JULY 19, 1979

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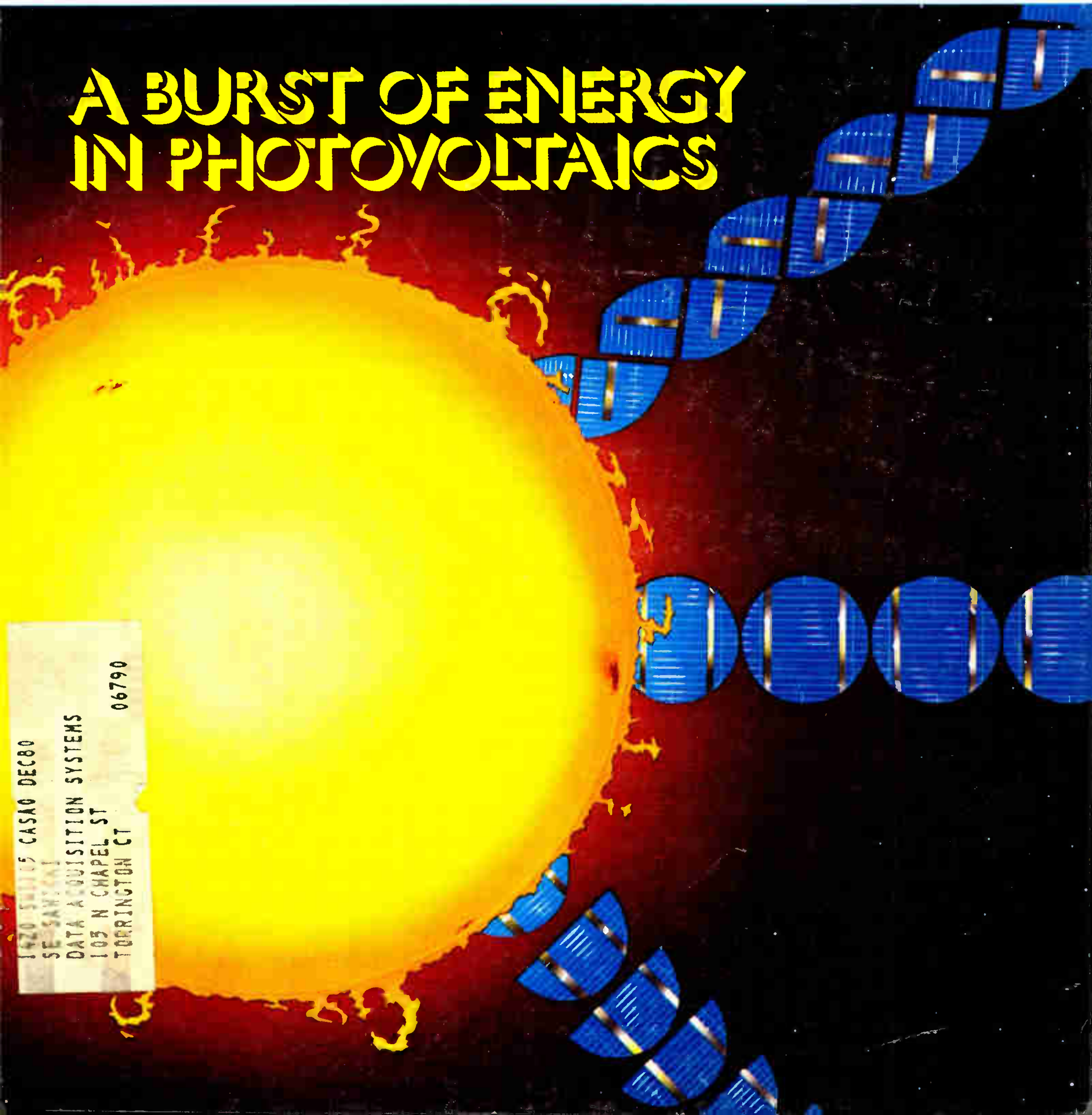

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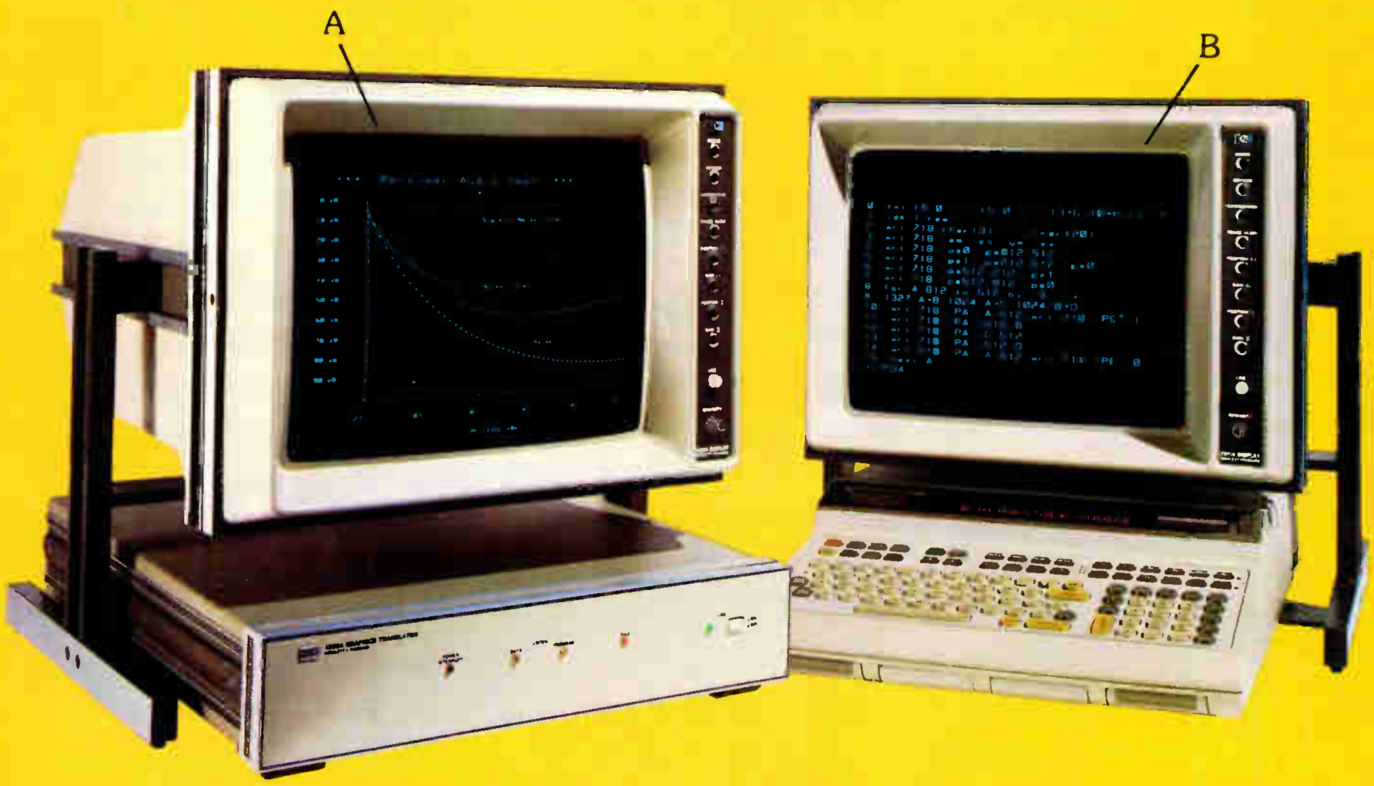

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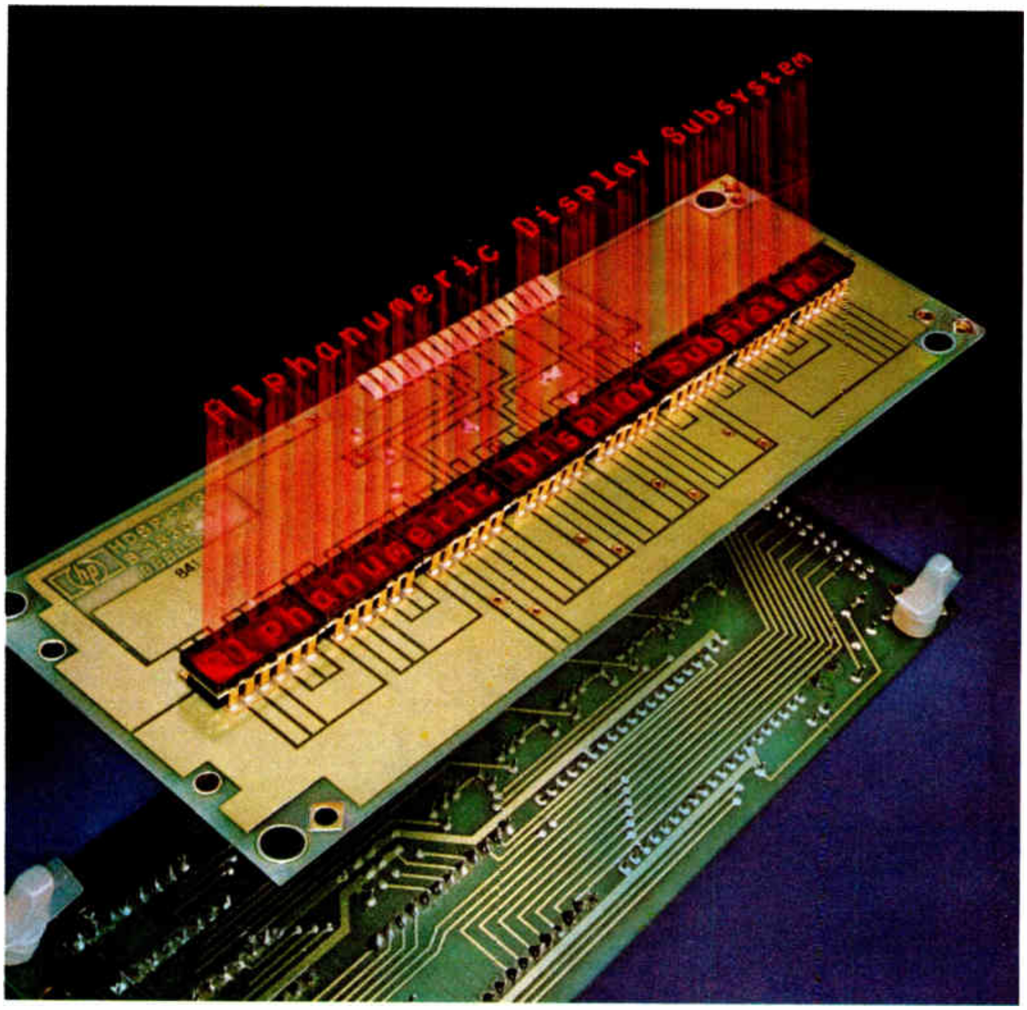

Alphanumeric Display Subsystem

Electronics
The International Magazine of Electronics Technology
Vol. 52, No. 15 • July 19, 1979

Highlights

Cover: Photovoltaic activity heats up, 105
Solar cell efficiencies are nearing their theoretical limits, array costs have halved over the past six years, and production techniques are improving. By 2000, annual installed capacity should reach at least 5,000 megawatts, says this special report on worldwide progress in turning sunlight into electricity.

Cover is by Sean Daly.

Automating the secretaries' bosses, 81
The latest word-processing equipment is being programmed for greater data-processing ability, to which executives will probably gain access by way of desktop terminals.

The Conservative approach to electronics, 88
In promoting free enterprise, Britain's new Conservative government could have second thoughts about the National Enterprise Board and such state-backed enterprises as semiconductor maker Inmos.

Microcomputer doubles as data encryptor, 140
A single-chip computer can be programmed with the algorithm for the Federal data encryption standard. It both encrypts and decrypts data at a rate of 4,800 bits per second.

. . . and in the next issue
How bubble memories are organized and why . . . packaging innovations in the IBM 4300 computer . . . presenting an 8-bit-slice family.

Publisher's letter

Anyone who has waited in a gas line or watched television in the last few months is now aware that the world is in an energy crisis. Perhaps "crisis" is not the correct word, however, for it implies that there are some miracle solutions at hand to put everything back in place.

Rather, the industrialized nations are coming to grips with an energy transformation, learning to live with high-priced petroleum while attempting to devise substitutes. And one of the important new energy sources in the coming years will certainly be photovoltaics. The special report on photovoltaics (p. 105) is particularly timely.

Indeed, as industrial editor John Javetski points out, the present crisis attitude should help focus more serious attention—and funding—on solar energy. "There is a better chance than ever that photovoltaics will be able to supply significant amounts of electrical energy, up to 10% of U. S. needs, by the end of the century," he concludes.

If Congress responds to the incentives provided recently by the pricing policies of the oil-producing nations, there could be commercially produced solar cells going into new homes, factories, and office buildings by 1986. The key is price per watt, which today is about $10, a high premium to pay. But by the second half of the 1980s, as the market enlarges, costs should be down to $1 a watt.

The growth in applications also means the appearance of a new industry made up of semiconductor companies, oil companies diversifying into solar energy, and new, specifically solar-energy companies. Oil companies are already snatching photovoltaic experts from the semiconductor firms, according to John.

Though the energy crunch has greatly upset the rest of the world, the developers of photovoltaics are far from suffering from the same sense of helplessness. Rather than feeling jittery or depressed, the people involved in solar energy exude enthusiasm about the future.

"One question everyone in the infant industry always asked was, 'Are you a believer in photovoltaics?'" John reports. His report should make everyone else a believer, too.

Speaking of energy, Los Angeles bureau manager Larry Waller recently reviewed plans for a home in Arizona in which microcomputers will play a vital part in energy control. His report on the Ahwatukee project near Phoenix (p. 92) points out that the future use of microcomputers in the home will depend a great deal on how well the designers succeed in fitting the technology to the application.

Making the processors "transparent" to the user is how the team from the Motorola Semiconductor Group described the design goal. But in action even on a mock up, the electronics is impressive—and certainly impressed Larry.

"When you experience what high technology can do in performing actual daily chores, you begin to appreciate what this industry is all about," he observes.

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Readers' comments

Reduce!

To the Editor: The small number of states and control variables in the illustrative example in John J. Petrale's article "PROM controller makes fast work of serial jobs" [April 12, p. 134] allows them to be fitted into a standard small programmable read-only memory (256 by 4 bits). That may be why he didn't exploit the redundancy of the problem to reduce the number of input bits. In larger problems this could supply a significant economy by providing an alternative technique to the state-dependent multiplexing suggested in Fig. 4.

For example, we can get rid of 1 bit by observing that the input C is only effective when $\bar{B}$. Therefore an input encoder that validates $\bar{B}$ only in the presence of C would enable us to eliminate the C column from the truth table 2, thereby halving the volume of the control PROM.

More generally, if in place of the multiplexer of Fig. 4 we used a ROM addressed by s + c bits, where s is the number of states and c the number of input bits, but having the number of output bits equal to the largest number of defined transitions from a state node, the control PROM could be reduced to 2^{s+c} addresses, thereby saving bits even when the inputs are not disjointed, as required in the article.

In the present example, for instance, the largest number of transitions defined in the state diagram is three (states S_1 and S_4, where the self-transition must of course be counted, in addition to the two arrows shown in the diagram for each of these two states). We can therefore recode the control variables into 2 bits, where, say, 00 is the self-transition, 01 is one transition to another state, and 02 is another. Then the control variables can be encoded in a 256-by-2-bit ROM, and the control ROM becomes 32 by 4 bits.

I can assure you that in pattern-recognition problems such economies can be very substantial. In a machine I am currently designing, without such input encoding I would require 2,048 by 12 bytes—a substantial number of chips. Using input encoding, I can reduce that to less than half.

Morton Nadler
La Celle Saint-Cloud, France

Multitalented driver

To the Editor: In the XR-2276 New Product story in your April 26 issue [p. 216], Alan B. Grebene of Exar Integrated Systems is quoted as saying that National Semiconductor's LM3914 dot- and bar-display driver drives light-emitting diodes only. However, the data sheet clearly states that the LM3914 drives vacuum-fluorescent and liquid-crystal displays, in addition to LEDs.

It may be more appropriate to compare the XR-2276 to the 3-dB/step LM3915 or the VU-meter-type LM3916, both of which are intended for audio applications, rather than to the linear LM3914. As Mr. Grebene claims, it is true that a 12-point display may be more attractive than a 10-point one to some people. In other uses, 20 or 30 points permit excellent resolution over a 40-, 60-, or even 90-dB range, taking advantage of the ease with which LM3915s and LM3916s can be cascaded.

Michael Maida
Semiconductor Division
National Semiconductor Corp.
Santa Clara, Calif.

Make it clear and correct

To the Editor: In the Engineer's Newsletter for June 7 ["How to cross the technical language barrier," p. 152], it was reported that "the need for translation of technical terms [is] a priority." Indeed, that is true.

However, a higher priority must be placed on lucid and grammatical presentations—in English—of manuals, texts, specifications, contracts, and other defining technical information. Otherwise, the primeval programming syndrome, GIGO (garbage in, garbage out), becomes operative. In that case, literalness of translation disrupts cross-cultural communication even further.

Jonathan R. Slater
New York, N. Y.

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Programming systems for tomorrow...today

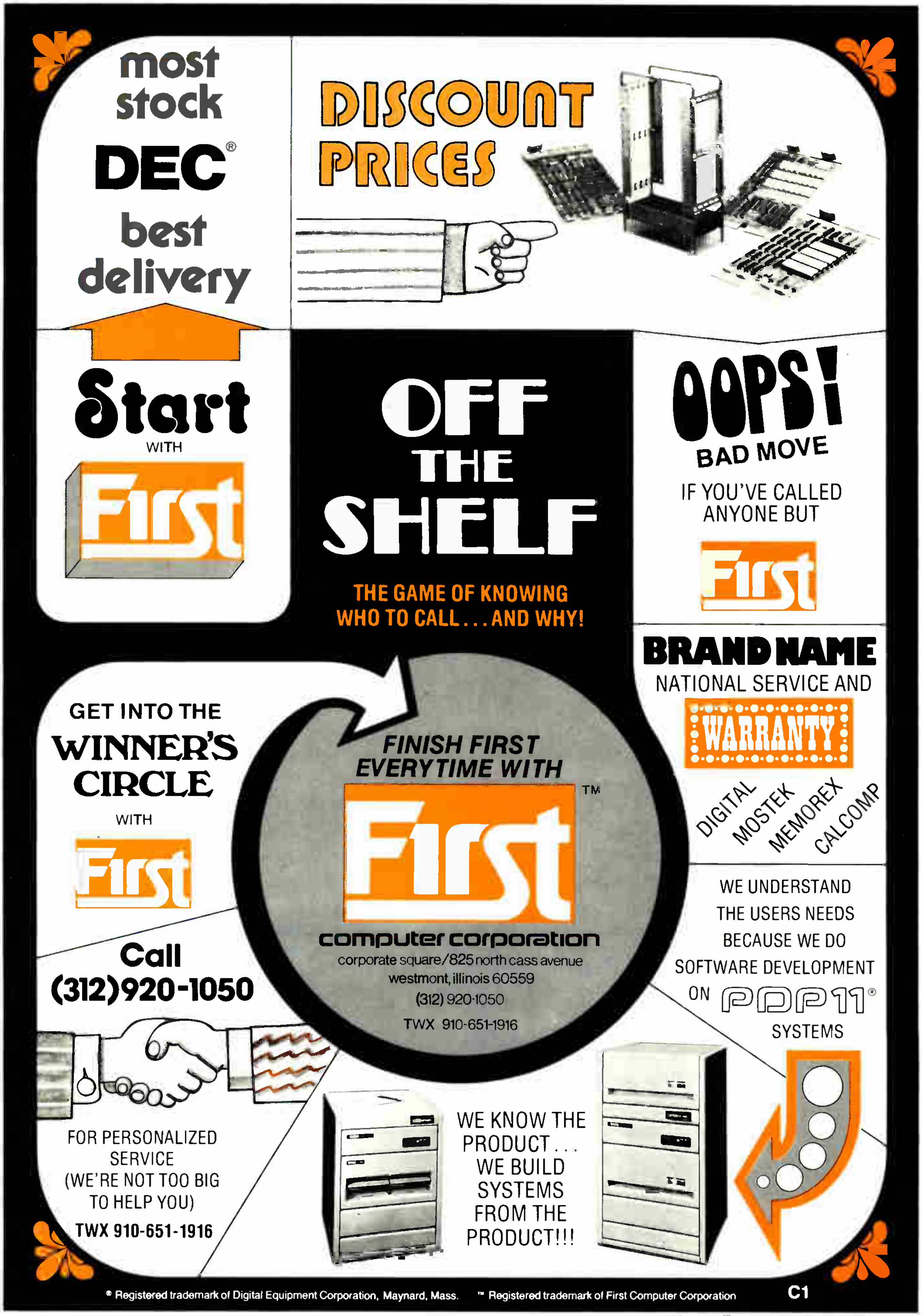
News update

■ Attempting to enhance the performance of production-level printed-circuit boards or repair design flaws in them can be a costly undertaking. Typically, it is done manually by large numbers of full-time production line workers employed solely to put down jumper wires implementing changes on the two-sided boards.

