says. One of the ion-beam problems is mask heating, which can lead to distortions of the projected patterns. "So is the slow throughput resulting from the low beam brightness," says Gelling of Philips.

Entire processing lines may one day be contained within a single piece of equipment, all but eliminating particulate damage

For all types of lithography, even optical methods, alignment accuracy is an area that must be improved as device features shrink. "Lining up the individual layers of the chip with respect to each other"—overlay accuracy—is the problem, says Plessey's Grundy. For example, to expose 0.5-μm details into a resist calls for a minimum of 0.15-μm overlay accuracy, a figure that Hutchital of Perkin-Elmer says can be achieved, "but not easily." Today's best alignment accuracy on a stepper is about 0.25 μm.

Some steppers may perform all the mask steps for each wafer on a single machine to get around the mask-registration problem, says Ultratech's Rutland. He believes his company has solved the problem for the next generation of process technology at least. But "in the future, one has to find a process with self-alignment," says Grundy. "You use the underlying layer to define the next layer."

It's likely that automation will play a role in solving lithography's alignment problems; certainly automated equipment will be the watchword in other kinds of processing gear. Driving the thrust into automation is the need to reduce contamination. "We spend a lot of money making clean rooms and then people bring in dirt," says Dunn of Plessey. Greater automation will reduce the need for people to be in the clean room, he says. In turn, this should help manufacturers get down to 0.1-μm feature sizes.



X-RAYS. The Karl Suss vertical stepper and Siemens alignment system help give the West Germans an edge in X-ray lithography.

"The people-less clean room is at least 10 years away," says Dunn. "But one is gradually seeing various parts of the process becoming more automated." Eventually, wafers will be completely contained inside the production machines, suggests Honeywell's Hegarty. "No one will touch the wafer," he says. "You might not even see the wafer until it comes out of the equipment."

In fact, eliminating the clean room full of equipment by containing the process within a single machine is a strong possibility, says Venkatesh Narayanamurti, director of the solid-state electronics research laboratories at AT&T Bell Laboratories in Murray Hill, N. J. "By putting in raw wafers at one end of the machine and getting out fully processed wafers at the other, the chance of contamination or particulate damage would be almost completely eliminated," he says. "In five to 10 years, you'll combine your crystal-growth apparatus with your processing apparatus so you never get any dirt at all. This machine itself would be the clean room."

Such machines may eventually reduce the amount of plant and capital a company need devote to a fabrication facility. But the demand for less-costly chip manufacture is already being addressed. To the bevy of young niche-market semiconductor firms appearing in the U. S., a small, low-volume, low-cost fab line can be an attractive alternative to searching out acceptable foundry service.

FAB FOR NICHES. Dallas Semiconductor has brought up a 6-in. low-volume CMOS chip-fabrication line for less than $10 million.

Three-year-old Dallas Semiconductor Corp. is an example of a startup that has brought up a small manufacturing facility without huge capital investments. The company has set up a low-volume 6-in. CMOS line—with relatively little automation—for under $10 million (see photo, above).

The fab line includes stepper lithography machines and dry-etch equipment, and can process 200 wafers a week. It came on line seven months after ground-breaking, says John W. Smith, co-founder and chief executive officer of Dallas Semiconductor.

Fabrication technology may thus push toward small-scale facilities suitable for niche companies at the same time that big plants with X-ray rings and other exotic production equipment evolve elsewhere. Together with the profound changes in CAD tools and the new device technologies that will make the billion-transistor chip possible, these new production technologies will drive semiconductor technology to higher levels of integration. Advanced technology, alongside a corporate environment restructured in terms of organization and cooperation, will redraw the semiconductor industry map for the 21st Century. □

PC BOARD WILL GO THE WAY OF THE VACUUM TUBE

By the year 2000, if not sooner, integrated circuits with millions of gates and thousands of interconnections will have overwhelmed printed-circuit-board technology, reducing it to a secondary role. The boards will be used for little more than power and ground distribution and perhaps for bus structures: all the chip-to-chip interconnections will be on large substrates of silicon or silicon carbide carrying either wafer-scale ICs or big chips in hybrid fashion.

Long before that—as soon as 1990—packaging designers will have to deal with commercial chips with areas of up to 250,000 mil², with up to 400 leads, and with dissipations of up to 25 W. Large lhip carriers with leads on 20- or 25-mil centers will house these ICs.

The percentage of surface-mountable IC packages in use also will rise substantially, and there will be increased use of multichip packages to boost circuit performance and to simplify interconnection to pc boards.

The ultimate solution for the 21st Century may be true wafer-scale integration, since the interconnections would be on-chip along with the millions of transistors. More immediately promising is the prospect of using silicon wafers as hybrid-circuit substrates and either reflow- or wire-bonding unpackaged ICs to them. With this method, relatively low-quality wafers can be used in much the same way as pc boards are, except that the interconnect traces can easily be up to 10 times denser than they are on ceramic hybrid substrates.

These interconnections can be laid down in layers on a silicon substrate using conventional lithographic techniques. An innovative alternative is to build silicon substrates with prefabricated interconnection patterns that can be programmed by the user to wire together the chips of a system or subsystem.

A few of the standard packages now in use will continue to survive for some time, although some will change to accommodate more leads on chips. The familiar dual in-line package will probably remain mechanically unchanged even in the 1990s, as will the small-outline IC package. The chip carrier will evolve tighter pad and lead spacing and will see more use of gull-wing leads instead of J-shaped leads, which present soldering problems.

Multichip packages in several forms—using leadframe connections or a large tape frame in a molded case—will move into the commercial world by the mid-1990s. Carrying four to nine chips each, they will confine much of the chip-to-chip interconnection within the package. This will make for dense interconnections with minimum wiring lengths, increasing system electrical performance. Externally, such packages may need fewer leads than one of the individual chips inside them. *–Jerry Lyman*

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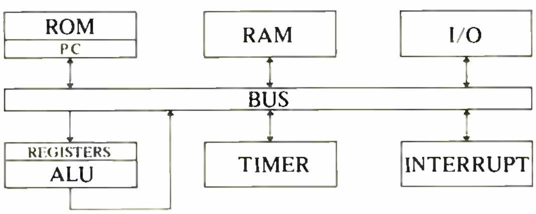

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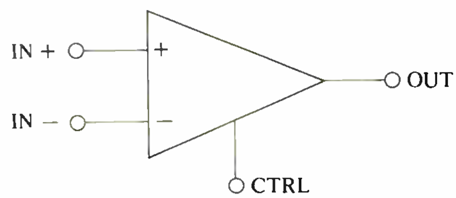

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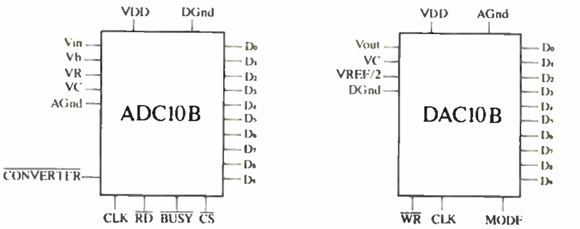

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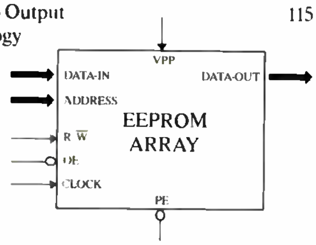
Clock To Output		115	(ns)
Technology			2μ CMOS



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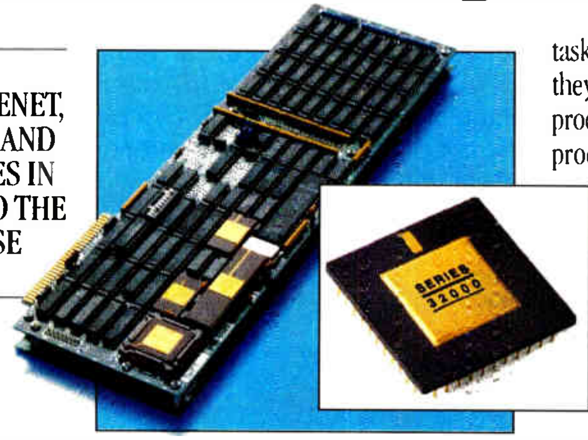

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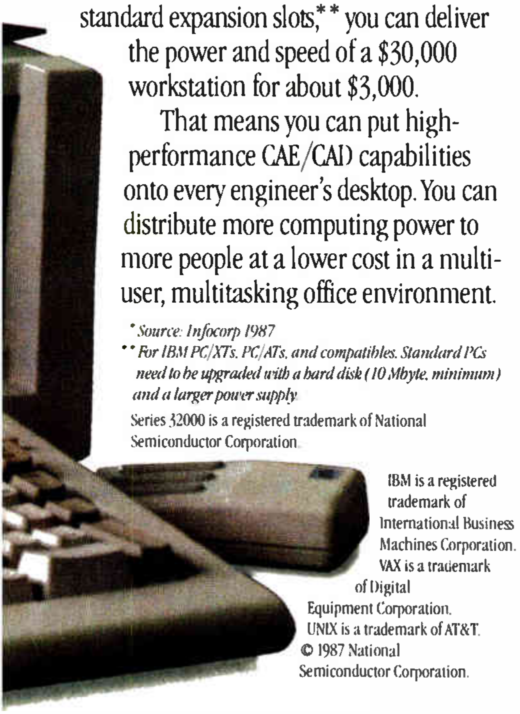