But now United Solder-Wrap Inc. of Dallas is taking aim at the problem with a modified version of its automated wiring and soldering machine introduced in 1976 [*Electronics*, April 14, 1977, p. 111, and May 25, 1978, p. 134].

Under computer control, the original Solder-Wrap systems are designed to string, strip, solder, and cut the wire needed for standard pc board connections automatically, producing boards with an extremely low profile and high integrated-circuit packaging density for prototyping and small production runs. The most important advantage it has over older techniques is that it tests its results at every step of the wiring routine; the others must wait until a board is completely wired before operation is checked. It is also faster, hence less expensive. Seven of the $70,000 systems have been sold to date, and United did $2 million in contracts for patented solder-wrap work last year as well.

Now comes the ECN100, a version of the original United M100 machine that uses minor hardware additions and modified software to automatically implement what is known in the trade as ECN (for engineering change notice). Thus it eliminates the need to measure, cut, strip, and apply jumper wires to production boards manually. With initial shipments of the new machines possible within the next 60 days, ECNs represent a new market for United. Armed with an influx of funding from the Scotland-based Prestwick Circuits Ltd., which bought controlling interest in the company last August, United is planning a marketing thrust soon to push the ECN machine in addition to promoting its other new and existing products. **-Wesley R. Iversen**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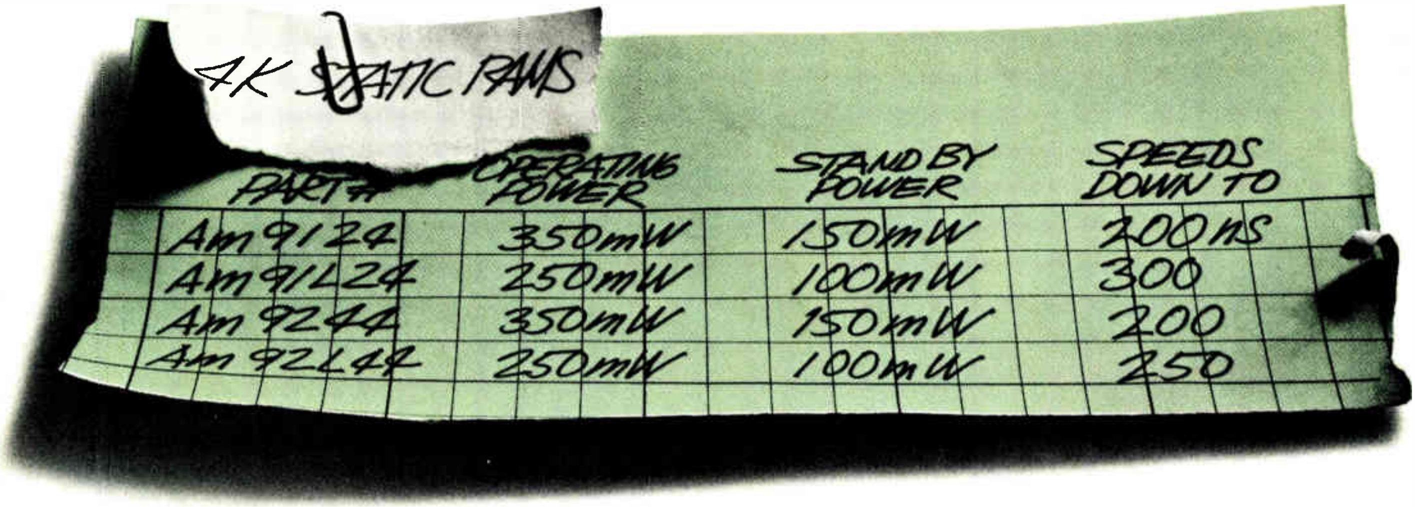

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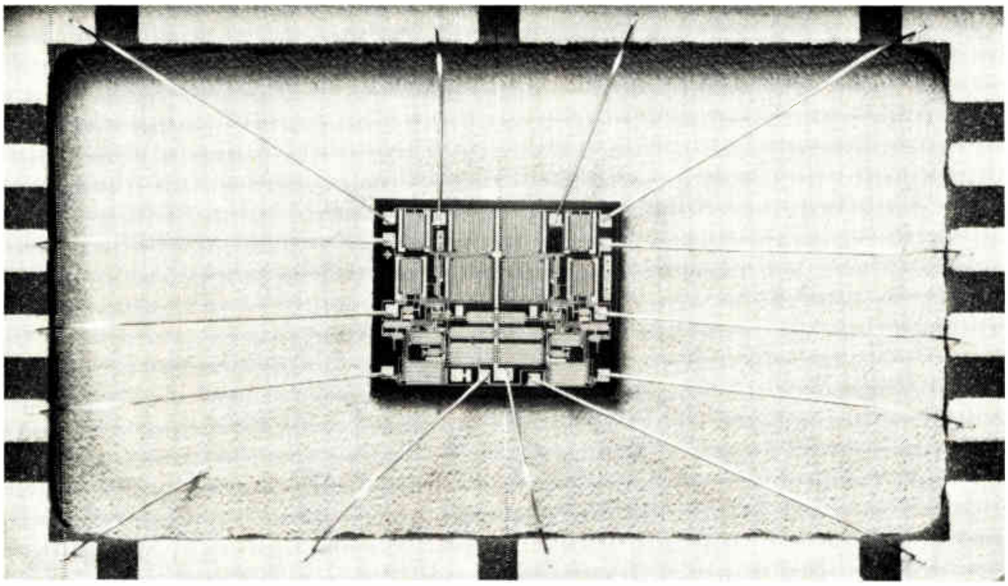

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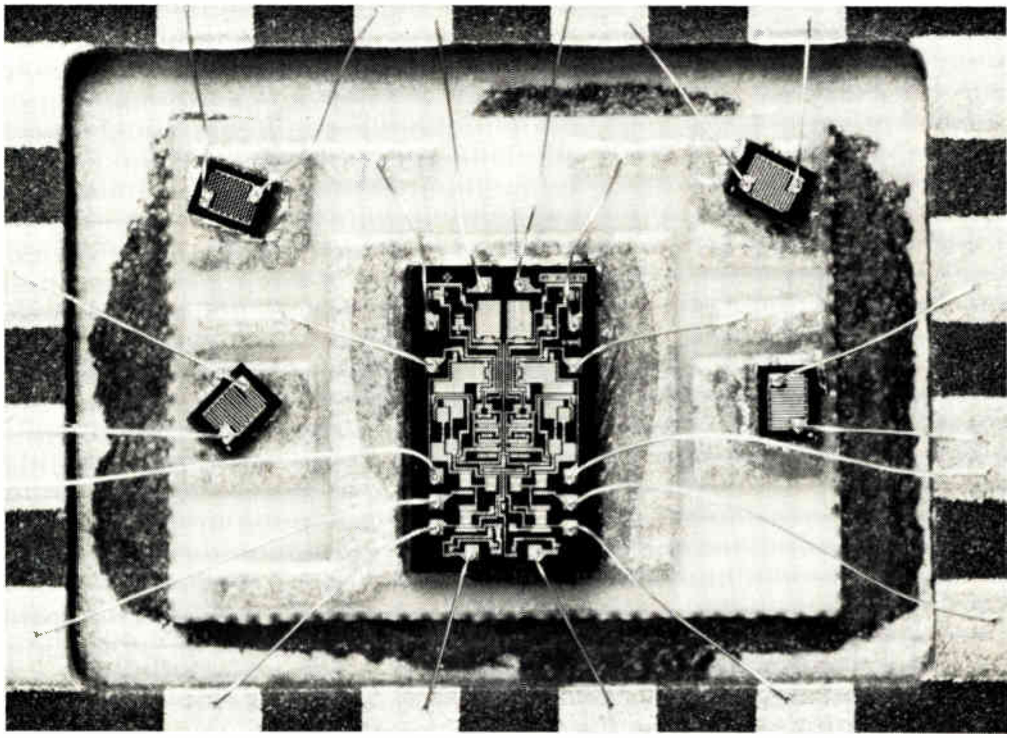

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People

Kooi heads Philips Research facility in Silicon Valley

Signetics Corp. has a new research facility to draw upon, set up by Dutch-based NV Philips Gloeilampenfabrieken, of which the Sunnyvale, Calif., integrated-circuit maker is a part. "Our presence here is to make it easier for Signetics to use the worldwide Philips organization," says Else Kooi, director of the facility, called Philips Research Laboratories, Sunnyvale. The unit is part of North American Philips, owned by United States Philips Trust, which also owns Signetics.

Establishing the laboratories follows a worldwide Philips pattern of setting up research facilities close by its operating units, explains the 47-year-old chemist, until recently deputy director of the NV Philips Research Laboratory in Eindhoven, the Netherlands. His new operation, though housed in Signetics quarters, will be independent of Signetics' direction but will work on projects that are related to the IC maker's bipolar and MOS microprocessor and memory business.

"We will have more long-term projects than they would," Kooi says. By the end of the year, working with a startup budget for equipment, personnel, and space of $10 million, he hopes to have 10 professionals on board, some brought in from elsewhere within Philips, the rest hired from outside. "We hope the name of Philips will attract people," he says.

Choices. But just what kinds of projects will his lab work on? Right now, Kooi considers this decision one of his more important challenges. "There are so many possibilities," he says. The present silicon-based technologies all show promise for the near future as companies work to get down to 2-micrometer geometries in systems-oriented chips, he says. This includes bipolar and MOS technologies, including integrated injection logic, complementary MOS, and silicon on sapphire. Gallium arsenide will also be important, but that's farther off, he says.

Kooi believes that "we can make certain translations because we are more familiar with Philips. Possibly, for instance, we could help Signetics translate Philips' integrated Schottky logic [*Electronics*, June 8, 1978, p. 41] into home-based products. We won't duplicate Philips research but we will play a role in creating a bridge," he says.


Bridge. Else Kooi hopes to help translate Philips research into Signetics products.

Kooi also says he has "some catching up to do, mostly with Signetics. I haven't had much contact with Signetics the last three years" because as deputy lab director in Holland he was responsible for materials and chemistry.

Sinclair looks ahead to flat-tube TV

First came transistor radio kits, then the single-chip calculator, digital watches, and around Christmas 1977, a tiny, "pocket-sized" Microvision television set with a 2-inch-diagonal screen. All these have given Sinclair Radionics Ltd. a front seat in the booming consumer electronics market ever since Clive Sinclair founded it.

That was way back in 1962, when he was a self-taught, 21-year-old electronics whiz. Now at 39 he is head of a firm, headquartered in St. Ives, Huntingdon, that is noted for electronic innovation and also for having somewhat too limited financial and marketing resources to make it big in the consumer electronics marketplace.

Last year, for example, it lost $4 million on sales of $13 million. Consequently, Sinclair is working to tie up with a larger, more powerful

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People

More push. A bigger sales organization will help Clive Sinclair promote his pocket TVs.

marketing organization. He also hopes to entice the public with another new device—a pocket-sized black-and-white TV set with a thin cathode-ray tube (see p. 67). Still in prototype, the thin-tube TV, with a 3-in.-diagonal screen, is easier to carry than Microvision, being not much bigger than a paperback book. Its simple structure and low component count promise a relatively low manufacturing cost, though with production two or three years away, it is still too soon to talk about price.

Early days. But Sinclair expects to profit from something he learned in the early days of transistor radio. In the 1960s, he points out, sales in the United States zoomed from 8 million to 30 million per annum. "This large step in volume was brought about by a change in the pattern of ownership," Sinclair says. "Radios became personal rather than household items, multiplying demand by four." He sees the same happening with the tiny TV sets: "There might be three or four pocket televisions in every household, eventually."

Naturally, Sinclair hopes these will be either his Microvision or his new thin-tube unit. At $400, Microvision, proved too expensive for the U. S. But plans are under way for a redesigned model with a more limited tuner—something along the lines of the $200 set introduced for United Kingdom channels only.

Though Sinclair will not commit himself on price for the flat-tube set, he mentions the truism that as price drops, sales climb. At $100, some 6 million pocket TVs could be sold annually, he believes. □

network for manufacturers.
Expand tomorrow.

access capabilities will put the information you need right at your fingertips. And the modular software design will assure your orderly growth by allowing you to add to, or reconfigure, your DS/1000 network without affecting your existing programs.

Our long experience as a supplier of distributed systems means that HP's advanced technology is available now. Since 1973, HP computers have been installed in distributed networks around the world, all backed by extensive support systems.

If you'd like to know more about the HP 1000 computer system in distributed networking applications, call your nearest HP office listed in the White Pages and ask for a hands-on demonstration. Or for more information, write Hewlett-Packard, Attn: Roger Ueltzen, Dept. 654, 11000 Wolfe Road, Cupertino, CA 95014.

HEWLETT hp PACKARD

Circle 19 on reader service card


Early this year,
Mr. Tom Armstrong
of ITT Electro-Optical
Products Division
approved the 3,000th
mile of optical fiber
for shipment.


Can you
supply
ten components?
a thousand?
ten thousand?

Editorial

Britain's second Industrial Revolution

Great Britain's new Conservative government is attempting some radical surgery on the nation's ailing economy, and its initiatives could have a profound effect on the strong electronics industries in the island nation. The basic line being followed by the Thatcher administration is to dismantle the Labour Party's structure of state aid to industry and return the emphasis to private enterprise, while at the same time making the climate more temperate for venture capitalists.

Under the just-defeated Labour government, there was much talk and some action involving government funding as well as government props for start-up and established companies. Ferranti Ltd. and ICL Ltd. were recipients of some of this largesse, while of the new businesses started by the National Enterprise Board the best known to the electronics community is Inmos, the semiconductor maker with its plant in Colorado Springs.

But now Prime Minister Margaret Thatcher and her party's guru, Sir Keith Joseph, who is also Minister of State for Industry, are determined to sell off government's holdings, cut taxes, and turn to the private sector for financing of Britain's ailing industrial base. On the surface, that appears to be a perfectly good way to do it, though they might find venture capital less than plentiful. One Englishman, now an electronics executive in California, has this to say about his countrymen: "In the UK, venture money is hard to come by—and your backers don't know what you're talking about. It's shattering to find out how easy it is to find money in the U. S. And what's more, they understand the technology."

There will be other problems, not least of all the reluctance of the powerful trade unions to accept a program and budget with nothing in them for the working man. Sir Keith may well find it impossible to turn the clock back to the Victorian heyday of his textbooks. But he has adopted a cautious—one might call it conservative—approach. If he continues taking this route, there could yet emerge a new alchemy for breathing life into Britain's declining manufacturing industry.

Let's all go fishing

A citizen of these United States could well be forgiven the desire lately to dig a hole somewhere and pull it over his head. One recent day's report of current events included news that sunspot activity next year could snarl communications noticably, gas lines in various parts of the country were still long, some people were getting panicky over Skylab, and, the last straw of all, some physicists say the sun is shrinking.

What is a person to do? Well, one can always dig that hole. Or, better yet, one could sit down and calmly remind oneself that things might be worse and probably have been. There is a good deal of technological brilliance out there that is going to work on solutions to these problems—although the sun will just have to be permitted to shrink if that's what it wants to do—and chances are they eventually will be solved. Whether the answer is synthetic fuel or sunspot-proof communications, or even Skylab fallout shelters, the people who put a man on the moon and fluorides in toothpaste will be able to find it.

So until they do, maybe we should all just try to relax, say, at a ball game. Or maybe we should *all* go fishing.

Meetings

IECEC—Intersociety Energy Conversion Engineering Conference, IEEE, Sheraton Boston Hotel, Boston, Aug. 5–10.

Pattern Recognition and Image Processing Conference, IEEE, Hyatt Regency O'Hare Hotel, Chicago, Aug. 6–8.

Siggraph '79—Sixth Annual Conference on Computer Graphics and Interactive Techniques, Association for Computing Machinery (New York), Hyatt Regency O'Hare Hotel, Chicago, Aug. 6–10.

Conference on Simulation, Measurement and Modeling of Computer Systems, National Bureau of Standards *et al.*, University of Colorado, Boulder, Colo., Aug. 13–15.

International Conference on Parallel Processing, IEEE, Shanty Creek Lodge, Bellaire, Mich., Aug. 21–24.

23rd Annual International Technical Symposium and Exhibit, The Society of Photo-Optical Instrumentation Engineers (Bellingham, Wash.), Town and Country Hotel, San Diego, Calif., Aug. 27–30.

Compcon Fall '79—19th IEEE Computer Society International Conference, IEEE, Capital Hilton Hotel, Washington, D. C., Sept. 4–7.

Second International Fiber Optics and Communications Exposition, Information Gatekeepers Inc. (Brookline, Mass.), Hyatt Regency O'Hare Hotel, Chicago, Sept. 5–7.

25th Annual Holm Conference on Electrical Contacts, Illinois Institute of Technology (Chicago), Palmer House, Chicago, Sept. 10–12.

Dielectric Materials, Measurement and Applications Conference, Institution of Electrical Engineers (London), University of Aston, Birmingham, England, Sept. 10–13.

Fall Conference, USE Inc. (the organization for those who use Sperry Univac's series 1100 computers, Bladensburg, Md.), Diplomat Hotel, Miami, Fla., Sept. 10–14.

Optical Communication Conference, IEEE, RAI Conference Building, Amsterdam, Sept. 17–19.

Ninth European Microwave Conference, Institution of Electrical Engineers (London), The Brighton Centre, Brighton, Sussex, England, Sept. 17–21.

Wescon/79 Show and Convention, IEEE and Electronic Conventions Inc. (El Segundo, Calif.), Brooks Hall and St. Francis Hotel, San Francisco, Sept. 18–20.

Autotestcon—Automatic Support System for Advanced Maintainability Conference, IEEE, Radisson Hotel, Minneapolis, Sept. 19–21.

Telecom '79—Third World Telecommunications Exhibition, International Telecommunications Union, Palais des Expositions, Geneva, Sept. 20–26.

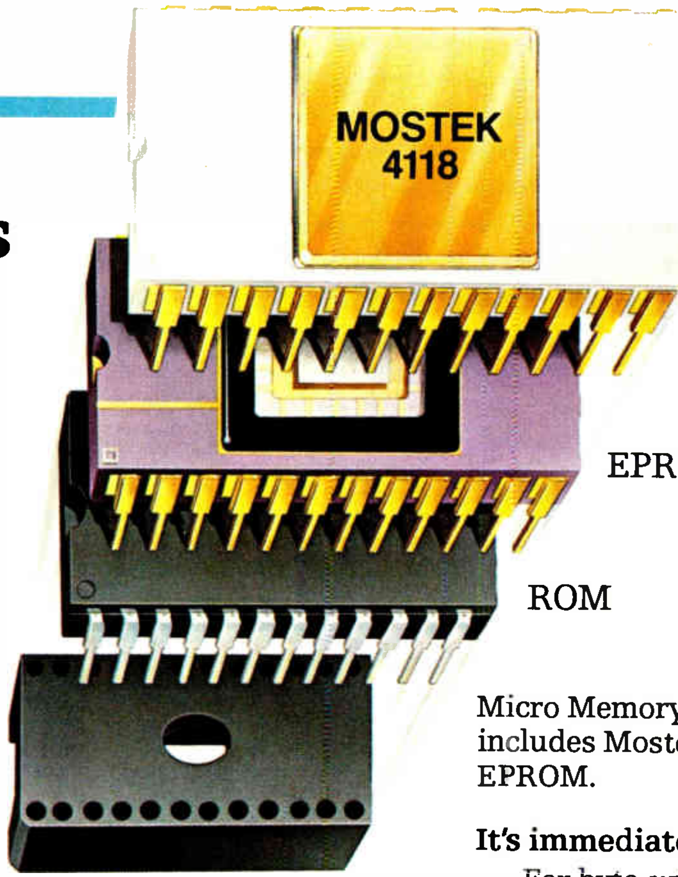
Mini/Micro Computer Conference and Exposition, sponsored by the organization of the same name (Anaheim, Calif.), Anaheim Convention Center, Anaheim, Sept. 25–27.

Short courses

CRT and Matrix Systems Design, a two-part course to be held Aug. 13–17 at the University of Wisconsin–Extension, Milwaukee. For information, write to John T. Snedeker, Department of Engineering and Applied Science, University of Wisconsin–Extension, 929 N. Sixth St., Milwaukee, Wis. 53203, or call (414) 224-4193.

Invitational Computer Conferences—show and seminars to be held at 10 cities around the country starting September. For information, write to Conference Coordinator, B. J. Johnson & Associates, 2503 Eastbluff Dr., Suite 203, Newport Beach, Calif. 92660, or call (714) 644-6037.

Finally. Compatibility.



With Mostek's new 8K static RAM.

Compatible with ROMs and EPROMs. Compatible with microprocessors. Mostek's new 8K static RAM offers total flexibility for your system. Organized as 1Kx8, the 4118 is a next generation Micro Memory,™ available today.

It's a Micro Memory!

Designed for 8-bit and 16-bit systems, the 4118 interfaces directly with all present and future generation microprocessors. A Chip Select control is provided for easy memory expansion and decoding, and internal latches are available to latch the Address and Chip Select inputs. If the Latch function is not needed, it can be easily bypassed. An Output Enable control provides easy user control of the bus in all bus configurations. System design is simplified with the MK4118.

It's more than common!

With a pinout common to standard 24-pin ROMs, PROMs, and EPROMs, the 4118 still has more. Access time is a fast 120ns (max.) and power dissipation a low 200 mW (typ.). The 4118 is the newest addition to our compatible Micro Memory family which includes Mostek's 2716 EPROM.

It's immediately available!

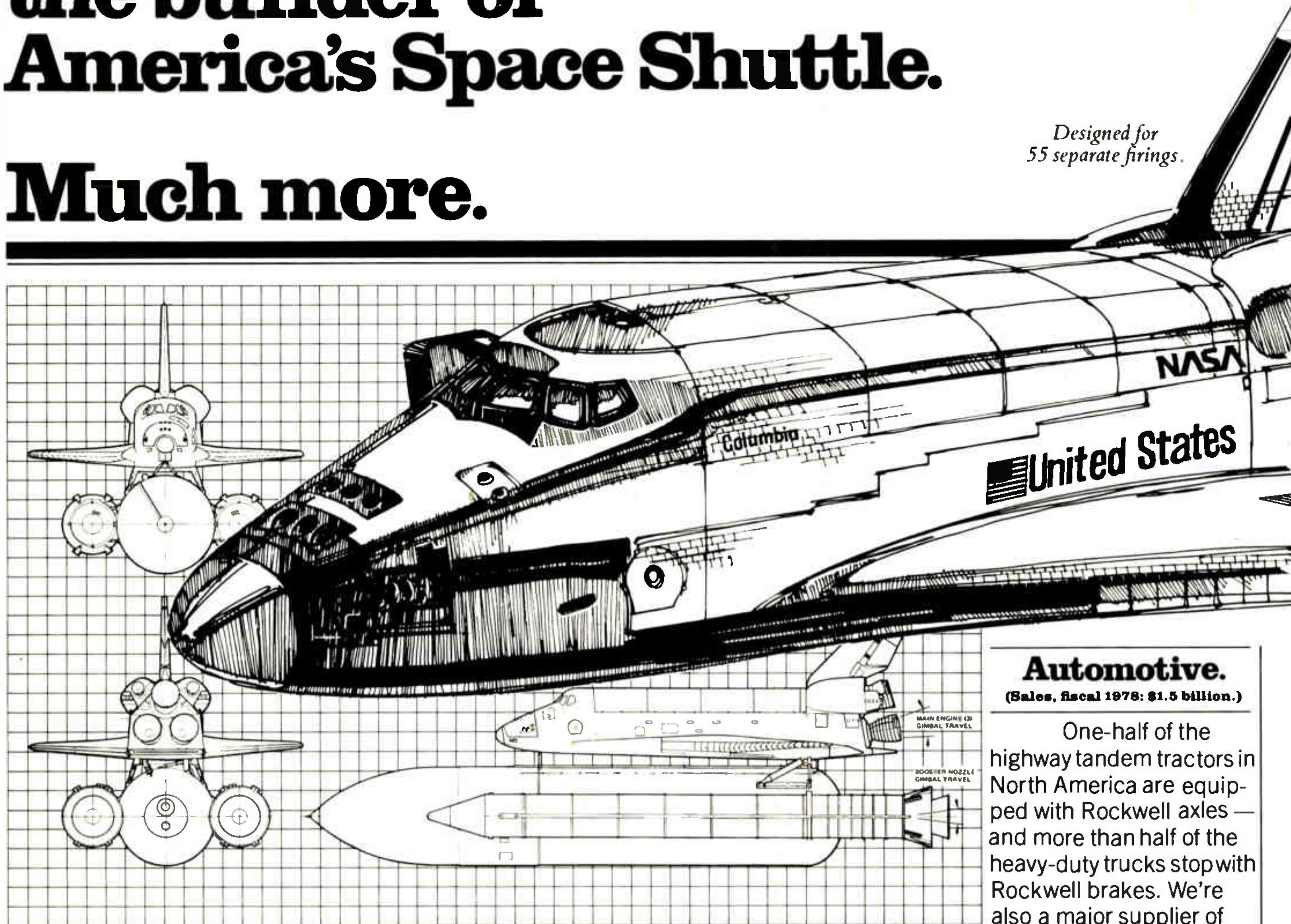
For byte-wide, memory applications requiring density, flexibility, and immediate availability, Mostek's 4118 is the one to choose. For the location of your nearest distributor, call 214/245-0266, Mostek Corporation, 1215 West Crosby Road, Carrollton, Texas 75006. In Europe contact Mostek Brussels; phone (32) 02/660.25.68.

MOSTEK®

Rockwell is more than the builder of America's Space Shuttle.

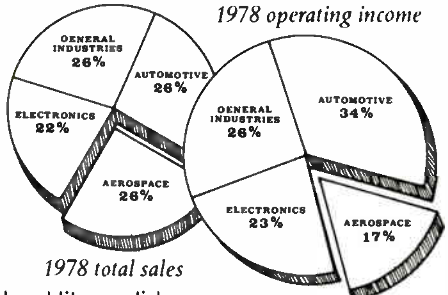
Much more.

Designed for 55 separate firings.



If you think of Rockwell International as a company that makes spaceships, you have good reason. We are prime contractor to NASA for Space Shuttle orbiters and their main engines, and for integration of the entire Shuttle system and selected payloads. The Rockwell-built orbiter is the world's first reusable spaceship, capable of at least one hundred missions into space and back. It will launch like a rocket, haul like a truck, work like a space station, then return to Earth and

1978 operating income



1978 total sales

land like a glider.

But aerospace is only part of the Rockwell story. Rockwell International is a major multi-industry company, applying advanced technology to a wide range of products — in aerospace, automotive, electronics and general industries. Following are some examples of our balanced diversification.

Aerospace.

(Sales, fiscal 1978: $1.4 billion.)

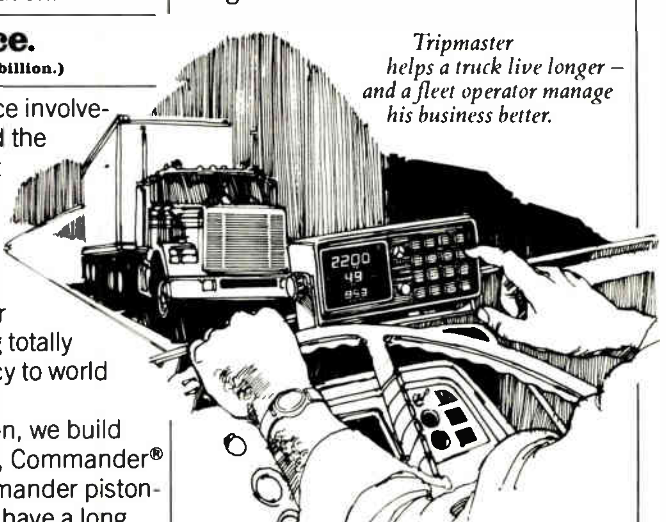
Rockwell aerospace involvement extends well beyond the Space Shuttle. Our rocket engines have been used to launch over two-thirds of all U.S. manned space flights and satellites, and we're building the Navstar satellites that are bringing totally new standards of accuracy to world navigation.

For general aviation, we build Sabreliner® business jets, Commander® 690B propjets, and Commander piston-powered aircraft. And we have a long, proud history as a designer and builder of U.S. military aircraft.

Automotive.

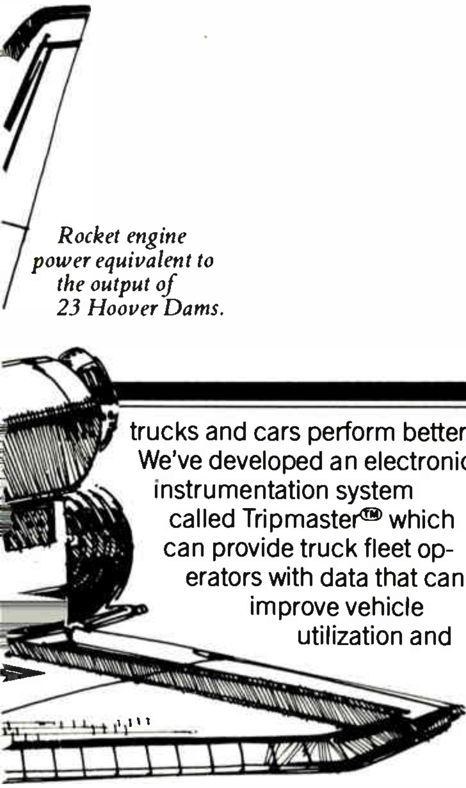
(Sales, fiscal 1978: $1.5 billion.)

One-half of the highway tandem tractors in North America are equipped with Rockwell axles — and more than half of the heavy-duty trucks stop with Rockwell brakes. We're also a major supplier of drivelines, steel and styled aluminum wheels, mechanical devices, castings, stainless steel wheel covers, reinforced plastic and other components for trucks, trailers, buses, vans and passenger cars.

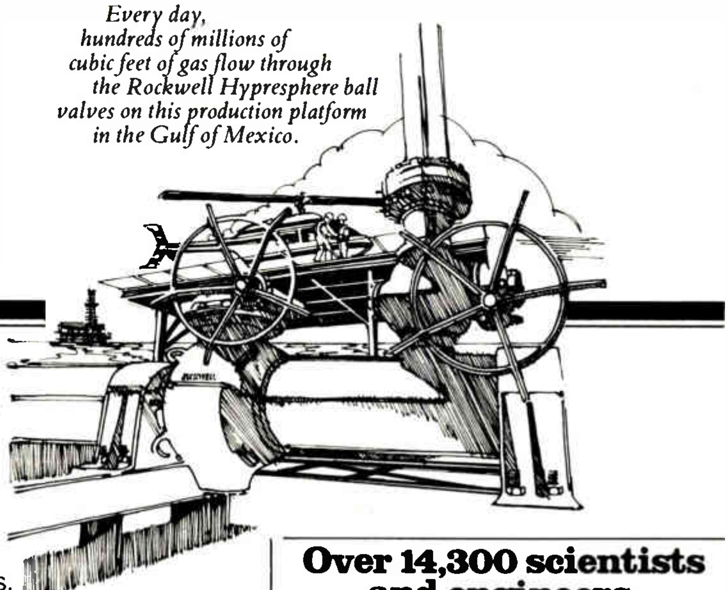


Tripmaster helps a truck live longer — and a fleet operator manage his business better.

In this age of rising costs, Rockwell is creating products that can help

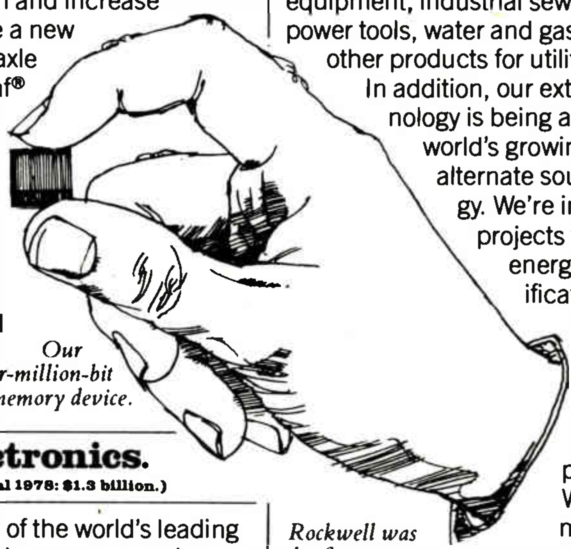


Rocket engine power equivalent to the output of 23 Hoover Dams.



Every day, hundreds of millions of cubic feet of gas flow through the Rockwell Hypresphere ball valves on this production platform in the Gulf of Mexico.

trucks and cars perform better. We've developed an electronic instrumentation system called Tripmaster™ which can provide truck fleet operators with data that can improve vehicle utilization and operating efficiency. Some of our components that can help cut a trucker's fuel consumption and increase payloads include a new aluminum front axle beam, Taper-Leaf® springs and Stopmaster® brakes. Our weight-saving products for cars include reinforced plastic components and aluminum wheels.



Our quarter-million-bit bubble memory device.

Electronics.

(Sales, fiscal 1978: $1.3 billion.)

We're one of the world's leading suppliers of avionics — communications, navigation and flight control equipment for air transport, general aviation and government aircraft. We also make microelectronic systems and devices and guidance and control systems. And we manufacture and install telecommunications systems for businesses and governments worldwide.

One of Rockwell's latest electronic achievements is the production of bubble domain memories. We developed and market a device measuring about two-fifths of an inch square that can store up to 256,000 bits of information. It has no moving parts and retains its data without use of power. Mechanical mass storage computer memories can now be replaced by smaller, faster, more reliable, more energy-efficient systems.

Rockwell was the first company in the world to produce a 256,000-bit memory for commercial applications.

General Industries.

(Sales, fiscal 1978: $1.5 billion.)

Most of America's major daily newspapers are printed on Rockwell-Goss presses. We also make textile equipment, industrial sewing machines, power tools, water and gas meters and other products for utilities.

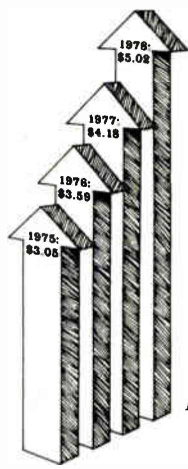
In addition, our extensive technology is being applied to the world's growing need for alternate sources of energy. We're involved in projects for nuclear energy, coal gasification, flue gas desulfurization, and solar, wind and geothermal power.

We also manufacture valves — plug, pipeline ball, gate, globe, angle and check valves for America's power needs. Our Flow Control Division is one of the world's leading suppliers of high-technology valving for U.S. and international energy markets. Rockwell valves are used in oil and gas production, transmission and processing; natural gas distribution pipelines; coal slurry pipelines; synthetic fuel processing plants; electric power plants; shipboard power plants; and in many other energy-related markets.

Over 14,300 scientists and engineers.

Of our 114,000 employees, one in eight is either a scientist or an engineer. They constitute about one percent of America's total scientific-engineering community. This technological base positions us for leadership in each of our product areas. It also makes our corporate slogan, ". . . where science gets down to business," a fact.

Business is good.



Earnings per share

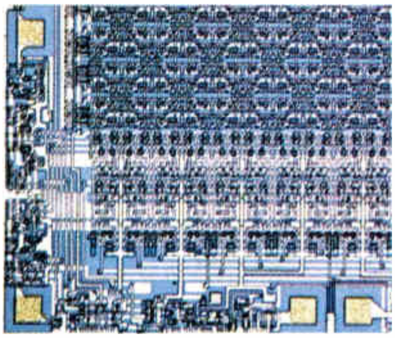
Rockwell International's total sales for 1978 were $5.67 billion. Fiscal 1978 was the most profitable year in Rockwell's history. Net income, up 23% over fiscal 1977, was $176.6 million, generating a record $5.02 per share.

For more of the Rockwell story, please write us: Rockwell International, Dept. 815G, 600 Grant Street, Pittsburgh, PA 15219.

Rockwell International

...where science gets down to business

High throughput, high yield, high reliability: Manufacturing integrated circuits with the Perkin-Elmer Micralign 200 Series



The crux of microcircuit manufacture is the printing of tiny, complicated electrical patterns on photosensitive materials. The challenge is to reproduce these patterns crisply and accurately, in production quantities, at competitive prices. This is exactly what Perkin-Elmer Micralign mask aligners do.

The newest Micralign, the Model 200 Series, is responsive to the semiconductor industry's needs. It achieves 2-micron geometries or better in production, distortion/magnification tolerance of .25 micron and four percent uniformity of illumination.

Like other Micralign systems, the Model 200 Series uses the 1:1 optical projection concept, pioneered by Perkin-Elmer, to focus light from a mask. The mask contains many repeats of a single pattern. In one fast scan the Model 200 Series exposes all of these patterns onto a silicon wafer coated with a photosensitive material. After development, the wafer is further processed—etched, doped, and recoated. By repeating this procedure a number of times circuits are built, layer on layer, on a single wafer. Finally the wafer is cut to separate each individual circuit.

Because dust, heat and vibration are major enemies of precise projection, the 200 houses its optics in a quiet, clean, wear-free world of their own. Vibration is minimized by two frames, one inside the other. All vibrating components have been mounted to the outer frame, thereby isolating the projection optics from all sources of vibration.