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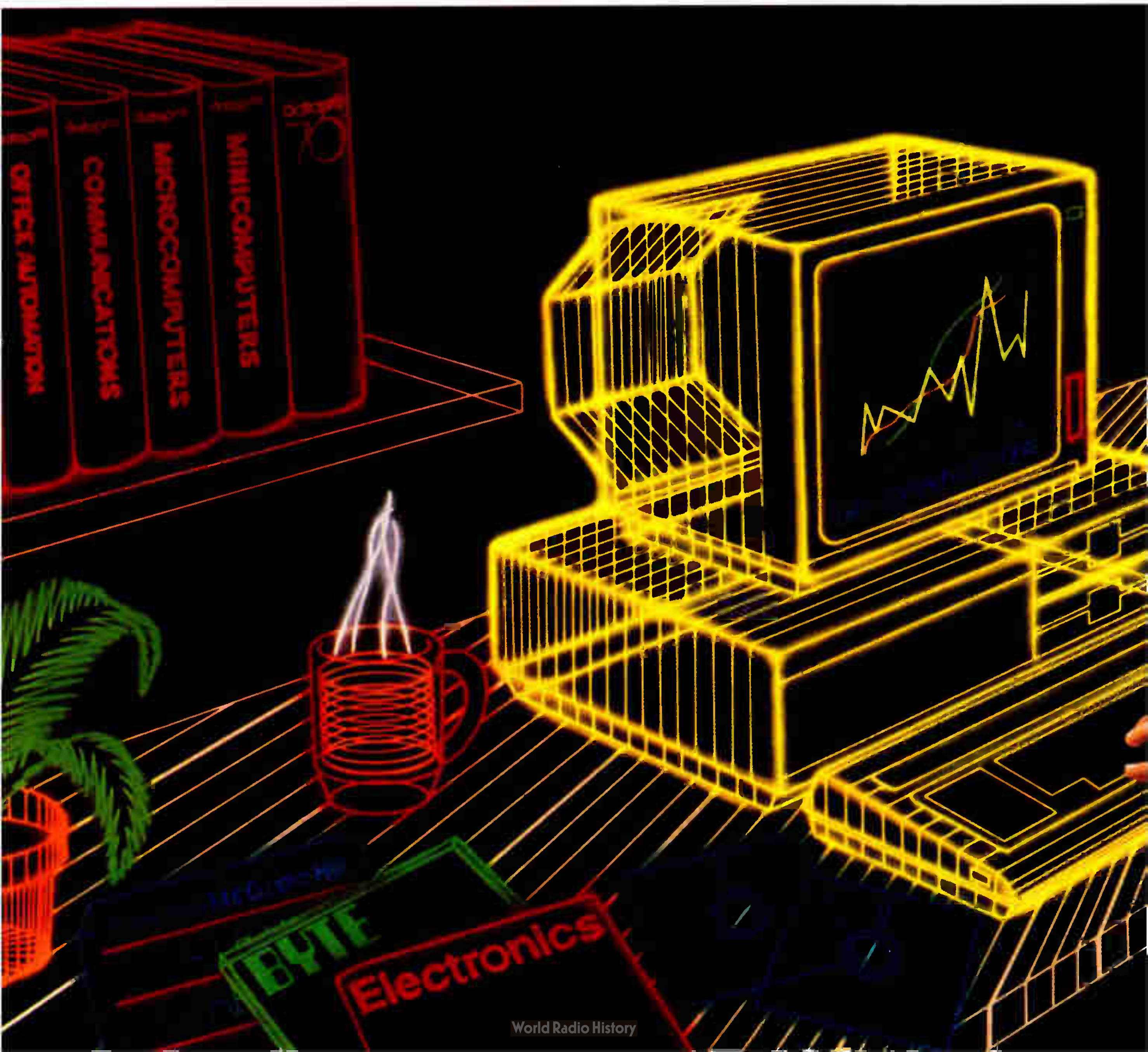

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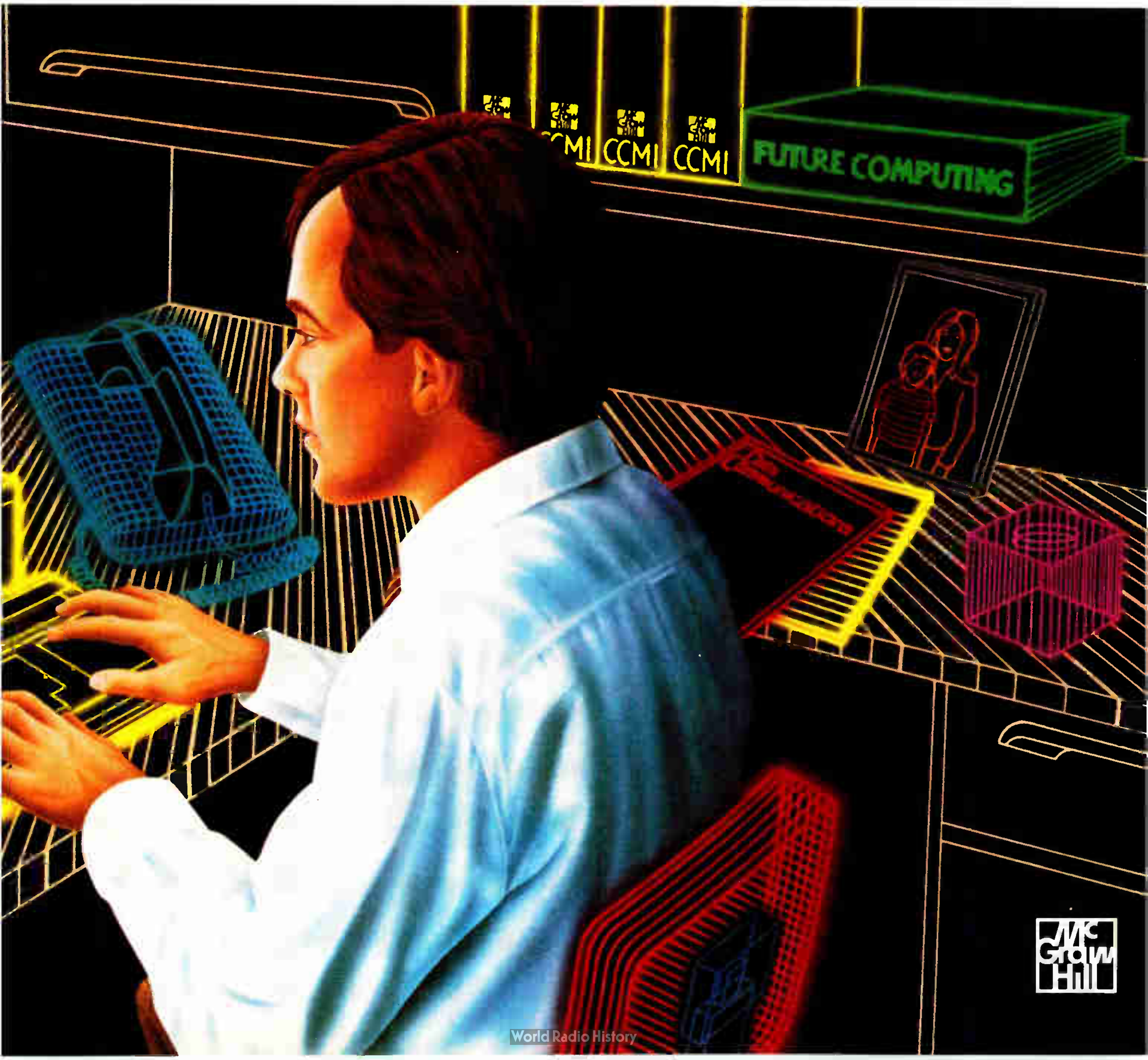

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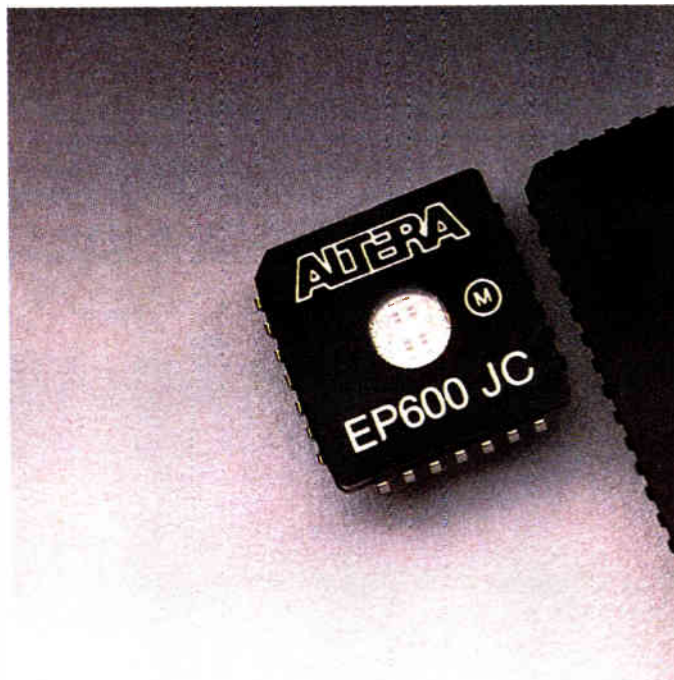

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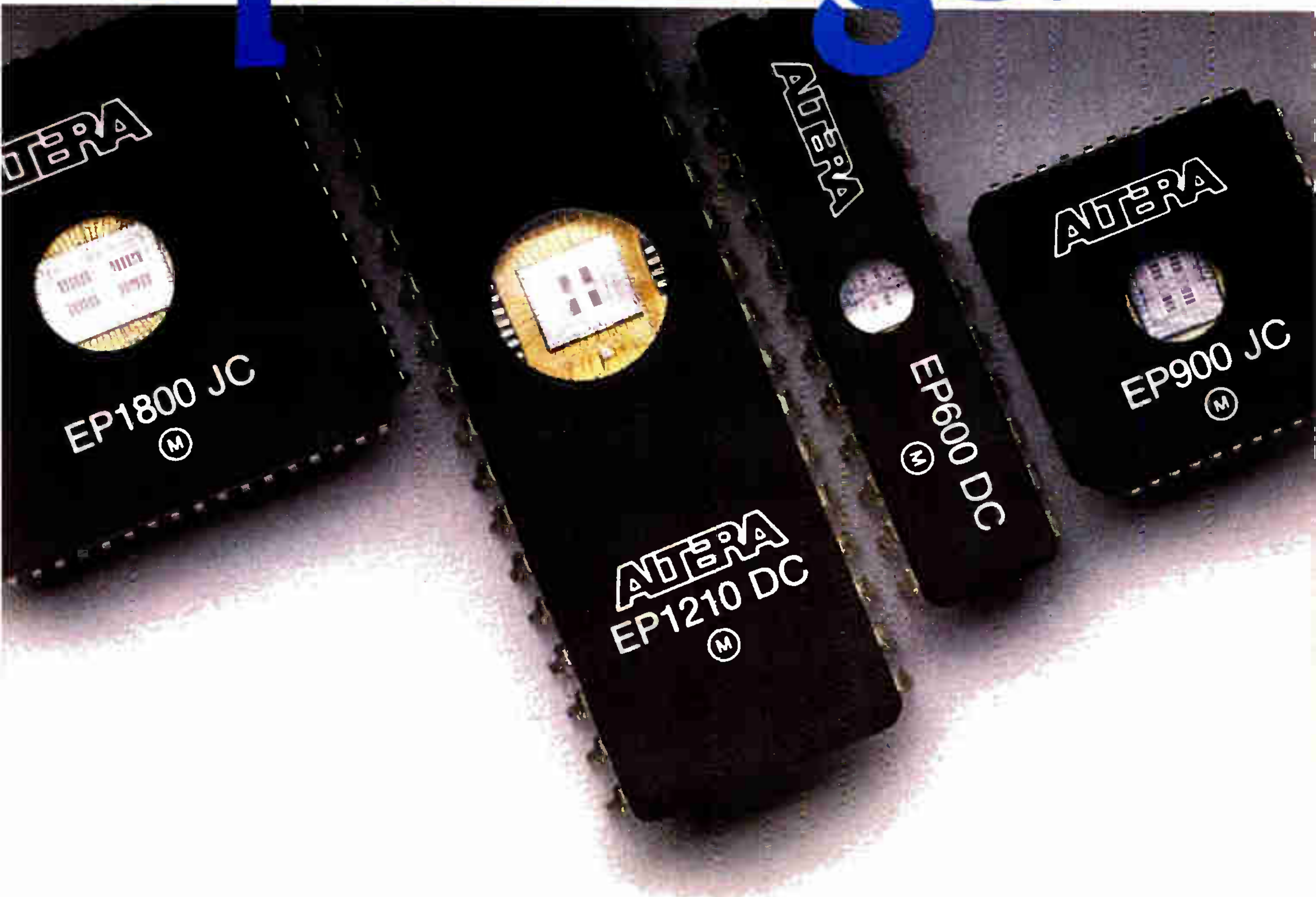