The 200 Series has a built-in environmental chamber. External air is blown through the top of the unit. The air is filtered and temperature regulated. A positive-pressure, Class 100 environment is carefully controlled to better than 1°F.

Options include automatic wafer loading and a revolutionary automatic alignment system. Deep UV coatings for even smaller geometries will be available soon.

"Sputtering" thin films onto microcircuits quickly, uniformly, economically: The Perkin-Elmer 4410

The thin metal films used in making semiconductors are deposited by sputtering systems. Evacuate a chamber; fill it with argon; place a high-potential cathode on the ceiling of the chamber and a lazy susan loaded with silicon wafers on the floor; attach to the cathode a target of the material to be deposited; turn on the current.

That, in essence, is sputtering. The current ionizes the argon, and the argon ions in their efforts to reach the cathode bombard the target material, knocking off atoms which settle, uniformly dispersed, on the wafers circling below. Layer by layer, the film builds up to the desired thickness.

Perkin-Elmer sputtering equipment has long set industry standards worldwide. Our latest unit, for example, the 4410, features a novel delta-shaped DC magnetron cathode and microprocessor controller. Both play an important role in producing the high quality films and high throughput essential for the economic production of semiconductors.

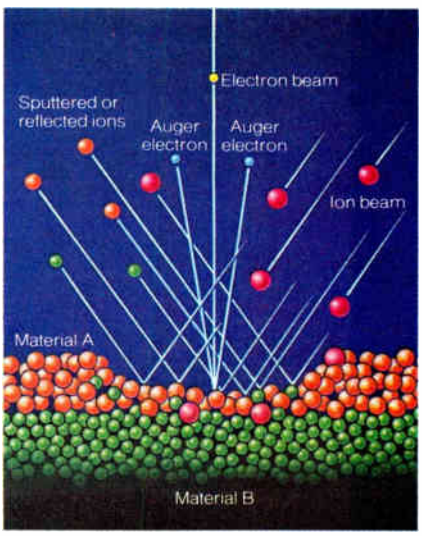
The Delta™ cathode deposits aluminum alloy and other metallic films at very high rates. This is important for building dependable microcircuits today. It's even more important for the high density semiconductor devices of the not-too-distant future.

The microprocessor automatically controls all process variables and eliminates human error. It thus assures run-to-run repeatability for high yield and throughput.

All of which help make the 4410's return-on-investment better than that of any competitive system.

The Perkin-Elmer SAM 590: Probing semiconductor quality layer by atomic layer

As the Micralign system is the world's leading producer of micro-electronic surfaces, so the leading tool for analyzing such surfaces is the Perkin-Elmer 590 Scanning Auger (pronounced Oh-djay) Microprobe, familiarly known as SAM.



Three-dimensional materials characterization using Auger analysis with ion sputter-etching.

Typical tasks for SAM include evaluating the integrity of a semiconductor's thin film interfaces and checking to be certain impurities were not introduced during manufacture. Or detecting such imperfections as microscopic aluminum spikes between semiconductor layers which can cause short circuiting. Or scrutinizing bonding pads for trace contaminants which cause poor bonding adhesion.

To do such jobs, SAM bombards a specimen with a beam of electrons, causing the emission of X-ray photons and chemically specific Auger electrons. These Auger electrons originate in the topmost two or three atomic layers of a specimen surface. By measuring the kinetic energy and number of Auger electrons emitted, SAM provides a quantitative as well as qualitative identification of surface constituents. If the electron beam is scanned, SAM can map the distribution of chemical elements over a selected area.

SAM incorporates an ion bombardment gun that continuously erodes an area of the surface so that the microprobe can analyze downward, layer by atomic layer. This makes possible a true three-dimensional analysis of thin films.

Where applications require, SAM can be expanded into a multiple-technique instrument through addition of ESCA (Electron Spectroscopy for Chemical Analysis), which measures electrons released due to X-ray stimulation of a surface, and SIMS (Secondary Ion Mass Spectroscopy), which detects ions emitted after primary ion bombardment.

For more information on these products, please write: Corporate Communications, Perkin-Elmer, Main Ave., Norwalk, CT 06856.

PERKIN-ELMER
Responsive Technology

Circle 31 on reader service card

HP to introduce microprocessor development unit . . .

Although the project is code-named Pisces, Hewlett-Packard Co.'s planned thrust into the field of microprocessor development systems is more than just a fishing expedition. HP's Colorado Springs (Colo.) division is poised to launch a bold offensive come mid-September with a multiuser universal microprocessor development system.

Unlike existing development systems, it can either stand by itself or be linked to an HP series 3000 general-purpose computer for more extensive software emulation programs or to access a larger data base when the number of users warrants it. HP reportedly has developed a specially designed calculator-controller that is, in effect, a subset of its 9825 desktop computer. The controller is said to be able to accommodate a half-dozen or so users (possibly on a time-shared basis), each at separate terminals that provide in-circuit emulation of microprocessor hardware and software. The system, called PDS, is expected to use a fixed hard disk initially; eventually it may also have a removable disk to provide archival program storage. Pisces will cost about $25,000, with a typical three-terminal configuration expected to cost about $35,000.

. . . as well as personal and scientific computers

On the heels of Texas Instruments' long-awaited move into the personal computer field last month, Hewlett-Packard Co. also is tossing its hat into that arena with a family of machines. The initial entry from HP's Corvallis (Ore.) division is the model 41, based on a hand-held calculator and code-named Coconut. To be sold for about $600, it has an alphanumeric keyboard and four ports for connecting an optional printer, random-access memory, and math packages, for example.

The next item on the division's agenda is understood to be a calculator–desktop computer unit that includes a full alphanumeric keyboard, a small cathode-ray-tube display, a built-in printer, and a 16-kilobyte main memory (expandable to 64 kilobytes). A floppy disk and a plotter are optional. Expected to make its debut later this year, this high-end personal computer, code-named Chestnut, will use Basic and cost $2,500.

Meanwhile, HP's Data Systems division is planning a major entry of its own with the introduction of a 32-bit 1000 series (formerly 2100 series) scientific computer by year's end. A spokesman for HP's Cupertino, Calif., Computer Systems Group neither confirms nor denies the reports.

GenRad, software house merge their resources . . .

GenRad Inc. of Concord, Mass., and Structural Dynamics Research Corp. of Cincinnati are about to announce a joint marketing agreement that would combine GenRad's computerized structural analysis and mechanical test systems with SDRC's software. Under the agreement, **test systems from GenRad's Acoustic, Vibration, and Analysis division, Santa Clara, Calif., would be supported by SDRC software.**

. . . with new systems as first fruit

As many as six new programmable test systems may emerge this summer from the GenRad-SDRC meld. The key characteristic of the new systems would be **a combination of low cost—a range of about $40,000 to $80,000 is being mentioned**—and user programmability. Nowadays, mechanical design engineers must choose between costly programmable systems or inexpensive hardwired systems with limited performance. The new systems would change that, for they would be aimed at acoustic-signal and structural analysis, plus vibration control.

Electronics newsletter

990 module series from TI to get magnetic storage

Look for new board products soon from Texas Instruments Inc. designed to introduce the 990 series of 16-bit microcomputer modules to the world of nonvolatile magnetic storage. Expected this quarter is the TM990/303, a floppy-disk controller board capable of handling dual-sided, double-density disks. TI's Houston operation, which markets the 990 module family, is also planning to bring out a 990 bubble memory module before year-end, but is **currently reevaluating a design that makes use of the company's 92-kilobit magnetic bubble chips.**

National, Intel to second-source disk controller chips

National Semiconductor Corp. by spring 1980 will be an alternate supplier of Western Digital Corp.'s dual-density floppy-disk controller chips. National's parts, the IN582892 and IN582893, will be functionally equivalent to the WD1791B-01 and WD1793-1 currently being offered by the Newport Beach, Calif., company. Both parts feature dual-side dual-density select, but only the former has an inverted data bus. Neighboring **Intel Corp. also has plans to second-source a dual-density controller,** but it will be the μPD765 from NEC Microcomputers Inc., Wellesley, Mass.

New Itel units to battle IBM's 3033, M series

Apparently feeling that the best defense is a good offense, Itel Corp.'s troubled computer operations [*Electronics*, July 5, p. 54] **is introducing two new high-end mainframes** to battle IBM: an AS/7 model 7033 to compete with the top-of-the-line 3033 and an AS/8 7034 to contend with the impending so-called M series, which Itel in San Francisco expects IBM to unveil in the second quarter of 1980.

Motorola prepares to second-source 1-K-by-1-bit static RAM

Like a number of other companies in the MOS business, Motorola Inc.'s Semiconductor Group is working hard to develop its own version of Intel Corp.'s 2147, an industry standard 4,096-by-1-bit fast static random-access memory [*Electronics*, April 26, p. 125]. But Motorola's Austin, Texas, MOS memories operation **has also developed definite plans for the low end of the rapidly growing market in fast static RAMs.** Now slated for sample quantity deliveries during the first quarter next year are the MCM21151 and 2125A, which will be second-source versions of similarly designated 1-K-by-1-bit fast static parts from Intel.

Addenda

General Electric Information Services Co., Rockville, Md., will acquire Mitrol Inc., Lexington, Mass., on Aug. 31. **Mitrol, a $4.5 million software company, produces an industrial manufacturing system called** MIMS.. . . . Lifeboat Associates, a microprocessor software supplier in New York City, has announced **a C language compiler for the 8080.** It sells for $110, with documentation, and runs under the CP/M operating system. . . . Continuing his fast rise within Xerox Corp., **Donald J. Massaro has become president of the Office Products division** in Dallas, Texas, which has been reorganized to include more lines from the Business Systems division in El Segundo, Calif. Massaro, 36, was promoted in April to the presidency of Xerox Memory Systems in Santa Clara, Calif., after heading Xerox-owned Shugart Associates. . . . Robert S. Pepper will take over Aug. 6 as **general manager of RCA's Solid State division.** He is vice president and general manager of Analog Devices Inc.'s Semiconductor division.

IF YOU THOUGHT ALL WE MADE WAS ROMs.

Think again.
ROMs are only part of Electronic Arrays' growing family of NMOS memory products.

EA has RAMs.
The EA 2114L 4K static RAM features five guaranteed access times ranging from 150 to 450 nsec.

EA has EPROMS.
The EA-2716 16K UV Erasable PROM, which operates from a single +5V power supply, and the EA-2708 8K UV EPROM are both pin compatible with EA ROMs.

And you know our three-week ROMs.
EA's 8K, 16K and 32K ROMs feature very fast access times (350 to 450 nsec), full TTL compatibility and three-state outputs.

Call Electronic Arrays for memories: ROMs, RAMs and EPROMs.
550 East Middlefield Road, Mountain View, CA 94043, (415) 964-4321. Philadelphia (215) 643-1447. Chicago (312) 858-8505.

ELECTRONIC ARRAYS.

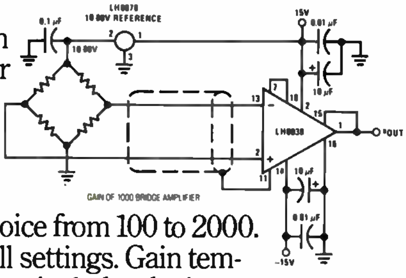
ROMs, RAMs, EPROMs.

If you can instrumentation

build a better amp, we'll hire you.

Anyone thinking they can whip-up an amp superior to our LH0038 should first review the job requirements.

The LH0038 Precision Instrumentation Amplifier is a hybrid consisting of 4 amplifiers, a low noise input stage, and a complete thin film resistor network.



GAIN OF 1000 BRIDGE AMPLIFIER

This enables a gain choice from 100 to 2000. Non-linearity is 1ppm at all settings. Gain temperature coefficient of 7ppm includes the internal gain setting resistors.

Specs are guaranteed over temperature ranges of −55°C to +125°C. Input noise from 0.1Hz to 10Hz is only 0.2 uVp-p. Common mode rejection is 120 dB. And the entire amp is hermetically sealed. (Plus 883 processing is available, too.)

If you can do all that and charge the lowest price on the market, without incurring expensive, time-consuming costs for testing, trimming and reworking your creation, while being sure it fits a standard DIP package, then you have our attention.

Now, if you can back it up with a warranty like we do, you've got yourself a job.

If you can't do all that, hire us.

National Semiconductor
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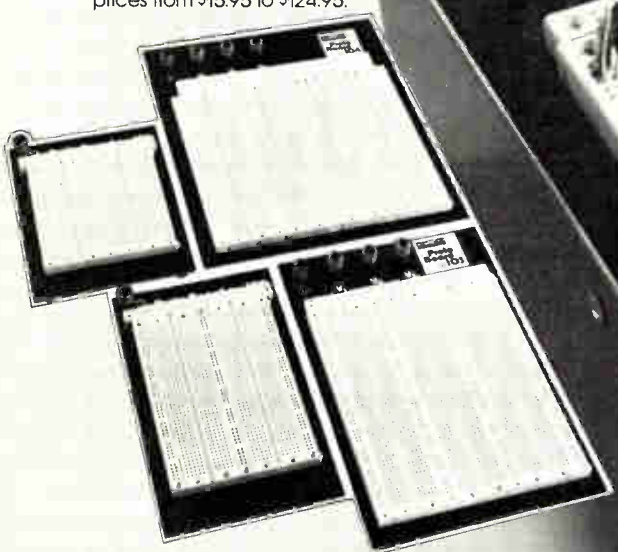

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Magnetics conference looks at new processes for bubble memories

by Benjamin A. Mason, New York bureau manager

Josephson-junction logic, magneto-acoustic keyboard also described at joint parley in New York City

The electronics of the day after tomorrow are hot topics at this week's Second Joint Intermag—Magnetism and Magnetic Materials Conference in New York City. Among more than 400 papers are numerous presentations on bubble memories, Josephson junctions, and the like.

Some highlights, reported in this story and the three that follow, include:

- Ion implantation in contiguous-disk bubble memories, which are denser than conventional types.
- Scaling down a production process to get 2-micrometer permalloy bubble devices.
- A keyboard with a magneto-acoustic delay line as a key sensor.
- A current-switched Josephson-junction logic gate.

Just how contiguous-disk propagation patterns are made is one session's topic—and the title gives the "how" away: "Ion implantation in bubble devices."

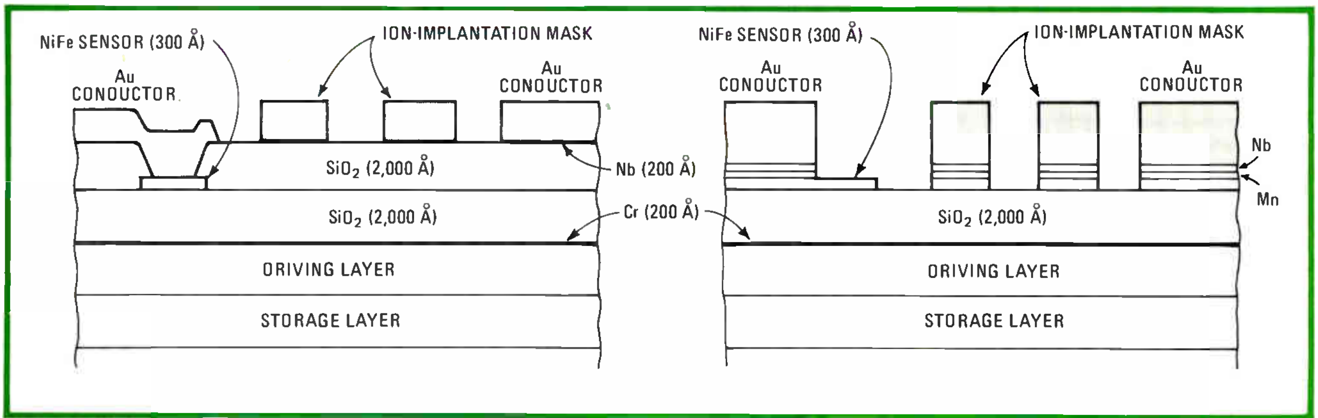
Session chairman Raymond Wolfe of Bell Laboratories in Murray Hill, N. J., says the idea originated at Bell, with IBM Corp.'s Watson Research Center, Yorktown Heights, N. Y., also doing considerable research. Both organizations are discussing their work.

As Wolfe explains it, ion implantation through a photoresist mask alters the surface of the thin garnet film in which the magnetic bubbles define themselves. It changes the axis of magnetization of the treated area from perpendicular to parallel to the film. To guide the bubbles, it also provides the magnetized domain walls that IBM has described previously [*Electronics*, March 1, p. 39].

Not only is the implantation process akin to that used in semiconductor manufacture, Wolfe notes, but the propagation method is like that used with conventional permalloy patterns. External coils generate the rotating magnetic fields that drive the bubbles around the loops and past sensing circuitry.

There are differences in the way the two research groups produce their patterns, Wolfe says. The Bell group puts a photoresist and the subsequent implantation right onto a single garnet layer that both contains the magnetic bubbles and acts as a support; the material is the critical factor in this technique. IBM grows a magnetic epitaxial layer for the bubbles on top of nonmagnetic supporting garnet, then another magnetic layer for the implantation; the epitaxy process is the critical factor here.

Also, the Bell chips use photoresist for patterning right on the garnet while IBM's have a layer of gold and then photoresist. The propagating pattern is etched from the gold, which also can form the conductors



One-step lithography. To produce the contiguous-disk bubble memory at left takes three masks and lithography steps: one for sensors, one for vias, and one for conductors and ion-implanted patterns. As explained in a paper by IBM researchers, the device they are developing, right, needs no vias, and one masking and lithography step produces the other three features.

for control circuits. Bell must add conductors in a second step. Thus, IBM's gold layer solves the problem of aligning the control circuitry with the propagation lines.

Forming both propagating and conducting patterns in one step eliminates a masking step from the typical four needed. An IBM paper by Kie Y. Ahn and Susan M. Kane reports on reducing the number of masking steps to one, eliminating the need for critical alignment.

The previous structure, shown at the left in the figure, requires vias, but the new structure on the right eliminates them and their related processing steps, including one of the three lithography steps.

The other two lithography steps, one for the sensors and the other for the conductors and ion-implantation mask, are combined. The resulting device has a minimum drive field of 20 oersted and bias-field margins of 15% at a drive field of 50 Oe. These figures compare favorably with samples made by conventional multimask processing, researchers say.

Eliminating the second silicon-dioxide insulating layer permits use of lower-energy ion implantation. The final yield also improves because there is less uncertainty about the thickness of the insulation layers through which the ions are implanted. However, the process requires a three-level mask, and that calls for the very high alignment accuracy of an electron-beam exposure system. Moreover, the final sensor thickness is highly critical and the ion milling that achieves it can be difficult to control accurately.

Bubble memories

Texas Instruments is readying process for shrinking size of magnetic bubbles

Product researchers at Texas Instruments Inc. say they have developed a new planar processing approach for fabricating magnetic bubble memory devices that overcomes problems in scaling to 2-micrometer bubble devices from today's 3-μm bubble technologies.

To be discussed in a paper presented at the Second Joint Intermag—Magnetism and Magnetic Materials Conference, the technique will probably allow fabrication of a 1-megabit chip with an area of 1 square centimeter using 2-μm bubbles, says D. C. Bullock, who heads up the Dallas company's bubble memory product and process development research work. Bullock adds that the approach could easily be taken further, allowing 2 megabits of storage in 1 square centimeter using 1.25-μm bubble diameters.

Not effective. Impetus for developing the new process came when TI researchers found that they could not effectively scale to the 6- to 8-μm period ranges needed for 2-μm bubble devices using conventional nonplanar bubble-processing techniques. With the conventional approach, used by TI in the fabrication of its commercially available 256-kilobit bubble devices, a layer of an aluminum-copper alloy (Al-Cu) is deposited, patterned, and either ion-milled or wet-etched before deposition of the succeeding layers of silicon dioxide and nickel-iron (permalloy). The permalloy layer is then patterned and ion-milled.

But while that approach is workable for 3-μm bubble devices—such as TI's 256-kilobit part—that require a 12- to 16-μm period range, it is unworkable when scaled down, says Bullock. That is due to step coverage problems with the permalloy where it crosses over the Al-Cu leads at the smaller device levels.

The TI solution is to deposit a triple layer, a sandwich of Al-Cu, silicon dioxide, and permalloy, before doing any patterning or material removal. Processing is then done from the top down, instead of from the bottom up, as with the conventional technique.

After the three-layer deposition, the permalloy layer is patterned and ion-milled; this process is followed by patterning and plasma etching of the silicon-dioxide and Al-Cu layers underneath. The gate design used in the 256-kilobit chip was modified for fabrication with the new process, which because of the top-down approach requires that Al-Cu be present wherever there is permalloy, says Bullock. In fact, the permalloy acts as a partial mask for the Al-Cu because of its resistance to the plasma etch.

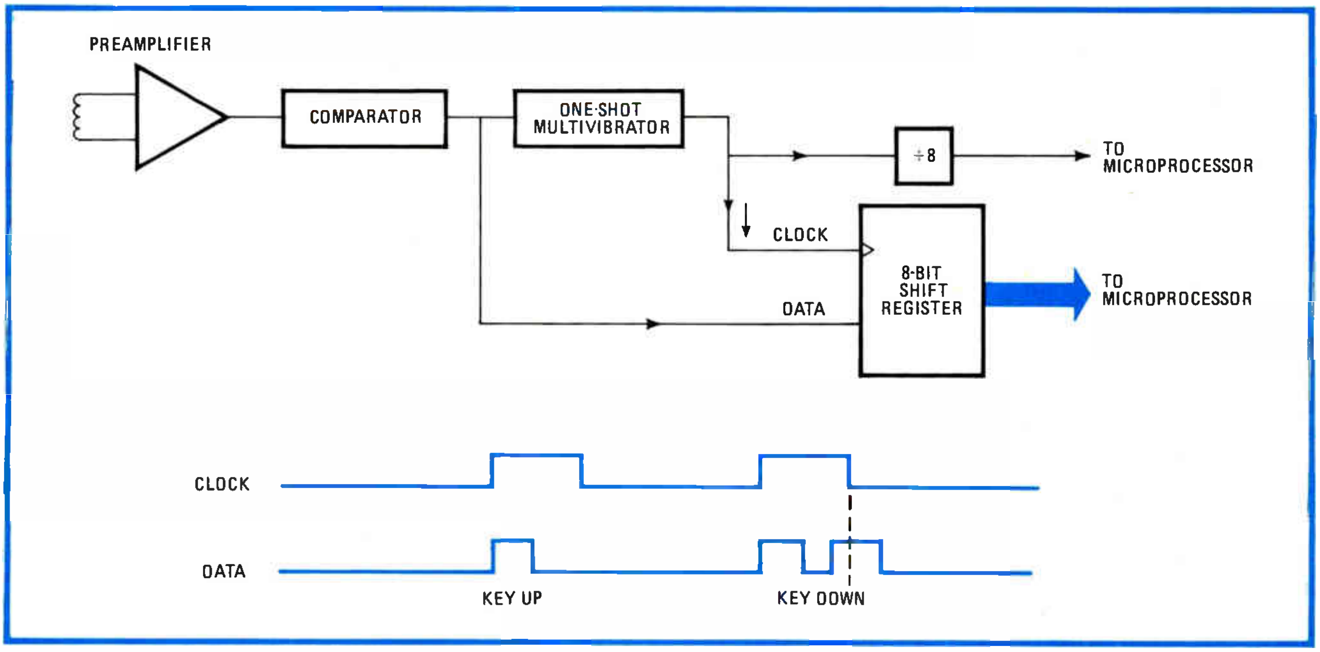
In addition to the plasma processing, which is new to TI bubble technology, the new technique calls for 10× reticules to be generated by electron beam, which are then used in a step-and-repeat manner. This contrasts with the 1:1 photo-masking technique used on TI's 256-kilobit devices.

Worthy process. The result is what Bullock calls a "production-worthy" process capable of 1-μm geometries with ±¼-μm registration. It is less costly than the old approach and produces devices not bothered by permalloy step coverage problems. Despite the emergence of alternative approaches to bubble technology, which use field-access ion-implanted lattice files and contiguous disks, for example, Bullock says he is confident the new process technique will enable TI, if it so chooses, to produce the next generation of 1-megabit chips without changing its basic bubble approach. "I really think the permalloy device will withstand all of the threats [from other technologies]," says Bullock, "at least for one more generation." **-Wesley R. Iversen**

Peripherals

Keyboard design relies on delay line

To the casual user, International Business Machines Corp.'s experimental keyboard may look and work like any other capacitive unit. But inside is something quite different:



Detection. Pulse from fixed magnet contained in each key of IBM keyboard triggers the one-shot, which clocks the shift register. When a key is depressed, the movable magnet it also contains generates a second pulse and a 1 is entered in the register.

the key depressions are monitored by the generation and detection of acoustic waves propagated along a plated wire.

As described at this week's Second Joint Intermag—Magnetism and Magnetic Materials Conference, the operation depends on low-intensity permanent magnets molded into the keys and a magneto-acoustic delay line consisting of a nickel-iron plating over a 125-micrometer-diameter beryllium-copper wire. The wire is threaded, serpentine fashion, under the keys.

The research group responsible, located at IBM's Thomas J. Watson Research Center in Yorktown Heights, N. Y., says the delay-line arrangement simplifies the wiring of the keyboard enormously. The conventional array of conductors on a two-sided printed-circuit board plus all of the associated circuitry can make up a significant part of the board's cost for a large keyboard, they note.

Easy axis. The nickel-iron plating —it is 2 micrometers thick— achieves an easy axis of magnetization around the circumference of the wire. When the key is depressed, its magnet's field locally rotates the magnetization in the plating on the delay line. A microprocessor in the system interrogates the keyboard by generating a 1-microsecond current pulse through the wire. This pulse in turn generates torsional acoustic waves under each depressed key that propagate to a detection coil at one end of the wire.

Since the propagation time to the detector identifies the depressed keys, each interrogation pulse is able to yield a list describing the status of each key. Thomas K. Worthington, a member of the IBM group, points out that the microprocessor can interpret the list in terms of shift and multiple-key meanings and that it can also handle the rollover problem that occurs when the typist depresses a key before releasing the previous one.

Pairs of magnets. A single magnet in each key would be the simplest scheme, but to time the resulting single pulse would require a highly accurate and stable clock, as well as rigorous tolerances in the meandering wire, according to the researchers. For a self-clocking keypad, IBM's setup uses pairs of magnets, one fixed at the key and one moving with the key as it is depressed, and the detection circuitry shown in the schematic above.

An initial interrogation pulse produces a signal from the fixed magnet of each key that triggers the one-shot multivibrator, which clocks the shift register on its falling edge. Another pulse begins; if a key is depressed, its movable magnet causes a second pulse to arrive at the one-shot, and a 1 is entered in the shift register.

The shift register assembles eight 8-bit words, each word representing eight keys. Thus a relatively slow 8-bit microprocessor may be used, reading the contents of the shift register every 64 μs.

The researchers say that the design of their unit is much more tolerant of debris or imperfections under the magnetic pads than are conventional capacitive or electrical contact keypads. The base plate is an inexpensive plastic molding, rather than a two-sided pc board; a single driver and the detection circuitry could be put on one silicon chip and all logic, including the processor, on another. Making the small magnets that are part of each key requires only adding ferrite powder to the plastic molding material that is used to fabricate conventional capacitive-type keys.

The concept's future is largely a

question of whether one of IBM's divisions wants to apply it to its equipment, Worthington says. He regards the keyboard design as practical. **-Benjamin A. Mason**

Solid state

Current switches Josephson junctions

Moving a little closer to the day when the super-fast, minimal-power Josephson junction becomes practical for logic circuitry, Bell Laboratories is unveiling a current-switched version. Such designs "are simple, compact, and relatively tolerant of fabrication variations," reports a team of researchers from Murray Hill, N. J.

Most work with Josephson junctions has been with magnetically switched gates, says team member Theodore A. Fulton. Current-switched gates have proved sticky going. "Frankly, up to this point, no one has thought of a reasonable design," he says.

The Bell Labs team is reporting on its work at this week's Second Joint Intermag—Magnetism and Magnetic Materials Conference, in New York City.

According to the Bell team, the current-switched gates "rely on a direct summing of the gate bias current with control current inputs to cause switching from the low-resistance state to the high-resistance state." It therefore shows promise for logic, memory, and switching applications.

As well as designing the basic gate structure, the researchers have gone on to fashion a flip-flop and logic module, one version of which is shown in the figure. The basic gate uses two Josephson tunnel junctions and a small resistor in a loop, as shown in the schematic.

In the simple and compact gate, one junction (J_1 or $\bar{J}_1$) is called the summing junction and the other the diode junction, although actually either could perform the summing that starts the switching.

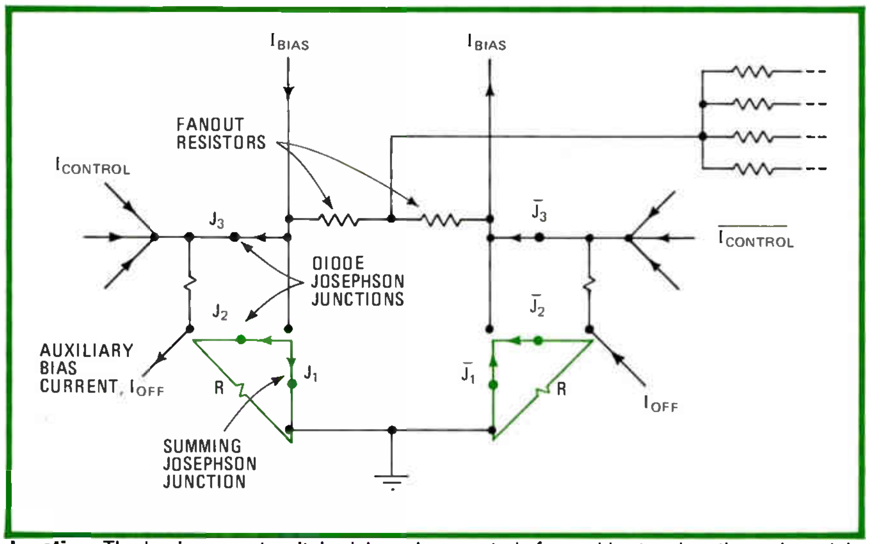
Less critical fabrication. The standard magnetically switched Josephson gate also has two junctions, but a third leg has to have a fairly large inductance, rather than a small resistance, Fulton says. Thus it is bigger; and because performance depends on a precise inductance value, the fabrication is a much more critical step than with Bell's current-switched gate.

The research team has expanded its basic gate to incorporate a second diode junction. "The extra diode allows looser tolerances on I_m," say the researchers. I_m is the maximum current that the superconductors making up the junction will produce at a zero voltage and liquid helium temperatures. Because Josephson devices have low gain, they must be made to resonably tight tolerances on I_m, but the two-diode structure is a way out, Fulton says.

Demonstrator. To test the capabilities of their current-switched design, the Bell researchers devised the more complex logic circuit shown in the figure. Different combinations of current bias perform several operations, including three-input majority, two-input OR and AND, three-input minority, two-input NOR and NAND, and inversion. Under some conditions, the circuit can add an exclusive-OR, and it can serve as a D flip-flop in clocked operation.

One limitation of the circuit, say the researchers, is that it leaks some current every time it switches. However, they report that the fanout current can still drive up to four subsequent gates.

Fulton says gate delays as low as 50 to 60 picoseconds have been produced. Future work will include design optimization and more complex circuitry. **-B. A. M.**



Junction. The basic current-switched Josephson gate is formed by two junctions, J_1 and J_2, and a small resistance, R. The gate switches when the threshold current in J_1 is exceeded. Bell used several gates in the setup shown for checking out various logic operations.

Commercial

Metro's fare cards failing too often

Increasing numbers of commuters in the nation's capital find that when they try to switch to the Metro—"the world's most modern subway system"—they have to fight to get on board. The challenger: Cubic Western Data Corp.'s automated fare-collection system known as Farecard. The system malfunctions close to 20% of the time, a figure double Metro's projected failure rate, officials say. Rush-hour chaos is mounting as the number of riders grows in the face of the area's gasoline shortage. Severe problems have arisen on a few occasions when all five Farecard vending machines in a single station have broken down,

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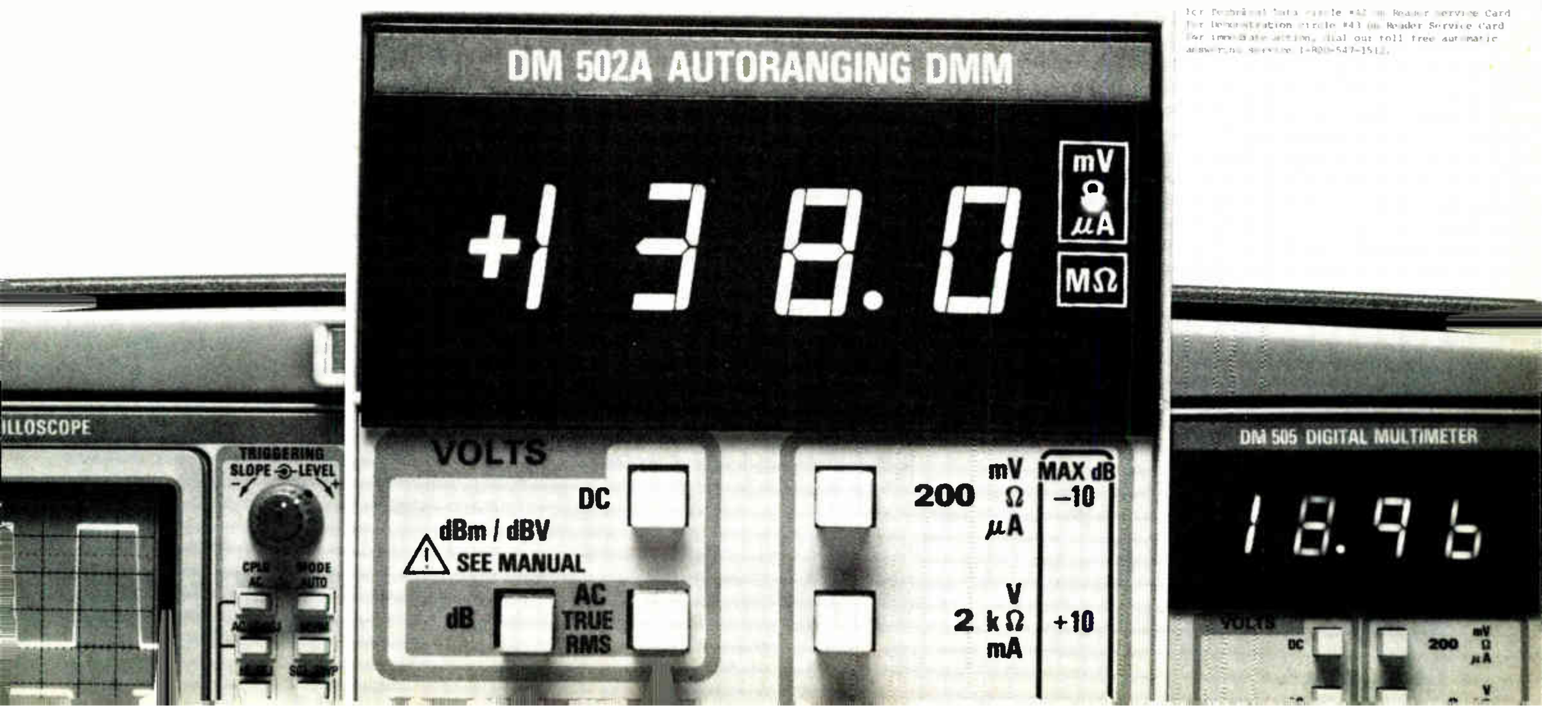


Cubic has $100 million winning ticket

Despite its problems in the Washington and San Francisco transit systems, Cubic Corp.'s Western Data subsidiary now virtually owns the automatic fare-collection field. Founded in 1968, and facing the likes of IBM, Litton Industries, GE, and Control Data Corp., which have made abortive passes at the field, Cubic has racked up $100 million in contracts in the last seven years. The company predicts a growth to $200 million sales in five years.

The latest contract, for the first-phase automation of the London rail system, was awarded to a joint venture, Westinghouse Cubic Ltd., based in Surrey, England. The project calls for about $22 million for engineering, prototype, testing, and preparation for production of the fare-collection system. If successful, the second phase—production and installation at the 300 London subway stations—will cost over $189 million.

Cubic's newest installations include a subway opened last month in Atlanta and a rail system scheduled to begin operations in Hong Kong sometime in September. Automatic Cubic equipment is also used in commuter airline terminals operated by Pacific Southwest Airlines. Other airlines are looking at the system too.

The basis of the fare-collection system is magnetically coded tickets that are read at individual collection stations controlled by Intel 8080 microprocessors. The collection stations in turn are linked to a central minicomputer, from which management can get real-time cash flow, traffic flow, and maintenance service data.

requiring station personnel to let riders through the gates without tickets (see "Farecard's failings").

In San Francisco, the Bay Area Rapid Transit system is having problems with its fare-collection system, also provided by Cubic Western, which is a San Diego subsidiary of Cubic Corp. These include troubles with the paper money validator not accepting wrinkled bills and the automatic gates not reading the coded magnetic stripe on each Farecard. As a remedy BART is embarking on a $2 million modification.

More drastic action is contemplated for the $5 billion Washington Metro. Its manager, Richard S. Page, reported to the subway's board of directors that if Cubic's system cannot be repaired quickly, it may have to be junked in favor of an alternative—perhaps an old-fashioned single-fare system. One of the options, say Metro system staffers, is suing Cubic for failure to satisfy the terms of its projected $53 million Farecard contract, of which $45 million has been committed [*Electronics*, Nov. 9, 1978, p. 57].

"All we're doing now is running around putting out fires," complains one Metro maintenance official, noting that spare parts for the Cubic equipment either are in short supply or malfunction on installation. Some existing equipment is being cannibalized for parts, he says.

At Cubic Western Data, Thomas B. Tuttle, director of domestic automatic fare-collection programs, concedes there have been problems, especially with the availability of spare parts, "which is at present a major area of concern." Cubic has, he says, maintained spares at its own expense in the Washington area.

Excluding equipment that is down or unavailable because of a lack of spare parts, the "Cubic fare collection equipment continues to maintain an availability level of 90% or better," Tuttle asserts. "This performance is far better than has been generally recognized." Moreover, Cubic has spent more than $1 million of its own to improve the equipment, he continues. The results were successful at a test station in Washington and were to be presented to Metro management earlier this month. **-Ray Connolly**

Farecard's failings

Failures of Washington's Metro subway ticket system "are not always the fault of electronics," says one city transit official, "but that doesn't help the frustrated rider." Sometimes, for example, the ticket vending machines are not stocked with change.