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NEW 32-BIT CHIP FROM NATIONAL HITS SPEEDS UP TO 15 MIPS

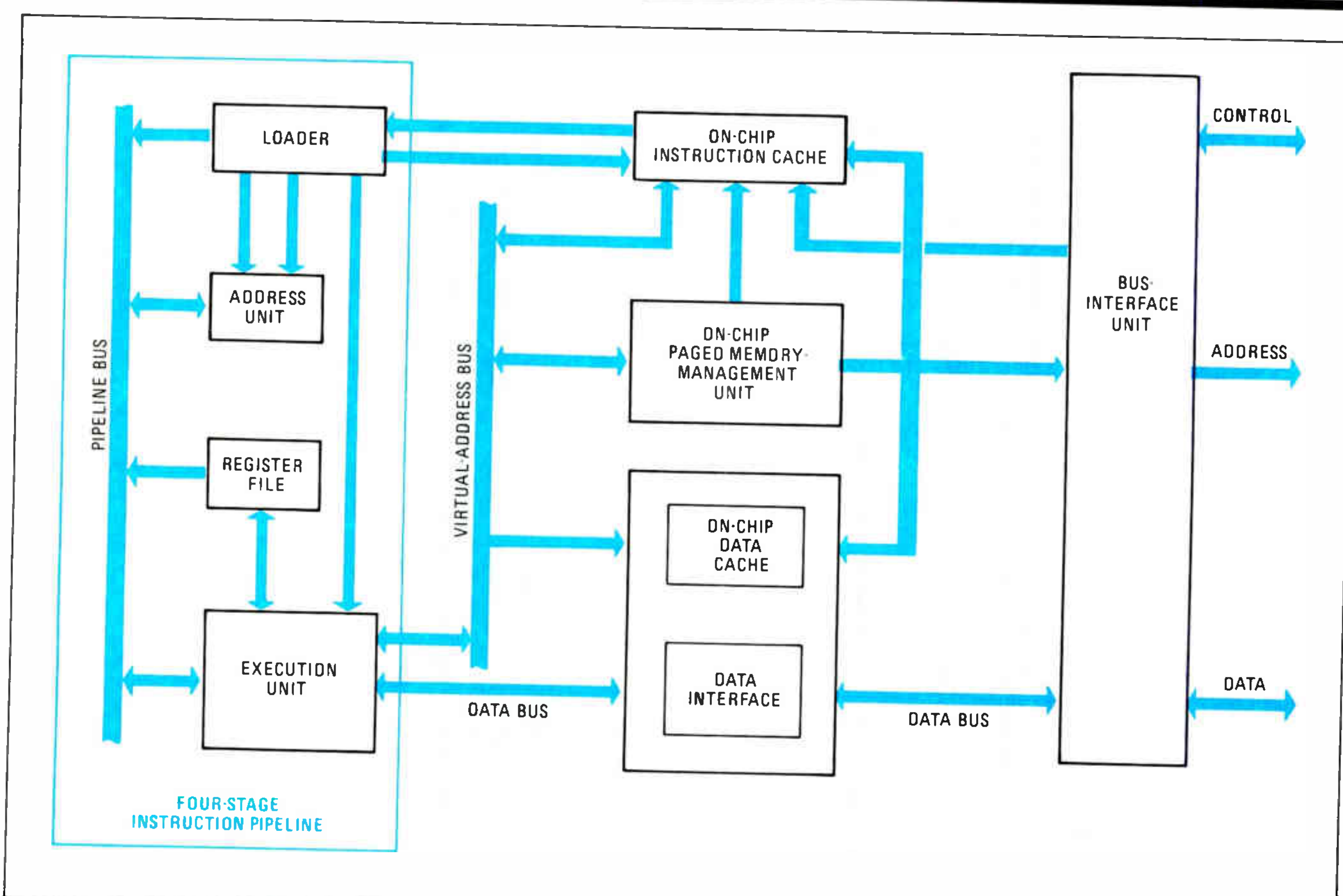
A new architecture lets the 32532 execute all basic instructions in just over two clock cycles and stay software-compatible with earlier 32000-series processors

by Alexander Wolfe

National Semiconductor Corp., the company that pioneered the 32-bit microprocessor with the introduction of the 32032 in 1983, is breaking new ground again with its latest chip, the high-speed 32532. Two versions of this chip, to be available later this year, will run at 20 MHz and 30 MHz, respectively, and the 30-MHz version will set a new performance standard for complex-instruction-set microprocessors: a sustained execution rate between 8 and 10 million instructions per second and a peak of 15 mips.

"The 32532 is the first member of our second generation of microprocessors," says David J. Schanin, chief scientist and technical director of the Series 32000. "The 32532 has a completely new internal architecture." National used a common architecture for its first generation of 1-mips microprocessors—the 8-bit 32008, 16-bit 32016, and 32-bit 32032—and the 3-to-4-mips 32-bit 32332. The 32532 remains software-compatible with these.

The 30-MHz version of the 370,000-transistor



1. PERFORMER. Innovations in pipeline, cache, and MMU help increase the throughput rate of the National 32532 microprocessor.

32532 will be preceded by a 20-MHz model with a peak execution rate of 10 mips and sustained execution of 6 to 8 mips. The 20-MHz chip will be built with a 1.5-μm double-metal CMOS process. First silicon will be ready in June, with sample quantities due out in autumn. National will shrink the process to 1.25 μm for the 30-MHz version. Initial dice for that version arrive this fall.

Applications in which the 32532 will see service include military systems, embedded controllers in laser printers and robotics, and Unix-based office-automation systems. The 32532 could serve as the heart of transaction-processing and fault-tolerant systems as well. And, as with the 32332, National is emphasizing multiprocessing.

In the new architecture of the 32532 (see fig. 1), performance-enhancing innovations abound. "This is our first very high-integration chip," says Max Baron, chief architect for the Santa Clara, Calif., section of the 32532's U. S.-Israeli design team.

THROUGHPUT ENHANCED

To pack the 32532's performance onto 340,000 mils^2 of silicon, National's microprocessor architects came up with a series of throughput-enhancing innovations; patents for several of them are pending. They include improvements to National's existing hardware architecture, in the design of the pipeline, caches, memory management unit, and bus interface unit. Such features as the integration of the pipeline, caches, and MMU onto the same piece of silicon, the real-time coherency of the caches, and the provisions for external monitoring of the chip's control signals lead the list of the patent-pending features. Other key 32532 features include the pipeline's branch-prediction logic and hazard-detection mechanism, the speed of the bus interface unit, and high-level-language compilers that generate efficient machine code.

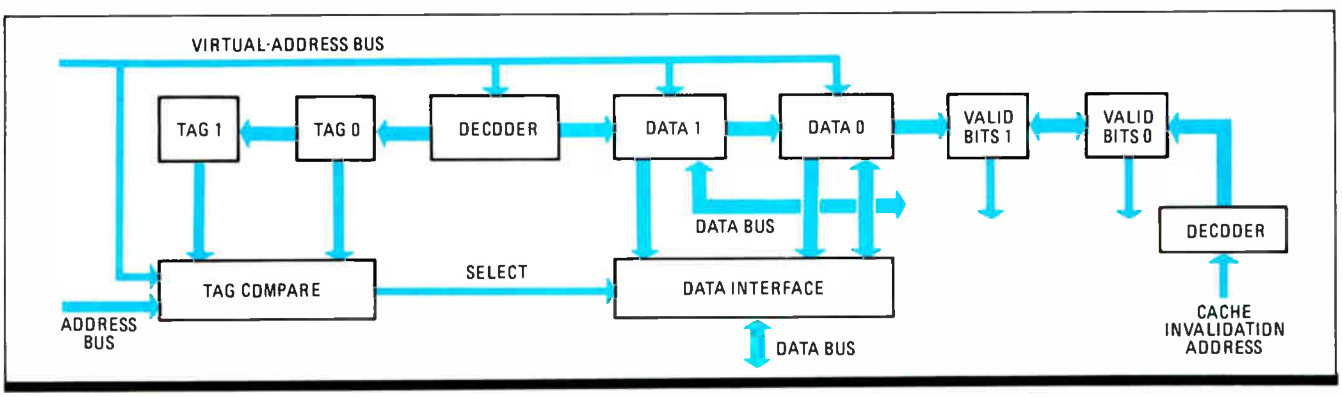
The chip's designers sought to reduce the total number of clock cycles required to execute all basic instructions—Add, Subtract, Move, Load, and Store—to two cycles. At the same time, they wanted the 32532 to maintain the register structure from the existing series 32000 chips to ensure software compatibility with existing applications programs. Designed with these guidelines in mind, the 32532 is organized into eight functional blocks: the four-stage pipeline, consisting of loader, address unit, execution unit, and register file; instruction and data caches; the MMU; and the bus-interface unit.