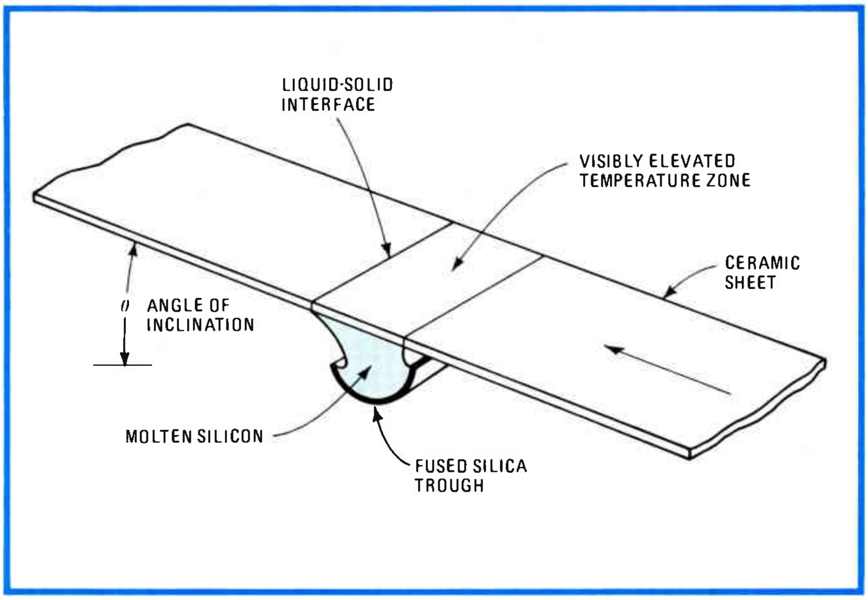
The system is supposed to work like this: a rider buys a magnetically encoded ticket from an automatic Farecard vending machine by inserting anywhere from 50 cents to $20. The ticket is then inserted in an entrance gate to activate it and is returned to the rider. At the exit station, the ticket is used again to leave the terminal through a similar gate, which automatically calculates the cost of the trip, deducts it, and prints the remaining value on the ticket which it returns to the rider. If the ride costs more than the value remaining on the ticket, the ticket is returned and a flashing message panel directs the rider to an "Add-fare" vending machine to pay more money.

But Cubic's baulky Farecard machines do not always work that way. "Bills get chewed up sometimes," an official explains, "or the machine returns the wrong amount of change—sometimes too much, like a slot machine jackpot, or more often none at all because it has run out." The magnetic heads used to record ticket values often get dirty and malfunction, says one maintenance specialist, who complains that the inaccessibility of the heads makes them difficult to clean. Slightly crumpled or torn Farecards also pose a problem when entrance or exit gates reject them.

Photovoltaics

Honeywell skims silicon melt

Skimming a skinny rectangle of carbon-coated ceramic across a trough full of molten silicon may produce an important breakthrough for photovoltaics: low-cost production of the basic solar-cell material. The experimental process, under development at Honeywell Inc.'s Corporate Technology Center,



Skimmer. Ceramic substrate, moved across a trough of molten silicon, picks up coating of crystalline material that can be used to fabricate photovoltaic solar cells.

Bloomington, Minn., could be the forerunner of continuous growth of sheets of large-grained polysilicon.

Honeywell's premise is that cheaper silicon is possible with supported growth—that is, a cheap substrate like ceramic on which large areas of the solar-cell material may be grown. Also, related work at the technology center has almost doubled the 5.5% efficiency Honeywell previously reported.

Essentially, the new skimming process is an advance over the dipcoating approach (p. 110) that the center originated, says J. David Zook, group leader of its low-cost solar cell program. In that approach, pieces of ceramic about 2½ by 3 inches are dipped into a crucible of molten silicon, which sticks to the carbon-coated underside.

However, holding the molten silicon in a long, narrow fused-silica trough permits larger sheets of silicon to be skimmed from the surface. Right now Honeywell is doing this with 2-by-20-in. ceramic substrates.

Zook says the molten silicon rises as high as 1 centimeter above the trough because of its high surface tension against the ceramic. This facilitates continuous skimming, since the silicon does not actually drop into the trough. (It also facilitates the acronym that the group came up with: SCIM, for silicon coating by inverted meniscus).

Along with the ribbon-growing process, sheet growth is an alternative to ingot growing of single-crystal silicon. However, supported sheet growth is inherently stable whereas unsupported ribbon growth is not, says Zook. Thus, interrupting the production process does not require a restart from "ground zero" as with ribbons; nor does such a problem as a carbonless spot spoil the coating of the rest of the sheet.

The original coating process was dreamed up in 1975 by J. Don Heaps of the Honeywell solar-cell group and Obert N. Tufte, who is Zook's boss. Federal funds funneled through the Jet Propulsion Laboratory financed that research; Heaps' work on SCIM over the past two years is funded by Honeywell.

Faster rate. The goal of Zook's group is a throughput rate of 0.15 square centimeter a second, which is higher than that for ribbon growing. Add to that the minimal use (and wastage) of the silicon and the continuous and stable nature of the SCIM process, and the result could be a cost per watt as low as 30 cents, well within the Department of Energy's 1990 goal of 15¢ to 50¢ (in terms of 1975 dollars).

The Honeywell group wants larger sheets of the aluminum silicate ceramic. Its supplier, Coors Porcelain Co., has produced 4-by-40-in. substrates, and Zook says cells as big as 4 by 4 in. may be possible.

An important attribute of the SCIM process is that it does not introduce ceramic impurities into the melt, which can be a problem with dipping. Fewer impurities will, of course, raise conversion efficiencies in the resulting solar cells.

Another contributor to hiked efficiency is a revised substrate architecture, Zook says. Earlier versions had solid ceramic with topside connections to the silicon. Now the substrate is slotted, so the connections can come up through it.

Working with 1-millimeter-thick ceramic, the Honeywell group is using 1-mm-wide slots, with about 1 mm between them. The more open space there is, the less the series resistance of the bulk silicon affects current collection, Zook says. Conversion efficiency is now running about 9.9% in 10-cm² cells, he reports. -Benjamin A. Mason

Solid state

TI sells off its germanium line

The ever-dwindling germanium transistor market lost another supplier last month as Texas Instruments Inc. sold its germanium line—lock, stock, and customer lists—to Germanium Power Devices Corp., an Andover, Mass., firm.

TI, which is getting out of the business after 25 years and a claimed 2 billion–plus units shipped, is among the last of the big semiconductor houses to forsake germanium. Motorola sold its line in 1976, but many other giants dropped out in the 1960s, when germanium transistors were largely displaced by silicon devices.

Down to three. According to TI, it is simply no longer practical for it to continue manufacturing and stocking germanium transistors. With its departure, says GPD president Oliver

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O. Ward, there are only three remaining U. S. manufacturers serving the market for germanium power and small-signal devices. The others are Lansdale Transistor & Electronics Inc., Phoenix, and Silicon Transistor Corp., Chelmsford, Mass.

Germanium Power Devices plans to move the TI production line from Dallas to its manufacturing plant in Andover, where it builds a line of germanium transistors traceable to earlier acquisitions from the lines of Bendix, Honeywell, General Electric, and others.

With a strategy aimed at taking an increasingly larger share of a continuously declining market—by various estimates, it is now less than $25 million domestically—GPD has managed to keep revenues growing yearly, says Ward. With the former TI line in place, he expects germanium transistor sales of $4.5 million this year and $5 million to $6 million in 1980.

Continuing. The GPD official sees a market for germanium transistors and their high-frequency capabilities continuing for the next 10 to 15 years because of various ongoing military programs that have had them designed in and other applications in computers. They are also used with automotive batteries, where, Ward says, germanium's low-loss voltage-saturation characteristics are important.

But Ward also concedes the need to expand GPD's germanium product line. As the germanium transistor market runs down, he promises, "our next move will be in the direction of adding something like germanium diodes." **-Wesley R. Iversen**

Companies

Amoco invests in Solarex Corp.

Petroleum multinationals, in their search for new sources of energy, are taking an ever stronger shine to photovoltaic solar cells. Standard Oil Co. of Indiana, better known as Amoco among gas-line aficionados, made that clear with its "$3 to $5 million" coup in early July that bought it a 20.6% interest in Solarex Corp. of Rockville, Md. That closely held, five-year-old company's estimated 1-megawatt annual output generates $11 million in sales and accounts for roughly half of U. S. photovoltaic production.

Solarex says it will use the new capital to build a plant using a "totally new manufacturing approach" that will start yielding an annual 2.5 MW late next spring and could be expanded to produce 5 MW annually. Moreover, the company says it expects to halve the cost per photovoltaic watt to from $5 to $7 by using antireflective, semicrystalline silicon sheets in a production process that halves the number of steps required. Solarex says it is not yet ready to discuss the manufacturing technology because of proprietary considerations.

Third sale. Solarex shareholders, of whom there are about 30, sold 20,000 shares to Amoco for $43.75 per share, with the difference between that $875,000 investment and the remainder of the money accounted for by the sale of an undisclosed amount of Solarex treasury stock. Solarex retains control, however, since it holds a majority of voting shares. The 20,000-share sale is the third by Solarex this year, similar minority interests having been sold in March to France's Moteurs Leroy-Somer, a large maker of electric motors and water pump machinery, and Holec NV of the Netherlands.

While Amoco's entry into the photovoltaics market is hardly the first by an oil company, "it got a good buy," says one energy securities analyst in Washington, who notes that Solarex has the largest share of any company in the evolving photovoltaics market. Earlier moves by oil companies have included Atlantic Richfield's acquisition of Arco Solar; Mobil's buy into Tyco Laboratories; and Shell Oil's investment in Solar Energy Systems Corp. Exxon also has its own extensive photovoltaics effort.

Solarex president Joseph Lind-

News briefs

Hitachi reports net profits jump 25%

Paced by computer and semiconductor activities, Hitachi Ltd.'s various operating groups produced a 25% increase in net income to $462 million in sales, rising 8% to $12.3 million in the fiscal year ending March 31, executive vice president Masafumi Misu said last week. Speaking to the New York City investment community, Misu said the Tokyo-based firm garnered a 19% sales hike for computers to about $1 billion, with over 40% coming from rentals. There were sizable increases in semiconductor sales; consumer products also did well, notably air conditioners to fight Japan's sweltering heat last summer. Hitachi expects its nuclear power generation business to grow because by 1988 Japan should be 20% dependent on nuclear power, as against 11% in 1978. Semiconductors will also be a major investment target, with Hitachi's 64-K random-access memory due to go into mass production early next year.

Demand for electronics execs slackens

One segment of the personnel crunch in the electronics industries is easing. According to the latest Korn/Ferry Index—a quarterly survey of demand for executives—hiring of top managers by electronics firms fell three points to 9% of total executive demand in the second quarter. In the second quarter of last year, electronics companies accounted for 12% of the hiring. The executive search firm was unable to explain the dip, but predicted that demand in the industry would pick up again for the rest of the year.

mayer and his partner, Peter Varadi, organized the company in 1973 after leaving the staff of Communications Satellite Corp. in the Washington area, where they were involved in the development of satellite solar power systems. **-Ray Connolly**

Employment

Dearth of technicians plaguing companies

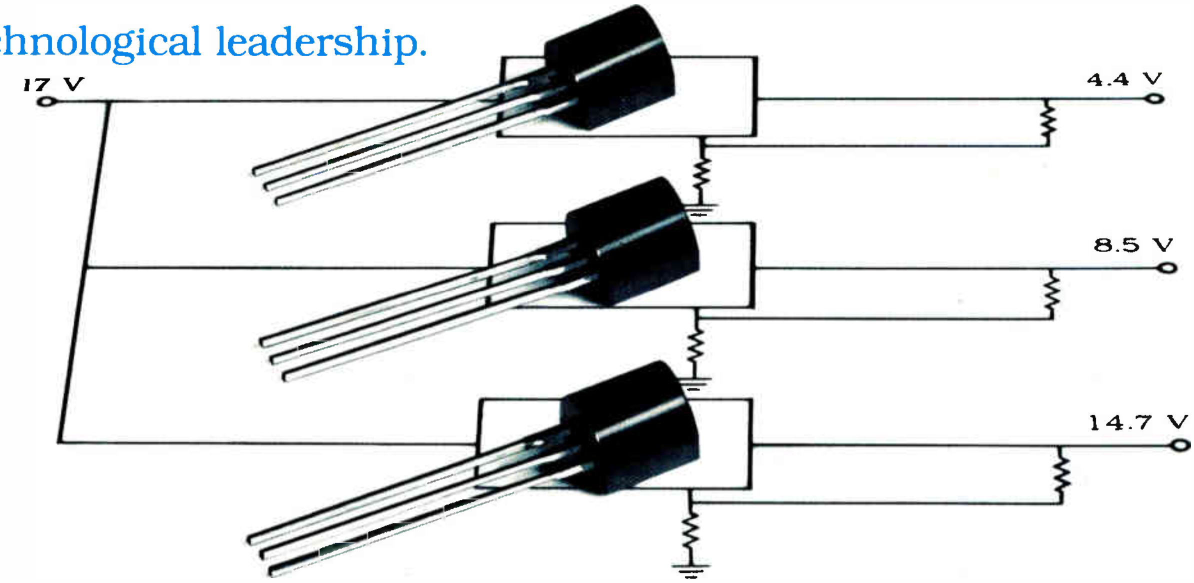
As if bustling electronics companies do not have enough trouble finding qualified engineers these days, they also face another crucial personnel shortage: technicians to run and maintain their capacity-choked production lines. So they now recruit the technician with almost as much attention as they do the beginning engineer, and they offer him almost as large a starting salary [*Electronics*, May 7, p. 90].

"A maintenance technician is almost as valuable as a good engineer," comments Richard Schaublin, employment manager for Advanced Micro Devices Inc., Sunnyvale, Calif. He says he is "about 35 [technicians] short right now, a higher number than last year." And Schaublin says that his larger Silicon Valley competitors are even more shorthanded. "As everybody expands, it's getting worse," he says. If nothing is done, "it will be the same in three to five years as it is now with engineers," he predicts.

"There's a tremendous market, especially on the West Coast, for electronics technicians with two-year degrees," confirms Jack Grout, corporate manager of employment and college relations, Hewlett-Packard Co., Palo Alto, Calif. This demand has hiked salaries of beginning technicians to from $1,000 to $1500 a month, not that much below beginning graduate electrical engineers, recruiters say.

Nationwide recruiting. As a result, "recruitment has gone from local to nationwide," states Roy Brant, vice president of human relations for National Semiconductor Corp. He says that his Santa Clara, Calif., semiconductor company recruits across the country by advertising the area's fine weather and the career opportunities in the highly concentrated center of technology where National is located. Adds AMD's

Technological leadership.



Kiss complexity goodbye with the first 100 mA, 3-terminal adjustable voltage regulator.

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Neg Fixed	79L00		7900C

*New Introduction (3rd Qtr. 1979).
†Tighter-spec'd 7800 version in TO-3.

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Schaublin: "They're usually fairly junior people who are single or not too family-oriented yet. They also rent so they're not as bothered by the high cost of housing as engineers might be. Rents are still reasonable." AMD, which has hired a former electronics school teacher to start in-house training courses, covers moving expenses and 14 days temporary housing costs for recruits.

No one knows for sure just how large the shortage is. But an American Electronics Association survey covering one third of California's electronics industry gives an indication, predicting that the total shortage will quadruple to 40,000 jobs this summer in 18 categories, including assembler trainees, technicians, draftsmen, field service technicians, and senior inspectors.

"Employers tell me they have a difficult time finding people, and the demand is across the board," says Mike Guntrum, labor market analyst for the California employment development department, San Jose. He says he sees no letup: "Wherever an industry is electronics-oriented there'll be a shortage."

State aid. To combat the shortage, the industry and the California state government are taking steps to train more technicians. For example, a state senate bill would provide $5 million for special electronics job-training courses. Individual companies are working closely with educators in local community colleges to put more courses into curricula so the schools will graduate more two-year students with electronics skills. The activities include plant tours by classes and guest lecturers from the companies.

The American Electronics Association, which is coordinating the programs, reports, for example, that Orange Coast College (in Southern-California's Orange County) and San Jose City College (Santa Clara County in the San Francisco Bay area) have scheduled courses for assemblers and technicians, and Mission College (Santa Clara County) plans to have an electronics training center for 1200 to 1800 students. **-William F. Arnold**

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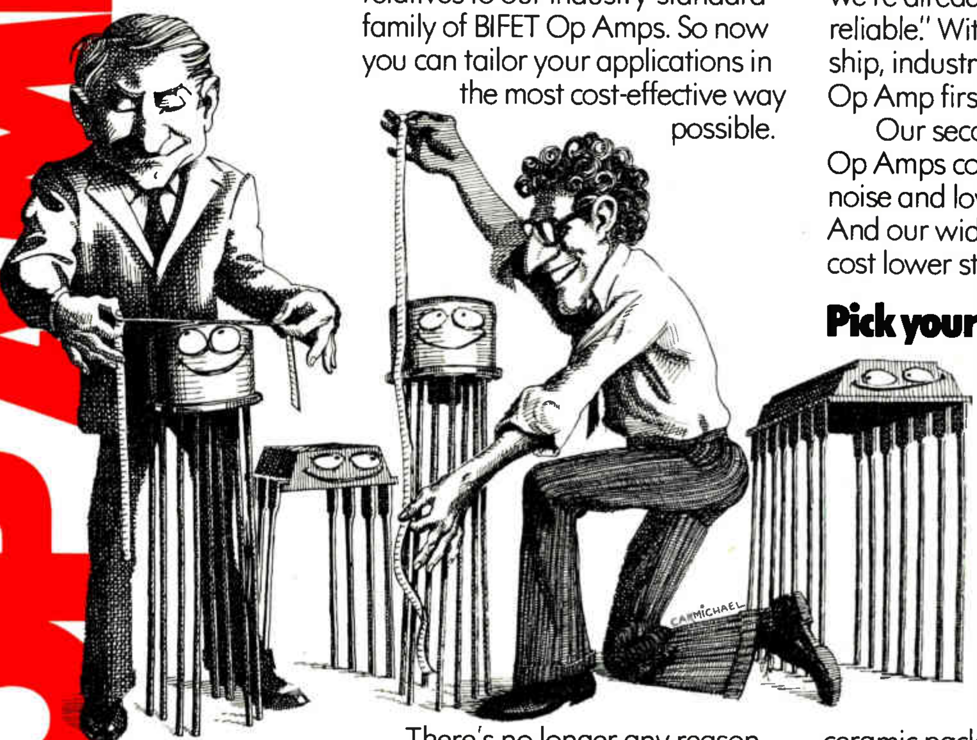

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Air Force readies C^3 proposal requests for Missile X

The Air Force request for engineering development proposals for the command, control, and communications system for its new intercontinental missile, dubbed MX (for Missile X), will be released next week, with July 27 as the target date. The C^3 system for the ICBM will be a major effort for the Air Force's Space and Missile Systems Organization. **Nearly 20 companies have shown interest in the project.** Selection of a development contractor is expected to be announced in early 1980 after evaluation of responses this fall.

DOE names three finalists for Saudi project

Battelle Laboratories, General Electric Co., and Martin Marietta Corp. have been named finalists in the Department of Energy's competition to develop a 350-kW photovoltaic power plant for a village in Saudi Arabia. **The job is worth $15 million to $30 million.** The timetable calls for selection of a winner by the end of the month, although that date may slip. The Solar Energy Research Institute in Golden, Colo., is managing the program, which one Washington bureaucrat labels "our CTN project—coals to Newcastle." To be built for the village of al-Jubaliah, some 50 kilometers west of the Saudi capital of Riyadh, the system will have a total capacity of 430 kW to compensate for dust and sandstorms in the region that could limit photovoltaic efficiency.