Working together, the 32532's pipeline, cache, and MMU enable the chip to come close to its designers' goal of two-cycle instruction execution. "Through our design improvements, we are able to achieve 2.1 to 2.15 clock cycles per instruction. On prior architectures, as well as competitive devices of roughly the same complexity, the average is about 2.4 to 2.8 cycles per instruction," says Roger Thompson, technical marketing manager for the 32000 series.

The pipeline operates on the established principle that overlapping the handling of different portions of different instructions improves performance. The pipeline's instruction loader, address unit, register file, and execution units can operate on seven instructions simultaneously.

Within this pipeline, the 32532 incorporates two key refinements: branch-prediction logic and a hazard-detection mechanism. Special circuitry in the loader handles branch prediction. When a branch instruction is decoded, the loader calculates the destination address and selects between the sequential and nonsequential instruction streams. Selections are based on branch condition and direction. But in 80% of all cases, the circuitry can correctly predict the next instruction following a branch in a program. That speeds throughput, because it saves two clock cycles of execution time, since correct prediction results in only a two-cycle gap in loading of instructions by the loader—compared with a four-cycle delay at the execution unit in designs where branch prediction is not used.

The hazard-detection mechanism in the address unit helps the 32532 avoid one of the pitfalls of typical pipelined architectures. Most pipelined machines want to read ahead to the next instruction during main-memory input/output operations. But such a read can overlap with a write operation, causing data to be lost. The hazard-detection mechanism probes the page table in the chip's MMU to test for any nonaligned data operations that cross page boundaries. Using this information, read operations can be delayed



2. INTOUCH. The cache coherency feature, implemented in hardware, keeps the contents of the data cache in synchronization with main memory.

so that they will not corrupt the first page of data that is being written to. Since reads preempt writes in typical pipelined machines, the same mechanism ensures that reads and writes are still executed in proper order.

Innovations in the on-chip instruction and data caches complement the throughput-speeding refinements of the pipeline. Because caches serve as fast buffers holding frequently accessed instructions and data, they reduce the number of external memory accesses required. As such, they allow the chip's users to avoid having to implement that memory in very fast but very expensive static random-access memory.

The benefits of instruction and data caches are related both to their size and their ability to maintain consistency with the portions of main memory of which they hold a copy. Maintaining that consistency, known as cache coherency, is important for the parallel and multiprocessor applications at which the 32532 is aimed.

The 32532's instruction cache contains 512 bytes of direct-mapped storage. It also includes a 16-byte buffer that can transfer an instruction to the pipeline's loader on each cycle.

Storing 1,024 bytes of data in a two-way set-associative organization, the data cache uses a write-through strategy to maintain internal cache coherency (see fig. 2). "When something gets written in memory and it is an item that has been copied earlier into the local memory, which is the cache, you want that memory write to be reflected in the cache as an invalidation of the old value," explains Baron. So whenever the central processing unit writes into memory, if that memory location was loaded in the data cache, the cache is also updated. Implementing coherency in hardware yields faster execution, since updating the cache would otherwise have to be handled in software, which would steal processor time from the applications program being executed by the chip.

Also included with the cache is a patent-pending feature intended to help engineers debug 32532 system designs. The chip provides outputs to allow the operation of the data cache to be monitored externally, in real time. According to National, this feature is not available on any other microprocessor.

Communications among the pipeline, caches, and MMU go through nine buses operating in parallel to provide a memory bandwidth of 240 Mb/s. The bus interface controls the bus cycles used when memory is referenced. It contains a three-entry buffer for these references, so it can simultaneously perform a bus cycle for an instruction fetch, hold that information for another bus cycle to write to memory, and accept the next data-read request.

To get the most out of applications programs running on the 32532, a set of optimizing compilers is available. For high-level-language programs written in C, Fortran, Pascal, and Modula-2, these compilers generate efficient machine code that optimizes the use of the chip's pipeline structure, branch-prediction logic, and caches. □

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REACH OUT, TOUCH SOMEONE, AND BUILD A CHIP

In the mid-1980s, developing a new microprocessor can require the efforts of scores of people. In the case of the 32532, it also spanned oceans and continents, and it turned out that splitting the design team into two camps halfway around the world from each other had some unexpected advantages.

The sheer scale of the 32532 project dwarfed the kind of project common in the semiconductor industry's infancy, barely 10 years ago, says Richard Sanquini, division vice president for microprocessors at National Semiconductor Corp., Santa Clara, Calif. "A major project then involved several tens of man-years of effort by a team of 20 to 30 people," he says. "By comparison, the development of the 32532 took some 200 man-years of effort on the part of almost 150 people. Most such efforts were centered in or around Silicon Valley, often in a few buildings no more than a few blocks from one another." By contrast, one quarter of the 32532 team worked at National's headquarters and the rest at its technical design center in Israel.

Sanquini found the arrangement to his liking. "The difference in time zones actually works in favor of keeping a project moving smoothly from day to day, since the beginning of our day in California is the end of the day in Israel," he says.

RICHARD SANQUINI

Sanquini's day typically began with a review of project reports from Israel and Santa Clara. Next came telephone conferences with key people in Israel, including Yaron Giora, managing director for National Semiconductor, Israel; and Don Alpert, chief architect in Israel for the 32532.

Finally, he would meet in Santa Clara with David Schanin, chief scientist and technical director on the Series 32000, and Max Baron, chief 32532 architect in Santa Clara. "Problems that arise in Israel during the day there can be passed on to us in California for resolution by the time they return for their next work day," he says. "Similarly, problems that we run into do not have to be postponed until our next work day, but can be handed off to Israel, with the confidence that someone is working on them with a fresh mind."

Sanquini, 51, joined RCA Corp. in 1959, eventually rising to the position of director of LSI logic operations. In 1979, Sanquini came to National as director of microprocessor operations, which included all 8-, 16-, and 32-bit designs. In 1982, the 4-, 8-, and 16-bit microcontrollers became part of his responsibility as division vice president for microprocessors.

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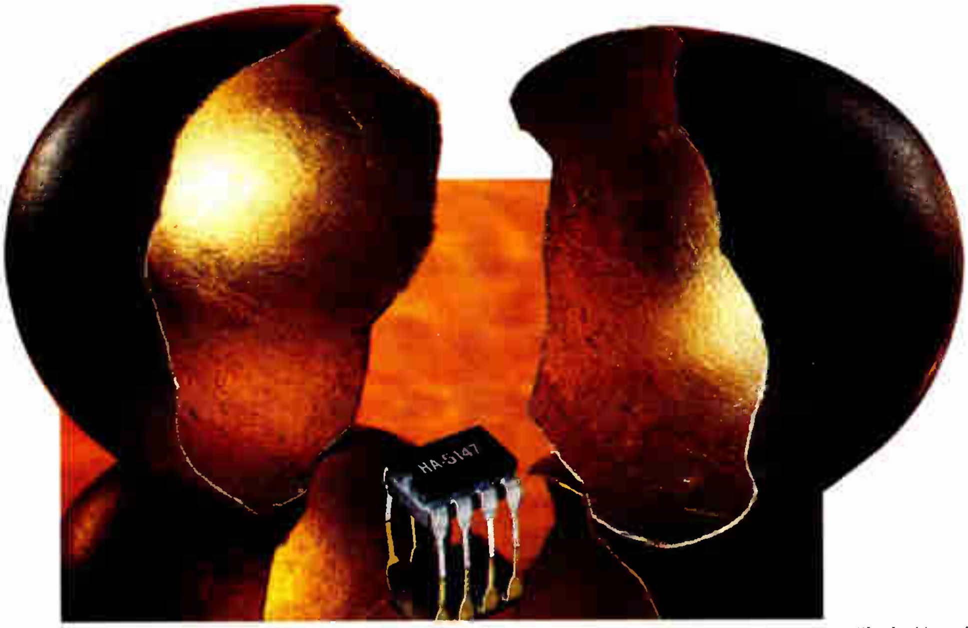

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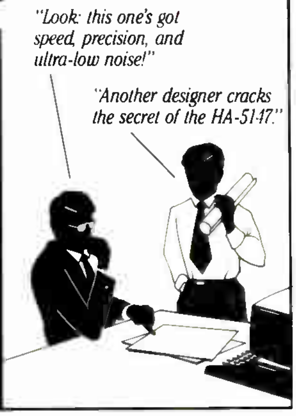


MILITARY/AEROSPACE NEWSLETTER

IBM INVESTS HEAVILY IN NAVY'S AUTOMATED PC-BOARD PRODUCTION EFFORT

As prime contractor, IBM Corp. plans to spend at least $25 million of its own money over the next four years on the Navy Manufacturing Technology Program's Circuit Card Assembly and Processing System—more than half the $40 million the Navy is set to spend over the same period of time. Key subcontractors for the program, including Unisys Corp., Westinghouse Electric Corp., and Robotic Vision Systems Inc., also are investing heavily in the program. CCAPS is aimed at developing an automated circuit-card-manufacturing capability for all the military services and contractors. So far, IBM has identified 42 subsystems it believes will be required to meet CCAPS requirements. Several of these, including solder joint, visual, and X-ray inspection systems, are under development by subcontractors. Westinghouse recently won two CCAPS subcontracts, one to develop and install Ada software and another to analyze the affordability of automatic component kitting. IBM is scheduled to demonstrate the CCAPS facility in Owego, N. Y. by early 1989. □

VARO TO MAKE NEW THRUST INTO MILITARY GaAs MARKETS

Texas-based Varo Inc. plans to invest more than $3.5 million as part of a new thrust into military markets for gallium arsenide materials and components. At the same time, the Dallas-area company aims to expand marketing activities for its photoluminescence system for nondestructive testing of GaAs materials. The military GaAs program is a spinoff of Varo's component production for image-intensification tubes that are used in its night-vision systems. Varo has processed approximately 20,000 square inches of GaAs wafer material for its third-generation portion of a $605 million contract with the U. S. Army for night-vision equipment, a contract received through a joint venture with ITT Corp. Varo intends to concentrate initially on making products by depositing epitaxial layers on GaAs substrates purchased from other manufacturers. □

WILL NAVY ADAPT NEW AIR FORCE FIGHTER?

Avionics vendors vying for Air Force Advanced Tactical Fighter program business may get an unexpected windfall from the Navy. Under budget pressures from the Pentagon, the Navy is considering modifying the Air Force's Advanced Tactical Fighter to fit its specifications, mainly for aircraft-carrier operations. Although the ATF program already calls for a joint Air Force/Navy advanced engine design, the Navy has asked competing teams led by Northrop Corp. and Lockheed Corp. to develop new proposals to build 522 modified versions of the aircraft. The Air Force is scheduled to choose between Northrop and Lockheed, which already are vying as prime contractors to build 703 of the Air Force ATFs for an estimated $45 billion. A "fly-off" of ATF prototypes is scheduled for 1990. Lockheed's partners are Boeing Co. and General Dynamics Corp. Northrop has teamed with McDonnell Douglas Corp. □

SENATE'S SEMATECH HEARINGS ARE ON SCHEDULE

Congressional action is on schedule for Sematech, the proposed semiconductor industry cooperative that would, with heavy Pentagon funding, attempt to meet Japanese competition by developing advanced manufacturing techniques [*Electronics*, March 19, 1987, p. 31]. Action would have to be completed by July 4 for the consortium to get started this year. A Senate subcommittee held two hearings on Sematech in March and has scheduled another for April 1. □

MILITARY/AEROSPACE NEWSLETTER

LOCKHEED MAY BE FIRST MILITARY CONTRACTOR TO USE 'ATE ON A CHIP'

Lockheed Corp., Calabasas, Calif., will likely become the first military contractor to use Giordano Associates Inc.'s Universal Pin Electronics "automatic test equipment on a chip" technology. Lockheed has signed a nonexclusive agreement with Giordano Associates for the UPE system, in which high-speed digital data is compressed off-line, then expanded and executed in real time. Integrating analog and digital stimulus/measurement capability by using VLSI chips and extending that capability to every ATE pin eliminates the need for ATE switching, according to Giordano Associates. Although its early UPE work was done under contract from the Army Electronics Command, Ft. Monmouth, N. J., the Sparta, N. J., company says its arrangement with the Army has allowed it to continue development activities in-house with joint-venture funding from Technology Funding Inc., a San Mateo, Calif., investment company. Patents were granted to Giordano Associates in May 1986 for the UPE design. Lockheed plans to include UPE technology in several upcoming military proposals. □

PENTAGON LOSES GROUND IN FIGHT FOR SECURITY CONTROLS . . .

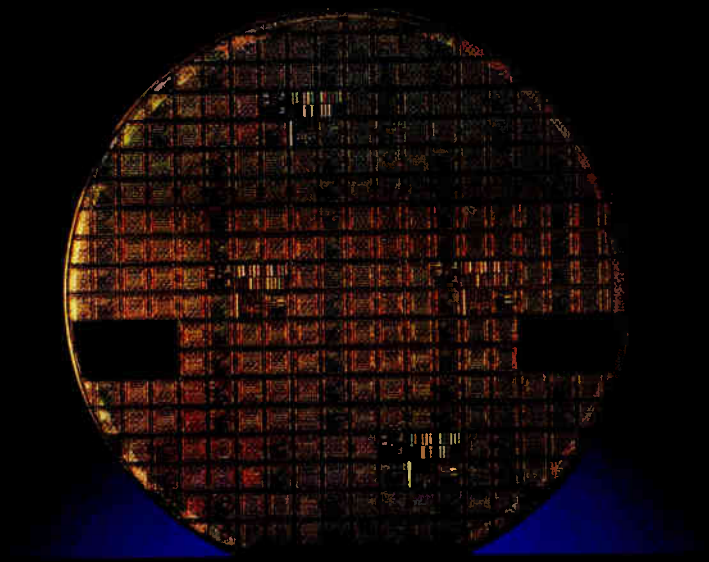
Defense Department control over federal computer and communications security is loosening. Under Congressional pressure, the Reagan administration last month rescinded National Security Decision Directive 145, its Defense Department-directed program to tighten controls over potentially sensitive unclassified government or government-derived information. Congress is now considering taking control of everything except defense-oriented computer-based security activities away from the Pentagon. A final hearing has been scheduled for mid-April on H.R. 145, called the Computer Security Act, which would put control of civilian federal-agency computer security programs in the hands of the National Bureau of Standards, instead of the Defense Department. DOD opposes the proposed bill. □

. . . WHILE NEW DATA BASE MAKES IT TOUGHER TO KEEP A SECRET

Despite years of complaints by the Pentagon and the Central Intelligence Agency, another arm of government—the Commerce Department's National Technical Information Service—is making it even easier to get access to technical weapons data. The agency has long been criticized for freely selling access to documents dealing with the design, evaluation, and testing of U. S. weapons systems as part of its effort to open up business opportunities. Now the NTIS has come up with a new twist: an on-line service called the Federal Applied Technology Database, complete with contact names, telephone numbers, sources of backup information, and new product listings. A free brochure describing the data base highlights U. S. government-owned semiconductor and laser patents as examples of business opportunities. □

SOFTWARE CONSORTIUM TRIES TO SPEED UP TECHNOLOGY TRANSFER

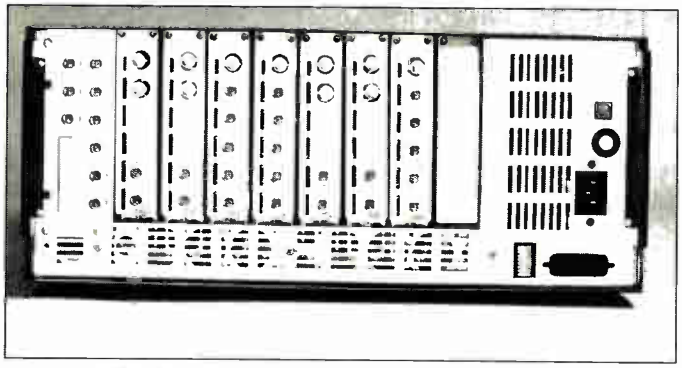
The Software Productivity Consortium of Reston, Va., is negotiating a contract with George Mason University's Center for the Productive Use of Technology for a study of ways the consortium can more efficiently and equitably transfer technology findings to its members. Set up to help close the gap between the availability of defense-system hardware and mission-critical software, the consortium's 14 aerospace company members each pay $1 million a year to support it. The Fairfax, Va., university organization, previously called the Technology Transfer Study Center, conducted the widely quoted technology transfer study that the Defense Advanced Research Projects Agency published in December 1985. □



NEW PRODUCTS

NEW TESTER GENERATION IS BASED ON INSTRUMENT-ON-A-CARD WORK

WAVETEK'S 680 MAINFRAME REPLACES A RACK OF 8 INSTRUMENTS



MINIATURIZED EQUIPMENT. Eight slots in the mainframe accommodate instruments-on-a-card to build the tiny equivalent of a rack system.

Wavetek Corp.'s 680 system marks the beginning of a new generation of miniaturized test systems based on advanced instrument-on-a-card technology. With it, a single 7-in.-high mainframe unit the size of a conventional rack-mount instrument can replace a rack of eight high-performance instruments. The 680 system also offers overall higher performance, because with eight cards operating interactively in the same mainframe, performance losses from rack-length cabling are eliminated.

The first version of the 680 system is a multisource signal generator for applications such as testing radar receivers at intermediate frequencies. It contains up to four 20-MHz arbitrary waveform generators and four 100-MHz pulse/timing generators with ±1 part-per-million accuracy, 100-ps resolution, and output voltage of 32 V peak-to-peak.

Other instrument cards to be announced soon will enable users to create 680 systems with both stimulus-generating and response-measuring functions, Wavetek says. Future cards will handle data acquisition and conversion, and avionics control and test.

VMEBUS LINK. The initial multisource version synthesizes signals by having the cards interactively feed outputs onto an analog summing bus built with impedance-matched stripline. The mainframe provides a control subsystem based on a Motorola Inc. 68000 microprocessor with a high-speed, 32-bit instrumentation bus based on the standard VMEbus, a clock with 1-ppm precision, a trigger generator, a high-speed triggering and synchronization bus, auto-calibration, an IEEE-488 interface, a front panel, and other system resources.

Radar-test signal bursts, for example, can be synthesized, Doppler-shifted, and timed with 100-ps accuracy. If the waveforms and delay times represent radar signals returning from a target, physical details of a distant target can be simulated with a resolution of a few inches.

While conventional signal-generation systems can simulate close-in targets as accurately, they have only nanosecond accuracy at the long delay times needed to simulate distant targets, Wavetek says. Also, a fully loaded 680 system with four of each type of generator costs $31,500, compared with $50,000 or more for conventional instruments and systems capable of generating such signals, says the San Diego company.

The 680 system is a general-purpose version of an eight-card, rack-mount module that Wavetek produces for a military avionics test system being developed by Honeywell Inc. The system complies with Air Force Modular Automatic Test Equipment requirements. The MATE-compliant version includes a test module adapter for system programming using the military standard Atlas language and Control Intermediate Interface Language. The adapter is a 680 system option. Military systems usually call for fully automatic operation and blank front panels. For commercial applications, Wavetek added a universal control panel and display.

Mathieu van den Bergh, Wavetek's system products manager, says the mainframe is also compatible with an instrument-on-a-card standard proposed by the MATE Users Group, but not yet adopted by the Air Force. A high-speed analog bus and other compatible functions were added to make the system suitable for high-performance test applications in MATE, Atlas, and other military ATE systems.

BECOMING STANDARDS. The mainframe is already becoming a de facto standard for instrument-on-a-card systems. Racal-Dana Instruments Inc. will soon be adding a compatible microwave-frequency counter/timer card equivalent to its model 1994 instrument. It has a frequency range of 150 MHz to 1.3 GHz and 1-ns time-interval capability. Datron Instruments Inc. will provide a 6½-digit digital multimeter on a card equivalent to its model 1602 DMM. These can be used with Wavetek's cards in stimulus-response systems for testing communications, radar, avionics, and other systems.

The goal of Wavetek, Datron, and Racal-Dana is to establish the 680 system as an IAC standard, according to van den Bergh. The 680 System is being introduced at the Electro show, with delivery set for within 12 weeks. The mainframe costs $6,700; the 20-MHz arbitrary waveform generator, $3,000; and the 100-MHz pulse/timing generator is $3,200. The Datron digital multimeter will cost $2,950, and the Racal-Dana counter will cost $2,800; both will be available this summer.