June sales upturn puts home products ahead for half

Sales of color and monochrome TV receivers to dealers picked up in June, as did sales of home video cassette recorders and auto radios, **pushing figures for the first half of 1979 for all four product categories above 1978 levels.** The June unit increases for color TVs (8.4%), monochrome sets (9.6%), VCRs (6.9%), and car radios (5.8%) more than offset the May downturn in color TV and drops in VCRs for both April and May [*Electronics*, June 21, p. 57]. First-half sales of color receivers were up 1.1% from the 1978 level, while monochrome sales advanced 6.5%, according to the Electronic Industries Association. Sales of 180,000 VCRs in the half were 26.6% higher than in 1978, and the 6.5 million car radios sold represent a 6.3% gain.

Fujitsu to supply 200 TDMA modems for SBS terminals

Japan's Fujitsu Ltd. has won a production contract from Satellite Business Systems Inc. for the first 200 time-division multiple-access (TDMA) burst modems for ground stations on customers' sites. The McLean, Va., satellite communications company, a jointly owned venture of Comsat, IBM, and Aetna Casualty & Life, declines to disclose the value of the Fujitsu contract, **the second award this year to a Japanese supplier.** Deliveries will begin next April. Nippon Electric Co. previously got an award for five rf terminals for use in SBS's 12-to-14-GHz tracking, telemetry, and command net [*Electronics*, Jan. 18, p. 57]. Nippon Electric's terminals, each with two 7.6-m limited-motion antennas and a 12.5-m steerable antenna, are to be installed at a control station near SBS headquarters. The network, to serve large U. S. organizations with digital voice, data, facsimile, and video communications, is set to begin operations in January 1981, after satellites are launched in the second half of 1980.

Washington commentary

U. S. metric conversion—kilometers still to go

Metric conversion is a phrase that has a certain magic. It's a subject that can make most of an audience disappear while putting the remainder to sleep. Thus metrification's proponents are learning to discuss it in more exciting contexts, like money and multinational markets.

Multinational manufacturers and users of electronics, for example, are at the forefront of the accelerating metric conversion movement for obvious reasons: manufacturers want to lower their costs and expand their global markets by replacing U. S. inches and pounds with the meters and grams used by the rest of the world. Multinational users of electronics, too, want to be able to buy U. S. instruments and other subsystems that will fit in racks and bays of foreign systems with metric dimensions. International Business Machines Corp. "is so far along in its metric transition that the company has discontinued publication of its inch manual," says the American National Metric Council. That makes good economic sense.

The poor economic sense of lost sales is reflected in the complaint of instrumentation user Svante Humbla, the operations and metrification chief of Lummus Co., an American-owned multinational designer and builder of refineries and chemical and pharmaceutical plants. The lack of U. S. products designed to metric specifications, Humbla points out, causes Lummus to buy abroad "even though equipment and commodities of the same quality could have been acquired domestically at more favorable prices" had metric versions been available.

NATO: a motivating force

Such arguments have been around for years with little impact on an American public resisting change. But the Department of Defense, for one, is now pushing the issue strongly, motivated by secretary Harold Brown's determination to achieve systems compatibility in the North Atlantic Treaty Organization. As a result, under secretary William Perry recently sent a memorandum to all military research, development, and procurement agencies that metric units will be used in all "technical reports, studies, and position papers forwarded for my information or action."

The Pentagon already has 11 metric weapons programs, all but one of them oriented to joint use by NATO and U. S. forces. The three of these in development that are going 100% metric include the Hellfire helicopter-borne battlefield missile, the Vehicle Rapid Fire System gun, and Sincgars—the single-channel ground/airborne vhf radio. The sole U. S. system now planned to be 50% metric is the proposed MX intercontinental missile that should be in operational inventories in the 1990s during the U. S. metric transition period.

Beyond these, DOD's metric coordinator, Howard Ellsworth, cites specific regulations adopting metric policy, the strongest of which is Directive 4120.18: "All new defense systems are to be metric unless it is not consistent with operational, economical, technical and/or safety requirements."

Getting support for conversion is tougher on the civilian side of technology, where Federal contract dollars are not involved and the agency, unlike DOD, is not the buyer spelling out specifications. The Federal Aviation Administration is finding that out as it surveys the civil aviation community. The immediate issue is the International Civil Aviation Organization's plan to make some units of communication metric on Nov. 26, 1981. The U. S. has consistently opposed the move to metric units in air operations and seems unwilling to change. Even ICAO has backed off on converting the nautical mile and knot to kilometers and kilometers per hour and now uses a December 1985 date only for planning purposes.

Even major newspapers like The Washington Post, which sees itself as a progressive and thoughtful journal, opposes U. S. adoption of the metric system. "In a world where much changes ineluctably and is unfamiliar, there's a sound case for taking a firmly reactionary stand on those happy occasions where the choice is harmless," the springtime editorial argues.

Harmless? Esther Peterson, the outspoken White House consumer affairs adviser, could not let such a lightheaded plea for a dual system pass. "There is a time to be reactionary, but only when reason is allied with the facts," she wrote back. "We cannot make such a claim for our complicated English system of measurements. Even the English are abandoning it."

After stating the monetary benefits of metric conversion for export expansion and trade balances, she came to what she called "the root of this issue." "It is a fact that our generation is called upon to adjust to many changes. How can we face the hard questions when we are not willing to tackle those less complicated?"

The hard answer is that we cannot without first recognizing that survival in a global economy is at stake. As Lummus Co.'s Humbla puts it, "learning and using metric is no big deal . . . and the sooner the transition period is put behind us, the sooner we will see the positive results." **-Ray Connolly**

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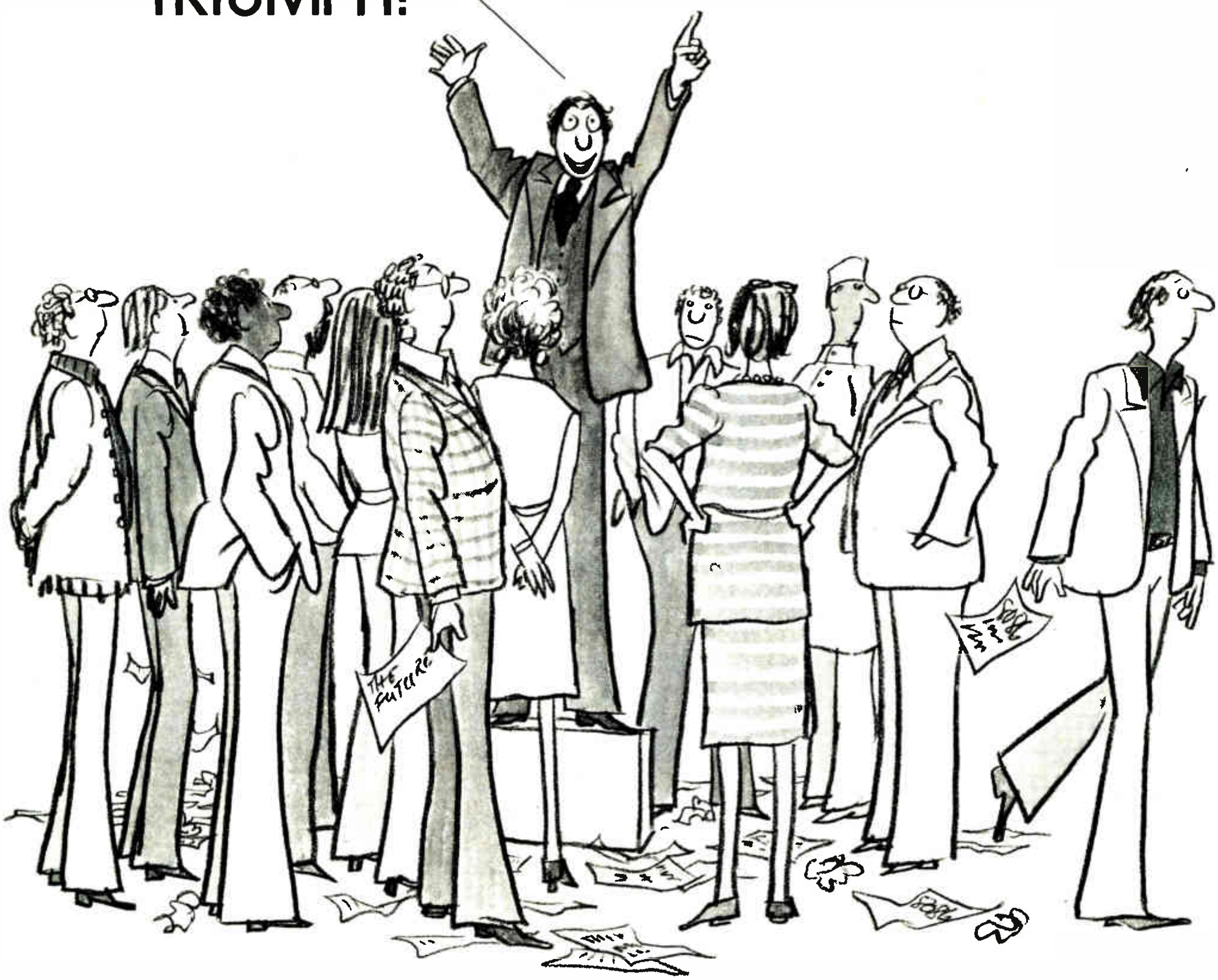

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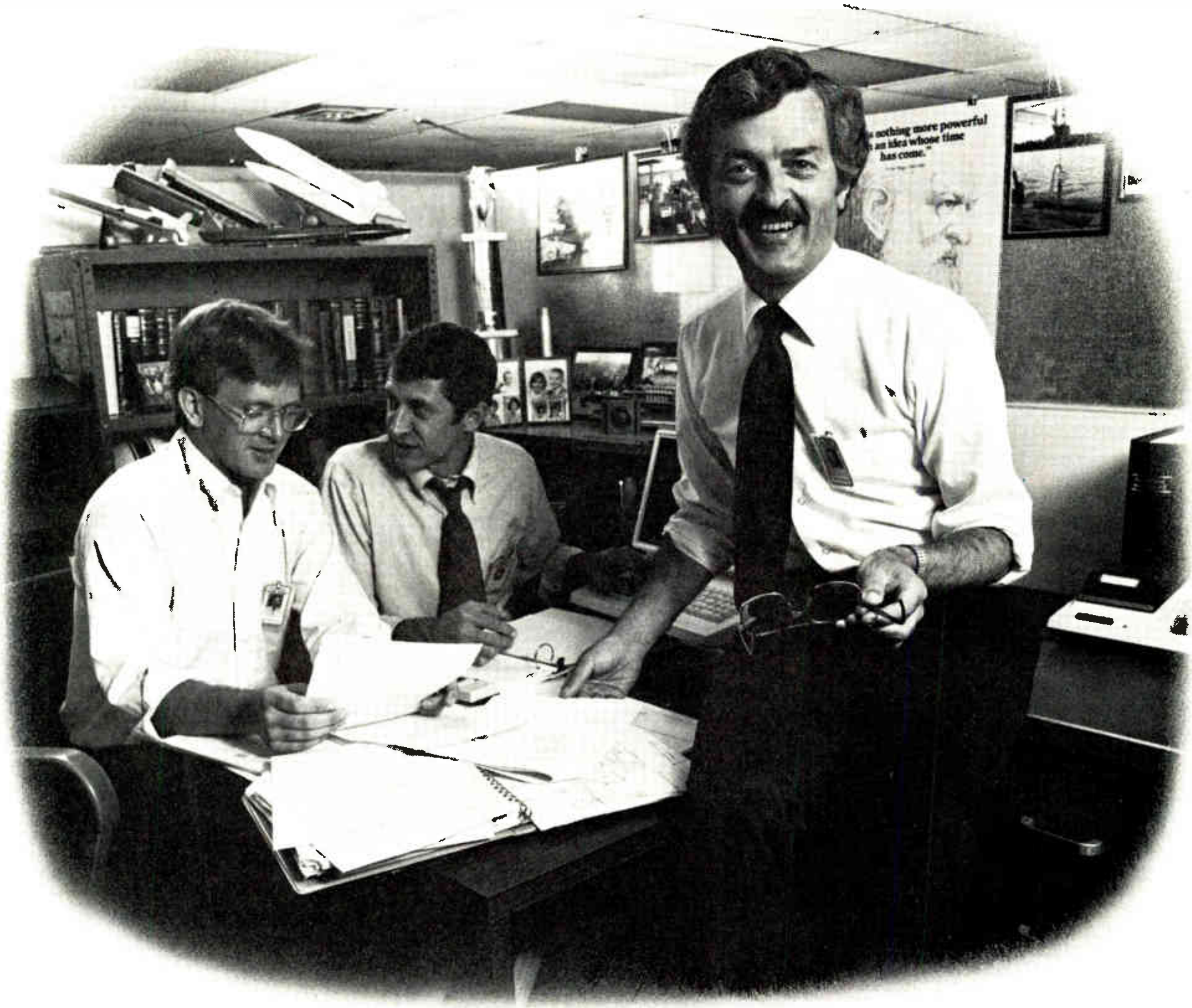

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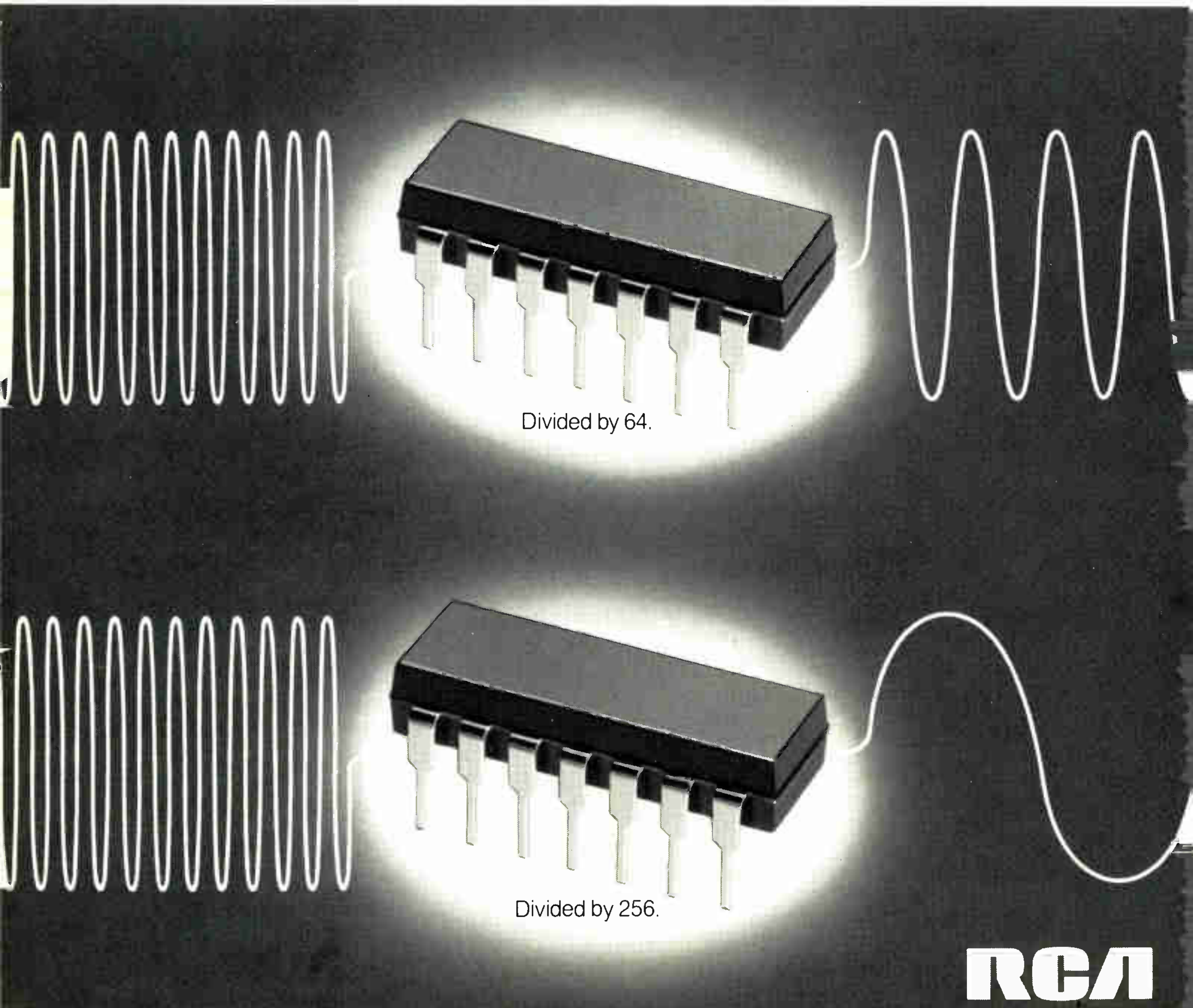

Circle 62 on reader service card

International newsletter

100% modulation achieved internally by He-Ne laser

Using a proprietary technology, engineers at Siemens AG have produced a communications-type helium-neon laser tube that can be modulated to a full 100%. Conventional lasers for communications applications check in with a maximum modulation of about 15%, the Munich-based firm says. Of note is the fact that **the new device operates without an external modulator.** Instead, the output is modulated by a technique involving a special resonator geometry and a specific gas pressure, but Siemens will not yet reveal details. The absence of an external modulator results in much smaller dimensions and greatly reduced costs compared with conventional communications lasers, says Thomas Barone, Siemens' marketing manager for laser devices. Designated the LGR 7625, it will sell for about $450, roughly $200 less than its conventional counterparts. Power output of the device is 0.4 mW. The first application of the LGR 7625 will be in new facsimile receivers made by Rudolph Hell GmbH, a Siemens affiliate. Its 100% modulation makes possible reception of pictures "with a heretofore unattained quality," Barone says.

Japanese firms form association for software and peripheral effort

Ten of Japan's leading data-processing firms have established a basic computer technology research association to manage a joint government-industry effort to develop basic software and peripheral equipment for the country's next generation of computers. The five-year project, approved earlier this year [*Electronics*, Jan. 18, p. 63], is now expected to cost some $259 million. **Masato Nebashi has been named executive director of the association.** He holds the same position in the VLSI Technology Research Association, which is now in the second quarter of its last year.

European VCR sales to double, report says

European sales of video cassette recorders for 1979 should double over last year's figure to 450,000 units worth about $540 million, according to the latest European consumer electronics survey from Mackintosh Consultants Co. in Luton, England. The report predicts that portable recorders will be an increasingly important factor as the switch to "electronic photography" from Super-8 home movies gets under way. It also predicts a color penetration of the TV market of 72% by 1982, up from 47% in 1978. The 1978 market for TVs was worth $5 billion for 9.9 million sets, with color units accounting for from 74% in Sweden to 15% in Spain. Japanese brands, including those manufactured in Europe, now hold some 10% of the European television market.

Siemens prepares for 16-K memory demand

Scrambling to meet the rising demand for 16-K memories, Siemens AG is gearing up for large-volume production of several types of these devices. One is a dynamic random-access memory, the HYB 4116, of which the Munich company **has targeted an output of about half a million this year and more than 3 million in 1980.** Another is the SAB 8716, an electrically programmable read-only memory with a 2-K-by-8-bit organization, a maximum access time of 450 ns, and a power dissipation of 132 mW in standby operation. The production goals for this device are 100,000 in 1979 and five times that the following year. Also in production is an 8-K electrically erasable PROM, the SAB 2808 [*Electronics*, March 15, p. 67]. Production in large quantities will begin when sufficient orders come in.