–George Sideris

Wavetek Corp., 9045 Balboa Ave., San Diego, Calif. 92123.
Phone (619) 279-2200 [Circle 380]

Electro/87

The 50,000 visitors and 700 exhibitors expected at the Electro/87 show in New York's Jacob Javits Convention Center on April 7-9 confirm its reputation as the largest electronics show on the East Coast. This section provides a sampling of the variety of products to be exhibited: everything from instrumentation to control systems, power sources, and production equipment.

SCOPE OFFERS 10-BIT PRECISION OVER 200 MHz

A digital storage oscilloscope from Philips Test & Measuring Instruments Inc. offers a 200-MHz analog bandwidth, 10-bit vertical resolution, and a 250-million-sample/s sampling rate—a combination of features that sets it apart from competitive instruments.

The PM3320 is able to capture glitches as small as 3 nanoseconds. It owes its performance to a technology Philips developed during the late 1970s and has used in other products, in which charges move in peristaltic patterns—a series of contractions. The profiled peristaltic charge-coupled device—called P^2CCD for short—down-converts an incoming signal's frequency so it can be digitized by a more accurate, low-frequency analog-to-signal converter.

The 3320 has two P^2CCDs, one for each channel. These devices, each consisting of 512 cells, are used at all frequencies that require equivalent time sampling. This eliminates the need for a separate sampling gate, thus improving reliability.

The instrument also offers a deep memory: 4,096 by 10 bits for single-channel operation; 2,048 by 10 bits for dual-channel; and a minimum of 512 by 10 bits for single-shot-mode operation. As many as four single- or dual-channel signals can be stored.

The PM3320's speed and accuracy target laboratory and quality-control applications, such as the analysis of electrostatic discharge from circuit components, pulses produced in laser-based communications equipment, and signals generated in ballistics testing, says Rob van der Werf, product manager for oscilloscopes at the Dutch company's test and measuring department.

Trigger facilities include dual-slope, positive and negative delay, and event and multiple-shot modes. Markers and cursors on the screen are used to simplify signal analysis by locating signal details for mathematical manipulation and expansion. Up to six horizontal and three vertical expansion modes are provided, according to van der Werf.

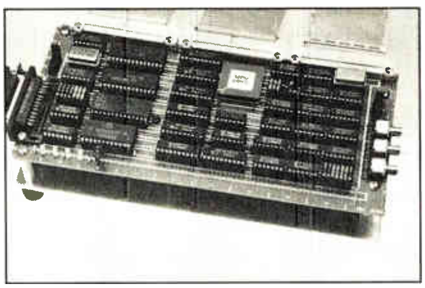
Designers paid particular attention to ease of operation. Some 150 functions and settings can be accessed by using the control hierarchy with the softkey choice displayed on the edge of the screen.

The instrument's screen measures 10 by 12 cm, instead of the conventional 8 by 10 cm—large enough to accommodate status data on actual and stored signals and soft-key labeling information, in addition to the normal oscilloscope traces. Available this month, the PM3320 costs $9,000 in the U. S. *–John Gosch*

Philips Test & Measuring Instruments Inc., 85 McKee Dr., Mahwah, N. J. 07430. Phone (201) 529-3800 [Circle 381]

EMULATOR SPEEDS ASIC DEVELOPMENT

Motorola Inc.'s MPU6805EVB Evaluation Board system speeds development and debugging of application-specific integrated circuits that incorporate a popular microprocessor-core standard cell from the company's 2-μm ASIC library. The board emulates a circuit's real-time performance in its target application.



Built around the company's 8-bit MPU6805 microprocessor core, the system lets designers model an ASIC's interaction with mechanism displays, sensors, or actuator displays in real time. None of these peripheral functions can be simulated with computer-aided-design software on a work station, says John Carey, merchandising manager for Motorola Semiconductor's ASIC Division.

The system saves time and money for designers, because it can test both hardware and software before the ASIC design is released for fabrication. Design costs for dense chips designed with the company's 2-μm CMOS library vary from $30,000 to $100,000 and generally require a design-cycle time of 10 to 15 weeks, says Carey.

The system includes three circuit-board modules connected by ribbon cable. The first is the MPU6805 microprocessor module, along with two interface chips and user-configurable random-access memory. The second is a user-module board that holds ICs corresponding to other standard cells in the ASIC design. Together, these two boards prototype the ASIC. The third module is a monitor/debug board for testing the system.

After prototyping the design on the boards, system developers can simulate software breakpoints, perform single-step tracing, and debug hardware. Programs that will ultimately be implemented in electrically programmable read-only memory can be debugged using RAM on the board, to avoid wasting EPROMs, says Carey.

Ultimately, the monitor/debug module is detached, and the board-level implementation of the ASIC is then tested in the target system.

Chips based on the MPU6805 are widely used in automotive and industrial-con-trol applications. Motorola offers the MPU6805 core as a special function within their 2-μm double-layer-metal standard library. It is adapted from the popular MC68HC05 high-performance CMOS microcomputer and executes an identical instruction set.

The MPU6805EVB requires a dc power supply of +5, +12, and -12-V and an RS-232-C-compatible terminal. Now available, the board costs $500. *–Ellie Aguilar*

Motorola Inc., Semiconductor Products Sector, ASIC Division, 1300 N. Alma School Rd., Chandler, Ariz. 85224. Phone (602) 821-4000 [Circle 382]

CONVERTER CUTS DC POWER NEEDS

By sidestepping the external dc power supply typically used to power digital-to-synchro converters, Natel Engineering Inc. designers have saved systems integrators the cost of incorporating the dc supply, have alleviated ground-loop problems, and have cut internal power consumption in half.

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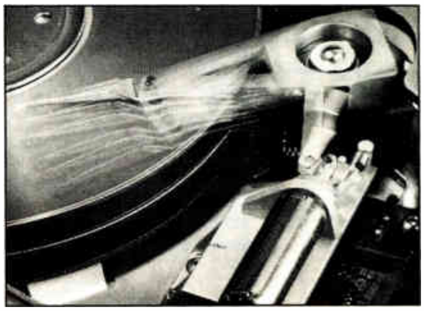
25-ms ACCESS IN A HALF-HEIGHT DRIVE

MiniScribe Corp.'s half-height, 5¼-in. Winchester disk drive uses an innovative read/write head design to obtain an average access speed of 25 ms—much faster than the typical 65 ms for drives now in use and comparable to high-end drives. The model 3053's 25-ms average access time includes settling time, the company says.

Robert Paul, marketing manager for the product, says this is the fastest access time for half-height Winchesters of similar capacity. Maximum access time for the 3053 is 62 ms, and the drive's data-transfer rate is 625 Kbytes/s. The disk's unformatted capacity of 53.3 Mbytes (44.6 Mbytes formatted) targets memory-hungry 32-bit personal computers.

To boost access speed, the MiniScribe's designers abandoned stepper-motor technology and used a rotary-voice-coil closed-loop servo system to position the arm over the disk. Unlike drives that position the magnetic read/write heads by moving them back and forth on a stationary arm with a linear stepper motor, the model 3053 uses a rotating arm that sweeps the head in an arc over the disk. Access time is improved by allowing the arm to actively seek data.



The rotary operation also increases immunity to shock and vibrations, says Paul, adding that the casing has integral shock mounts. The unit uses high-coercivity-oxide media, and data is recorded using the modified-frequency-modulation technique.

HALF MAKES A WHOLE. Since the device has the same three-disk, five-read/write-head construction used in many full-height 5¼-in. Winchesters, it can easily replace larger units. It also offers a standard ST-412/506 interface. Future members of the half-height product family are planned with other standard interfaces, Paul indicates.

"This drive is plug-compatible with many of the standard full-height drives, including our own 6053," says Paul. "That will make it easy for system integrators to save space for additional storage devices in the same PC slot." The unit is 1.6 in. high and weighs 2.5 lbs, compared with up to 4 lbs for similar drives. The drive is rated at 30,000 hours mean time between failures.

The 3053 dissipates 12 W during the seeking mode and has a startup current of less than 2.5 A. In small production quantities it sells for $650, and evaluation units are now available.

–J. Robert Lineback

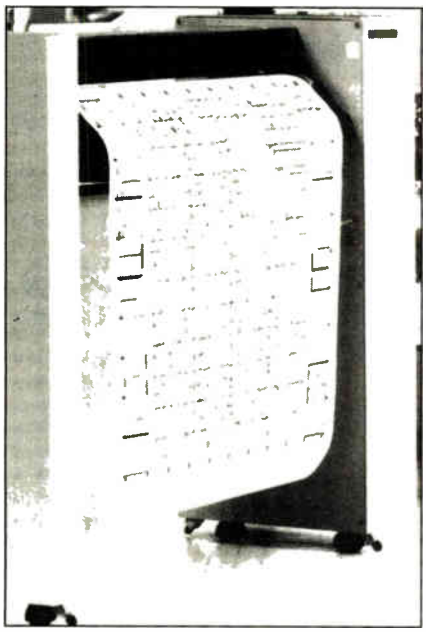
MiniScribe Corp., 1861 Lefthand Cir., Longmont, Colo. 80501.
Phone (303) 678-2012 [Circle 343]

EIGHT-PEN PLOTTER IS 50% FASTER

Hewlett-Packard Co. is replacing its eight-pen 758X drafting plotters with a new eight-pen line that increases throughput by 50% but costs 30% less. The new additions include the HP DraftMaster I, a single-sheet-fed machine, and the HP DraftMaster II, which is a top-of-the-line roll-feed model.

Both plotters achieve their speed from a 10-MHz MC68000 microprocessor, which processes vectors twice as fast as the microprocessors in previous plotters. The minimum data-transmission rate is 19,200 bits/s.

Other features include continuous pen motion, thanks to a smooth-curve generator; bidirectional plotting; a pen-sorting algorithm that keeps the plotter drawing with the same pen until the buffer is empty; and the ability to ignore unnec-



essary pen-up moves in graphics software. The DraftMasters come with RS-232-C and RS-422-A interfaces.

The DraftMaster I costs $9,900; the DraftMaster II is $11,900. Delivery takes four to six weeks.

Hewlett-Packard Co., 1820 Embarcadero Rd., Palo Alto, Calif. 94303. [Circle 345]

$745 I/O UNIT FOR PC DOES ANALOG, DIGITAL

Data Translation Inc.'s DT-2811 interface for the IBM Corp. Personal Computer XT and AT offers multifunction analog input, analog output, and digital I/O for as little as $745. It provides 12-bit analog input with 16 single-ended or 8 differential channels at 20 KHz. Two 12-bit analog output channels operate at 50 KHz each.

Also included is an application program for data acquisition, logging, and display. Two versions are available. The DT-2811-PGH provides software-programmable gains of one, two, four, and eight dB. The DT-2811-PGI, which sells for $845, provides gains of up to 500 dB. Both products are available now.

Data Translation Inc., 100 Locke Dr., Marlboro, Mass. 01752
Phone (617) 481-3700 [Circle 346]

MEMORY FOR HP 9000s BOOSTED BY 8 MBYTEs

The AM380 memory board from Infotek Systems boosts the Hewlett-Packard 9000 series 200/300 technical work station's memory by 8 Mbytes, with the use of zig-zag in-line packaging to mount its 1-Mbyte DRAMs, which have 200-ns access times.

Infotek software allows users to access the AM380's full 8-Mbyte storage capacity, and the single-card configuration optimizes the performance of the resident 7.5-Mbyte storage capacity of HP technical work stations by freeing computer backplane space.

The AM380 costs $5,600. Quantity and OEM discounts are available. Delivery takes 45 days.

Infotek Systems, 1400 N. Baxter St., Anaheim, Calif. 92806.
Phone (714) 956-9300 [Circle 347]

INPUT SYSTEM ALLOWS MENU CUSTOMIZATION

The IS/ONE input system for personal computers and work stations lets users customize their own subroutine menus. With an applications controller package called IS/Template Builder, users put together templates and then create transparencies of menus. The menus are laid over the template, rather than appearing on a screen.

The system features a digitizer tablet, either a corded or a cordless 4-button cursor control, and a software driver for MicroSoft Corp.'s Windows. Digitizer tablets are available in three sizes: 5.5 by 11 in.; 12 by 12 in.; and 12 by 17 in. Available now, a typical IS/ONE system costs $595.

Kurta Corp., P.O. Box 60250, Phoenix, Ariz. 85082. Phone (602) 276-5533 [Circle 348]

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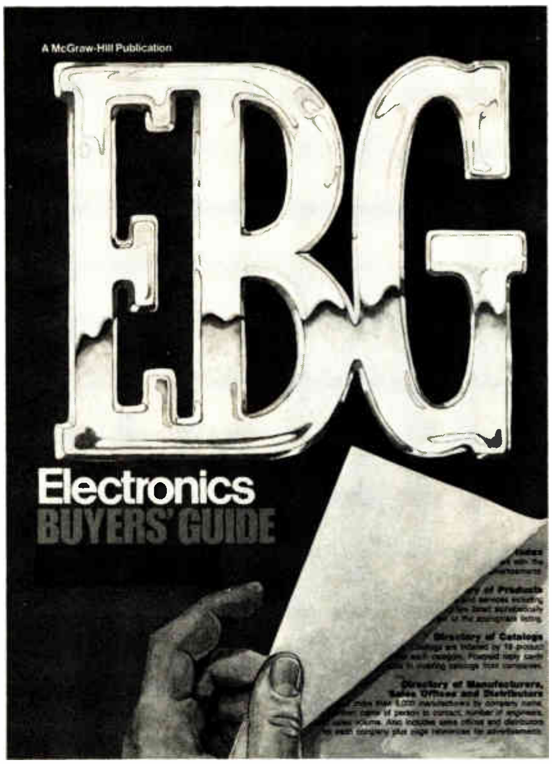

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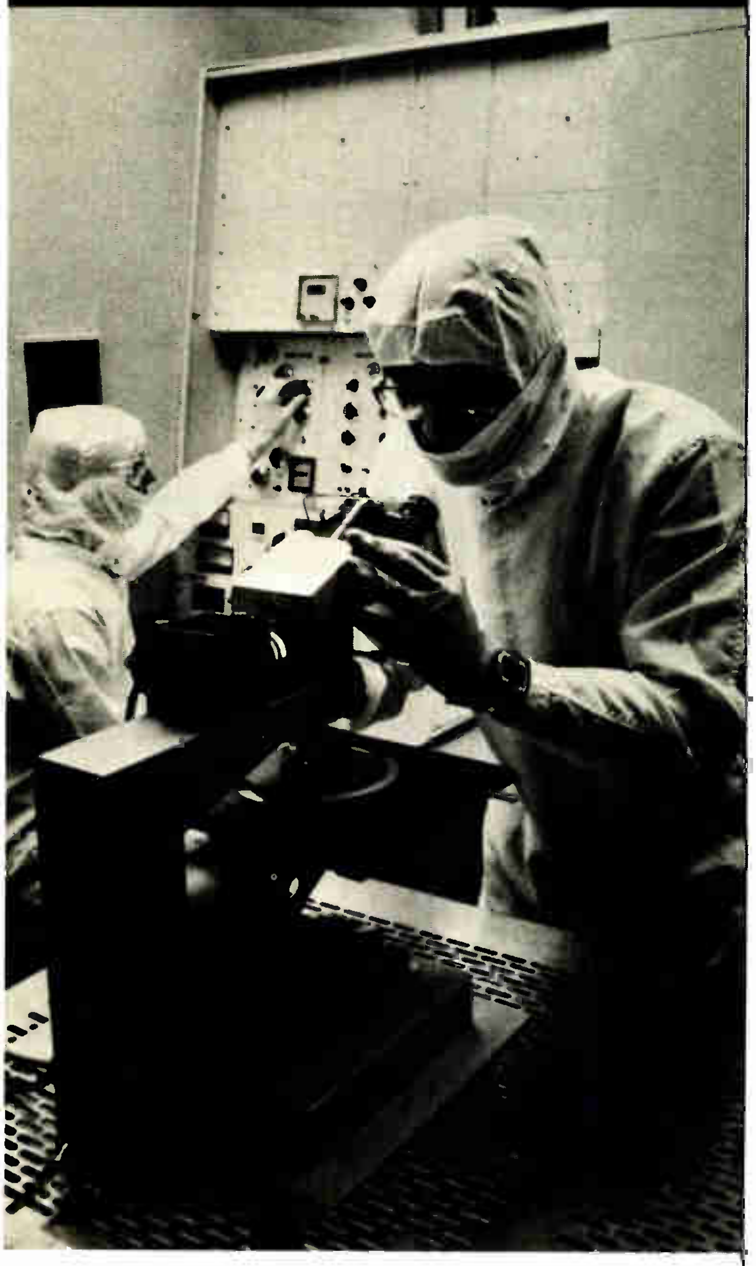
Production Design Environment

Product development in a production environment is one of Micron's unique and valuable attributes. Our Research and Development Department employs circuit designers, layout engineers, product engineers and technicians who mutually participate in product development.

The work climate at Micron is characterized by hands-on participation at all levels of the organization. Micron's reputation for innovation in circuit design, quality manufacturing and product reliability is due to the contribution and ideas of our people. And we consider our people to be our most valuable asset.

A Diverse Future

Micron's strategy for the future is to diversify its product line and expand its customer base. Our first steps toward product diversification include 2- and 4-MB memory expansion cards for IBM-compatible PCs. Our next steps will further enhance Micron's reputation for product innovation.



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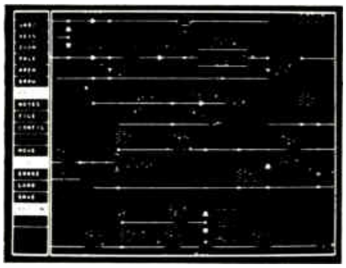

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Electronics

ELECTRONICS WEEK

SILICON COMPILER LEADERS MERGE

In a development that could strengthen the position of silicon compilation as a design methodology, the two leading design-automation companies have merged. Silicon Compilers Inc. of San Jose, Calif., and Silicon Design Labs of Liberty Corner, N.J., will become Silicon Compiler Systems Corp., with headquarters in California and a major engineering, design, and support center in New Jersey. Philip A. Kaufman, president of Silicon Compilers, will be chairman and chief executive officer of the new company. The two companies serve different segments of the IC design market; Kaufman says "the combined growth rate was 130% in 1986."

TANDON LANDS A $50 MILLION DEAL

Tandon Corp., says it will sell about $50 million in 3.5-in., 20-Mbyte Winchester disk drives during 1987 to Amstrad plc, the leading British personal-computer manufacturer. The largest single contract for Winchester drives ever signed by the company, this establishes Tandon as a major supplier for the 3.5-in. products, according to the Chatsworth, Calif., firm.

TI WINS BIG ON PATENT SUITS

Texas Instruments Inc. is a big winner in its series of patent suits, settlements, and licensing pacts with Far Eastern dynamic random-access memory makers. TI is getting about $134 million in fixed royalties from six Japanese companies settling with the Dallas company: Fujitsu, Matsushita, Mitsubishi, Oki, Sharp, and Toshiba. The fixed payments, covering 1987 to 1990, are being declared as a gain of $108 million in the first quarter, ended March 31. Meanwhile, TI is appealing a preliminary decision by a judge with the International Trade Commission who wants to terminate investigations against NEC Corp., one of three firms still being sued by TI. Litigation remains pending against Hitachi and Samsung.

TDK ATTRACTS U. S. MAGNETS PARTNER

TDK Corp., Tokyo, and Allen-Bradley Corp. of Milwaukee announced a joint venture, Allen-Bradley/TDK Magnetics, to produce ferrite magnets for the North American market at a plant in Shawnee, Okla., formerly operated by Allen-Bradley's Magnetic Division. Allen-Bradley wanted a partner to complement its technology and facilities for magnet production, while TDK sought to supplement its strength in materials development with such a production base in the U. S. The partners project first-year sales of $30 million to $40 million.

NASHUA BUYS INTO SPUTTERED DISKS

The Nashua Corp., a Nashua, N. H., computer systems firm that makes oxide-coated media for Winchester disks, is attempting to acquire sputtered-thin-film technology by buying Lin Data Corp., a Santa Clara, Calif., startup that claims about 30% of the thin-film-media market. The two firms have signed a letter of intent under which Nashua will pay $24 million for all classes of Lin stock. Sputtered thin-film technology is expected to overtake oxide media before the end of the decade.

GE, RACAL TIGHTEN EFT SECURITY

Under a cooperative marketing agreement, General Electric Information Services Co., of Rockville, Md., and Racal-Guardata Ltd. of Fleet, in the UK, will strengthen the security of electronic funds transfer systems for clients using GE's worldwide teleprocessing network. The GE/Racal solution is a two-tier cryptographic system linking message authentication with personal authentication. It will enable banks to generate secure payment instructions for automated delivery at any of their delivery points around the world.

HP SHIPS 930 TO BETA SITES . . .

Not until results are in from beta test sites will Hewlett-Packard Co. know whether it can meet specifications or revised shipment dates on its first Spectrum business computer, the HP 3000 Series 930. In announcing shipments to the first three of a dozen or so beta sites in late March, HP said that it is still fine-tuning the input/output problems that caused an initial delay in shipping the 32-bit reduced-instruction-set Series 930 last fall [*Electronics*, Oct. 16, 1986, p. 42]. HP is not backing off its performance goals of 4.5 million instructions/s, nor its plan to make the first commercial shipments by mid-1987, but it will guarantee neither at this time.

. . . AS IBM SHIPS 9370 EARLY

IBM Corp. will begin shipping its mid-range 9370 information systems two months earlier than its target date of September 1987. Selected 9370 model 20 and 60 processors will now be available in the U. S. and Canada starting in July. Shipments to customers in an early support program begin as early as April. IBM marketing representatives can configure the 9370 on-site in minutes using an on-line IBM artificial-intelligence-based configurator.

CHIP EXPORT RULES RELAXED

Now U. S. semiconductor makers should be able to sell products abroad more easily, as a result of new Commerce Department regulations relaxing rules on exports and re-exports. The new rules make possible foreign sales of U. S. components in 91 countries without explicit authorization, providing that the U. S. parts do not account for more than 25% of the product they go into. Further, the foreign manufacturer will be able to re-export the finished equipment to Eastern Bloc countries if the value of the U. S. components does not exceed 10%.

ZENITH MOVES TO KEEP U. S. JOBS . . .

Union workers at Zenith Electronics Corp.'s Springfield, Mo., color TV plant have agreed to an 8.1% pay cut in exchange for a promise by Zenith to maintain 600 jobs that would have been moved from there to Mexico. The five-year contract with the International Brotherhood of Electrical Workers local follows a similar Zenith move to add 600 new jobs at its Melrose Park, Ill., color-picture-tube plant, which was also made possible in part by IBEW concessions [*Electronics*, Feb. 5, 1987, p. 110]. Severe pricing pressure in TVs and other consumer electronics gear led to a $10 million loss for Zenith last year, despite record color-TV sales.

. . . AND CARRIES ON ANTIDUMPING FIGHT

Meanwhile, Zenith is petitioning the U. S. Supreme Court to review a lower court decision dismissing its 13-year-old antidumping case against Japanese TV makers. In 1986, the Supreme Court decided 5-4 to remand the antitrust portion of the case to the U. S. Court of Appeals, to evaluate the evidence of whether a conspiracy existed among the defendants, but did not rule on the antidumping issues. The Third U. S. Circuit Court of Appeals in Philadelphia subsequently found that its actions were so limited by the Supreme Court's mandate that it had to dismiss the entire case.

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2 17 32 47	62 77 92 107	122 137 152 167	182 197 212 227	242 257 272 349	364 379 394 409	424 439 454 469	484 499 704 719
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7 22 37 52	67 82 97 112	127 142 157 172	187 202 217 232	247 262 339 354	369 384 399 414	429 444 459 474	489 504 709 951
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13 28 43 58	73 88 103 118	133 148 163 178	193 208 223 238	253 268 345 360	375 390 405 420	435 450 465 480	495 510 715 958
14 29 44 59	74 89 104 119	134 149 164 179	194 209 224 239	254 269 346 361	376 391 406 421	436 451 466 481	496 701 716 959
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13 28 43 58	73 88 103 118	133 148 163 178	193 208 223 238	253 268 345 360	375 390 405 420	435 450 465 480	495 510 715 958
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		C2012		2.0	1.25	0.6	C: 0.5～1,800pF
						0.85	C: 470～100,000pF
						1.25	
		C3216		3.2	1.6	0.6	C: 0.5～270pF
						0.85	C: 470～220,000pF
						1.1	
		C3225		3.2	2.5	< 1.9	C: 750～8,200pF, 56,000～470,000pF
		C4532		4.5	3.2	< 1.9	C: 2,400～18,000pF, 180,000pF～1μF
		C5650		5.6	5.0	< 1.9	C: 5,100～33,000pF, 270,000pF～1.5μF
Multilayer Ceramic Chip Capacitor (High Frequency, Low Loss)		FC1414		1.4	1.4	1.6	C: 0.5～100pF, 150～3,300pF
		FC2828		2.8	2.8	2.8	C: 0.5～1,000pF, 470～22,000pF
		FR1414		1.4	1.4	1.6	C: 0.5～100pF, 150～3,300pF
		FR2828		2.8	2.8	2.8	C: 0.5～1,000pF, 470～22,000pF
Leadless Inductor (Wound Chip Inductor)		NL322522		3.2	2.5	2.2	L: 0.01～220μH
		NL453232		4.5	3.2	3.2	L: 1.0～1,000μH
		NL565050		5.6	5.0	5.0	L: 1,200～10,000μH
		NLF453232		4.5	3.2	3.2	L: 1.0～1,000μH (Shielded Inductor)
Multilayer Chip Inductor		MLF3216		3.2	1.6	0.6	L: 0.047～220μH
						1.1	
		MLF3225		3.2	2.5	1.1	
						1.8	
						2.5	
Multilayer Chip Transformer		MTT4532		4.5	3.2	2.8 max	L: 10～200μH
Multilayer Chip IFT		MIA4532		4.5	3.2	2.8	F: 455, 459, 464kHz
		MIF4532		4.5	3.2	2.2	F: 10.7MHz
Multilayer Chip LC Trap		MXT4532		4.5	3.2	2.8 max	F: fo ±2%
Multilayer Chip LC Filter	HPF (Tuner)	MXF4532H		4.5	3.2	2.8 max	Electrical characteristics are representative, please specify value when ordering.
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	BPF (VCR)	MXB5050B		5.0	5.0	2.8 max	
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	Equalizer (VCR)	MXB5050E		5.0	5.0	2.8 max	
	Delay Line (VCR)	MXB5050D		5.0	5.0	2.8 max	
Multilayer Chip Capacitor Network		MCN7575		7.5	7.5	0.9	C: 1～1,000pF (TC:CH) (10 capacitors)
							C: 10～1,000pF (TC:SL) (10 capacitors)
Ferrite Chip Beads		CB201209		2.0	1.25	0.9	Zo: 7, 10, 11Ω
		CB321611		3.2	1.6	1.1	Zo: 19, 26, 31Ω
		CB322513		3.2	2.5	1.3	Zo: 31, 52, 60Ω
		CB453215		4.5	3.2	1.5	Zo: 70, 120, 125Ω
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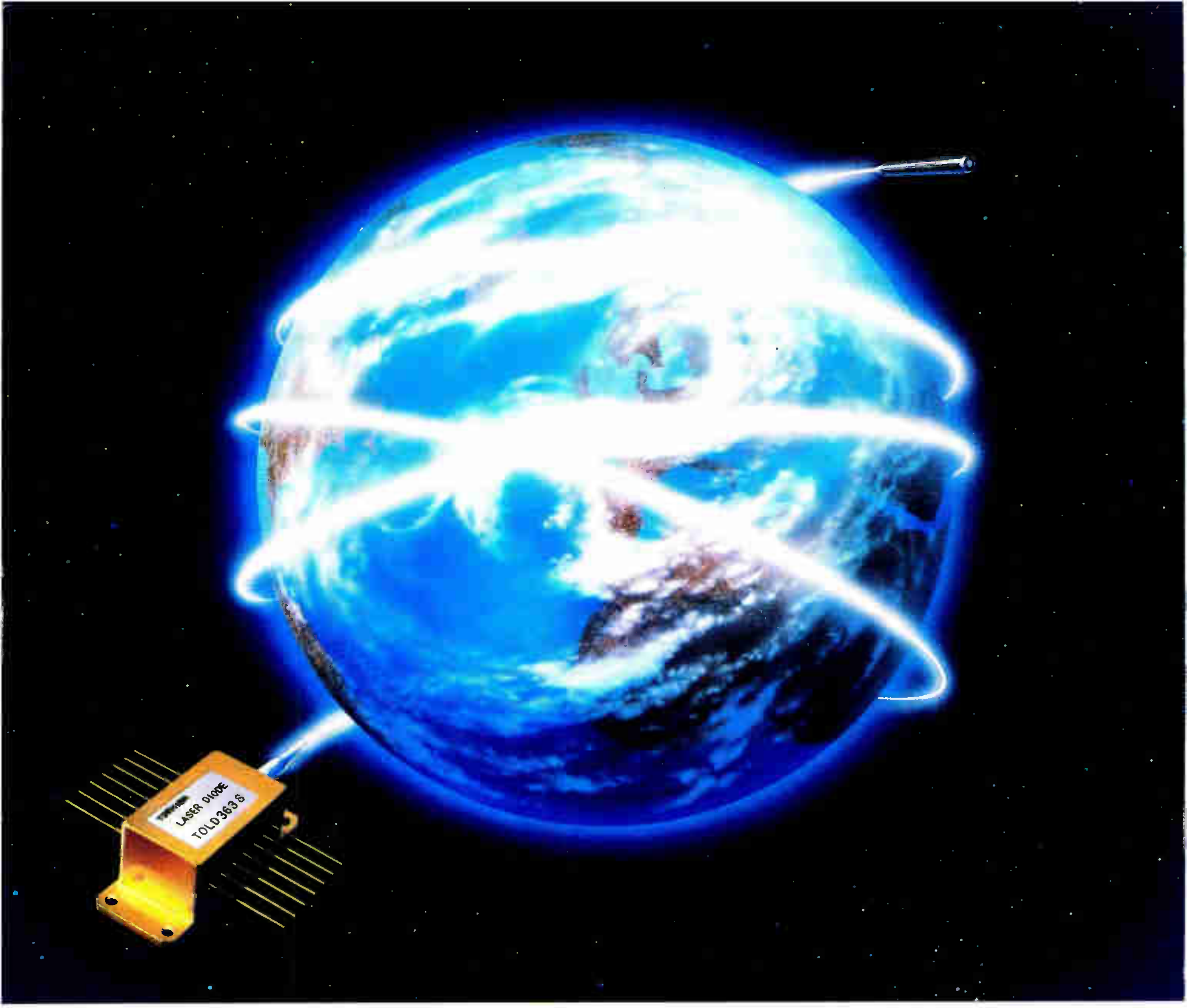

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