International newsletter

West German firm eliminates wet processes to make hologram fast

The Munich holographic equipment producer Rottenkolber GmbH has gone to market with a holographic test system that gets around the ordinarily used wet photo processes to produce a hologram in close to real time. The key element in the system is a photo-thermoplastic film material, from the chemical firm Kalle AG, that is electronically processed. The interface of the laser object and reference beams discharges a static load pattern onto the film material. By raising the temperature of the film, a phase grading is obtained that is identical to the load distribution. **It takes less than 3 seconds to produce a hologram with the new material** and display the test results on a television monitor (see also p. 72). The system sells for about $16,000.

European PTTs move toward viewdata standard

A European viewdata standard resolving the conflict between the British Prestel and French Teletel systems could be close. A discussion document defining such a standard has now been produced by a working committee of the European Conference of Post and Telecommunications Authorities (CEPT) and is circulating within national committees and the Consultative Committee on International Telephony and Telegraphy (CCITT). It's based on a proposal by the West German Bundespost that **each country keep its own character set and that international exchanges pass through national interfaces that automatically translate one character set into another** [*Electronics*, Nov. 23, 1978, p. 70].

French minis going to school

French high school students will find themselves sitting before new minicomputers when school opens in October. As part of its **plan to install 10,000 computers in high schools over the next 10 years,** the French education ministry will be buying about 200 minis from Logabax Informatique SA, a Paris minicomputer and peripherals house, and about another 200 from the Société Occitane d'Electronique (OE) in Toulouse, best known for its video games. The Logabax LX 500 chosen handles two minifloppy disks, has 32 kilobytes of random-access memory, and is built around a Zilog Z80 microprocessor. OE's model X1 also handles two minifloppy disks and has 32 kilobytes of RAM in the version selected; it is built around Motorola's 6800 chip. Both sell for about $4,000.

Addenda

The European Space Agency (ESA) has picked **AEG-Telefunken to develop and supply the complete communications system for the European communications satellite** (ECS). ECS, which will simultaneously handle up to either 15,000 voice channels or 11,500 voice plus two television channels, is scheduled to be operational in late 1981 and will be Europe's first commercial communications satellite. Frankfurt-based Telefunken will also participate in the design and production of the communications system for the planned West German television satellite, TV-Sat D. . . . France's mainframe computer company, **CII–Honeywell Bull, is linking up with a systems house** in an effort to capture foreign markets. The joint affiliate of CII-HB and Société d'Etudes des Systèmes d'Automation (SESA) will be called CII-HB Système and will be based in Paris. . . . The Swedish postal and telecommunications authority has contracted with the **Data Systems division of Netherlands' NV Philips Gloeilampenfabrieken to supply about $25 million worth of equipment for Teletex,** an electronic mail system [*Electronics,* Nov. 9, 1978, p. 69].


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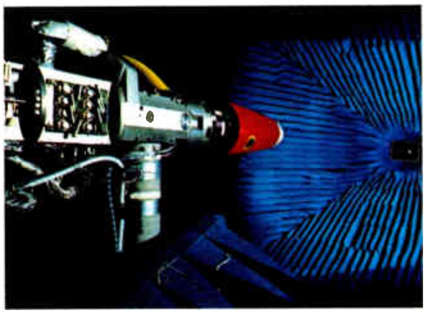
TI is No. 1 in supplying airborne radars to the U. S. Government.

We're currently developing major international markets for these products.

The U. S. Navy's ASW search radars have been supplied by Texas Instruments for more than 20 years. The S-2, P-3 and now the S-3 have all carried TI radar equipment. Other recent airborne developments include the radars for the U. S. Coast Guard Medium Range Surveillance Aircraft and the U. S. Navy's LAMPS Mark III Helicopter.

Related highlights:

- Terrain following radar was invented at TI. The F-111, A7, RF-4 and the European TORNADO rely on TI's terrain following and attack radars for successful execution of their complex missions.
- TI's GPN-24, a transportable airport surveillance and operations center for the USAF, is scheduled for initial production deliveries to begin this year.
- TI also is the leading producer of Air Traffic Control Radars. Our systems serve 400 airports around the world.



TI has produced more than 60,000 items for U. S. Navy and Air Force arsenals.

TI develops and produces complete missile systems. Our high technology provides a strong base for innovative solutions and improvements to existing systems.

We started in 1961 with Shrike, the first operational antiradiation missile. This system has been improved several times and is still effective today. Now we are developing the high performance successor to Shrike – the HARM (High Velocity Antiradiation Missile) program. Our responsibility includes its development, production and integration for multi-service use.

Other Defense Systems:

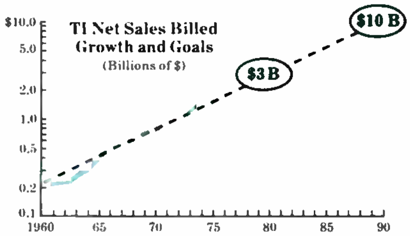
- The PAVEWAY laser guidance kits produced by TI are used throughout the free world for their increased accuracy, reliability and cost effectiveness they bring to conventional munitions.
- The HARPOON antiship missile depends on a TI active radar seeker for terminal guidance.
- Advanced programs for the next generation of missile systems are being developed at TI.

The Advanced Technology Lab is assigned to the future.

The Advanced Technology Lab in the Equipment Group is geared to lead the vanguard of developing technologies. The ATL's potential is boundless. Its job is to look ahead and prepare the Equipment Group for the future of revolutionary yet fundamental products that engineers can build upon for years to come.

The ATL's efforts are divided into five primary groups:

- Antenna Lab
- Microwave Lab
- Microelectronics & Circuit Design Lab
- Manufacturing
- Signal Processing Lab



TI is a worldwide organization into 10 times more technologies than you probably think.

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You're right if you said TI. But you're wrong if that sums up your picture of TI technology.

There's oil exploration. TI is the world's leading independent geophysical contractor.

There's engineered materials. TI is the world's foremost designer/producer of these materials (clad metals for auto trim, for example).

Then there's memory products. TI is a major manufacturer with activity in MOS, TTL, CCD and Magnetic Bubble Memories.

And distributed computing. TI is the leading developer and supplier of the microprocessors and microcomputers that have decentralized the computing and processing functions.

The point is, all this diversity means extraordinary breadth of opportunity for you. (See the back page for a list of TI activities that fit your particular career field.)

And since these are growth activities, we are positioned to grow. TI at year's end 1978 is at $2½ billion in annual sales. Our goal is to be at $10 billion by the late 1980s.

TI gives you technological leverage.

TI's leadership in solid-state technology is an advantage that translates hundreds of ways.

Three examples:

1. Our DABS air traffic control system employs TI distributed computing architecture.

2. Our Loran C receiver and VHF marine radio-telephone for fishing and pleasure boats use TI's advanced microprocessor technology to provide greater capability at lower price.

3. Our new digital scan converter for tactical aircraft radar systems looks tremendously promising as a replacement for existing analog systems. Reason: the new converter employs TI MOS RAM memories that will

substantially improve converter reliability and operating ease while reducing cost.

And there's no company like TI for keeping you involved and advancing.

Examples:

- Unusual career latitude. TI's broad range of career fields gives you internal mobility.
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- Innovators are championed. When anyone at TI needs funding to prove out a good, new idea the money's there. It comes from one of our built-in budgets for revolutionary programs. It doesn't have to be squeezed out of operating expenses.
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☐ Microwave Development	●	●		
☐ Logic Design	●	●	●	
☐ Signal Processing	●	●	●	
☐ Production Control				●
☐ Manufacturing Engineering	●	●	●	●
☐ Engineering/Control	●	●	●	●
☐ Computer Software	●	●	●	
☐ Assembly Methods				●
☐ Computer-aided Design	●	●	●	
☐ Computer-aided Testing	●	●	●	●
☐ Aerodynamics	●			
☐ Control Systems	●			
☐ Applied Mechanics	●			
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☐ Digital/Analog Circuit Design	●	●	●	
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Degree(s)

GPA   Date of Graduation

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From   To   Position

Description of duties

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SY2142	200-450nsec	500mW	1024x4	20 pin
SY2142L	200-450nsec	350mW	1024x4	20 pin
SY2142LV	200-450nsec	350mW	1024x4	20 pin
SY2101A	250-500nsec	275mW	256x4	22 pin
SY21H01	175-200nsec	450mW	256x4	22 pin
SY2111A	250-500nsec	275mW	256x4	18 pin
SY21H11	175-200nsec	450mW	256x4	18 pin
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Circle 66 on reader service card

CRT slims down for pocket and projection TVs

by Kevin Smith, London bureau manager

Placing the electron gun to the side of the screen cuts thickness and makes for a brighter image

After more than a decade of unrewarding research, the thin cathode-ray tube looks set to go into volume production. It has finally been perfected by a small British company, Sinclair Radionics Ltd., which plans to use it first in a pocket TV-radio with a 3-inch-diagonal black-and-white screen [*Electronics*, July 5, p. 67].

Clive M. Sinclair, founder and director of the St. Ives, Huntingdon, company is now completing a joint-venture agreement with a larger firm to establish a manufacturing plant for the new tube. First sets should be on the market within two years.

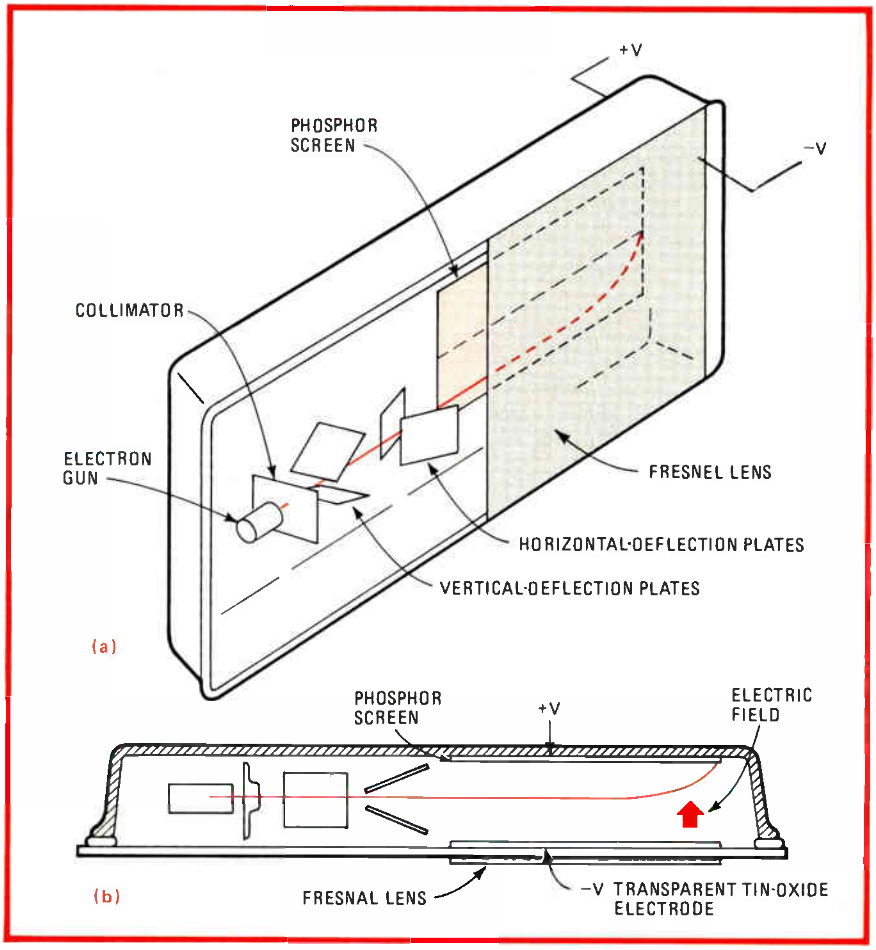
Sinclair also sees a big future for its tube in projection TVs. The high brightness attainable with the thin CRTs makes them ideal for use in such systems, and the firm foresees a three-tube projection TV with a 50-in.-diagonal full-color display. The optics and electronics could fit into a shoe-box–sized unit projecting onto a wall-mounted screen.

A single-tube full-color pocket TV is also planned, but so far only a black-and-white prototype has been developed. "We have no plans to compete with conventional CRT television," Sinclair cautions.

History. Attempts to develop a practical flat CRT go back to the 1950s. The one practical system to have emerged was devised by William Ross Aiken at Kaiser Electronics and Aircraft Corp. in the U. S. and required a high-voltage switching system. (Elsewhere, RCA Laboratories in Princeton, N. J., is currently working on using a traveling-wave structure to guide and extract the electron beam.)

Tony Krause, who now heads Sinclair's flat-screen development group, began working on the Aiken tube in the late 1960s while chief engineer at Twentieth Century Electronics Ltd. [*Electronics*, Jan. 20, 1969, p. 197]. After leaving the company, he developed a simpler version, but his latest thin CRT did not emerge until he teamed with Clive Sinclair to develop a tube for Sinclair's pocket TV.

The end product has evolved



Thin. Sinclair Radionics places cathode-ray tube's electron gun to the side of and in parallel with the phosphor screen (a). A transparent coating of tin oxide on the front plate forms focusing electrode that guarantees a circular beam spot on the screen (b).

significantly from the Aiken tube and is startlingly simple. Measuring some 6 by 2 by 3/4 inch, it is three times brighter, requires between one quarter and one tenth the power, and is half the volume of a conventional CRT with the same size screen, according to Sinclair.

One-sided. It is assembled from just two sheets of glass, a flat front plate and a vacuum-formed backing plate (see figure). The phosphor screen is coated on the interior of the backing plate and is viewed through the front face from the same side that the electrons strike. As a result, the brightness is more than double that of a conventional CRT with the same beam energy.

The electron gun is set to one side of the screen with its axis parallel to the screen. Two sets of electrostatic deflection plates in the gun assembly provide horizontal and vertical scanning, and a third set between the phosphor screen and front face bends the electron beam toward the screen. Without this additional focusing field, the angle of beam incidence would vary across the screen, spreading the beam spot into an ellipse. The focusing electrode is formed on the front face by a transparent tin-oxide coating.

If uncorrected, folding the electron optics would distort the raster scan to produce a keystone-shaped frame, in which the vertical edges are curved and the horizontal edges form the sides of a trapezium. Krause uses both electronic and optical techniques to correct for this distortion.

First, the screen height is reduced by as much as a half but the width kept constant. This narrows the angle subtended by the electron beam onto the screen, reducing both the distortion and the deflection power. The picture height is restored optically by means of a Fresnel lens, which can be inexpensively formed in a flat plastic faceplate. The trapezium distortion is eliminated by applying a correcting modulation to the vertical plates.

The tube assembly lends itself to low-cost mass production and has significantly fewer components than a conventional CRT, Sinclair says. Connections to the electron gun and deflection assembly, for example, are screen-printed onto the faceplate, and the assembly is attached in a single operation by a conductive frit.

This basic tube can be easily modified for projection TV systems. Both for cost and for optical reasons, a projection tube should ideally be as small as possible yet must be driven hard to achieve a bright projected image. The cooling problems to prevent phosphor damage are severe in a conventional tube, but since with Sinclair's CRT the image is viewed from the side of the phosphor that the electrons strike, the other side of the screen can be connected directly to a heat sink.

Japan

Amorphous AsTeSe thin film promises 20,000 pages on an optical disk

Direct read-after-write laser recording of 500 megabytes of information on a single 12-inch optical disk is the aim of researchers at Hitachi Ltd.'s Central Research Laboratory. The disk will be used to store files of 10,000 to 20,000 facsimile pages initially and perhaps as many as 50,000 with further improvements.

The researchers are confident they will soon achieve their goal. They are already able to store 30,000 TV frames having a bandwidth of 8 megahertz and a signal-to-noise ratio of 45 decibels.

Film. Key to the ability to record high-quality frequency-modulated TV signals on the disk is an arsenic-tellurium-selenium amorphous chalcogenide thin film deposited on a polymethyl methacrylate (PMMA) disk. The film allows clean holes with minimal irregularities around their periphery to be made with a 10-to-20-milliwatt laser. The smoothness of the shape of the holes, which store the information, makes for a high signal-to-noise ratio. Storage of 20,000 pages would be possible by switching to digital coding and using one of the redundancy-reduction schemes now popular for digital facsimile transmission.

In Hitachi's system, one of many such being worked on around the world, data is read out by a smaller laser than the one used for writing. Initial work has been done with argon lasers operating at about 4,880 angstroms for writing, but practical systems will most likely use a semiconductor laser operating at 8,200 to 8,300 Å. The lab has developed two suitable types—a buried-heterojunction laser and a channeled-substrate planar laser.

The disk has a track pitch of 1.8 micrometers. Laser power, beam diameter, and film material are adjusted so that the laser would burn round holes having a diameter of about 0.8 or 0.9 μm in the film if the disk were stationary. However, since the disk rotates at 1,800 revolutions per minute when recording TV frames, the holes are elongated.

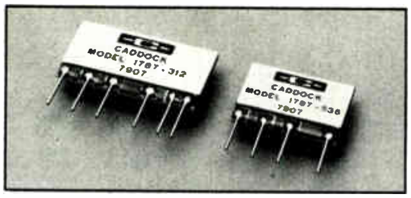
For digital recording of printed data, different parameters give the best performance. For one, the disk speed is slowed to 240 rpm. Thus the holes formed are approximately circular, because elongation at this lower speed is insignificant. The result is a gross data capacity of 1,000 megabytes, but about half that must be used for an error-correcting code to achieve the desired error rate of less than 1 in 10^{10}.

Stretched. The amorphous material used by Hitachi partially evaporates when hit by the laser beam, but the evaporated material accounts for perhaps only one fourth of the size of the hole. Melted material is pulled away by surface tension, thus forming a smooth edge, although with a slightly elevated rim. Reflection from the film is steady for the desired low noise level.

An advantage of the three-component compound is that changes in composition do not significantly

Current sensing resistors for multi-range instruments.

NEW



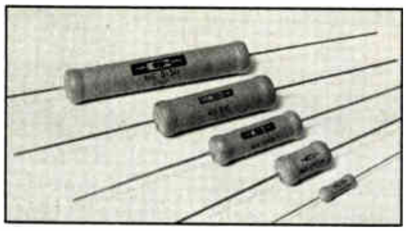
Caddock's Type 1787 Current Shunt Resistor Networks.

Absolute resistance tolerances of 0.25%, 0.1%, 0.05% and 0.02% make these 2-, 3- and 4-decade current shunt resistor networks the ideal replacement for expensive, bulky discrete resistors.

16 standard models are now available. The basic network design provides a series total resistance of 1000Ω, 100Ω, 10Ω and 1Ω. Other standard models provide commonly used variations of this basic design.

For Type 1787 data, circle Number 201.

Non-inductive precision resistors for power switching circuits.



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Caddock's patented Non-Inductive Design in power ratings from 2 watts to 15 watts assures minimum voltage transients in all types of power switching circuits.

High stability Micronox® resistance films operate to +275°C and years-long load-life tests demonstrate extended-life stability better than 0.05% per 1000 hours.

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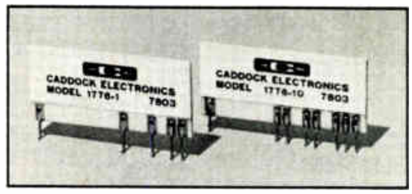
Off-the-shelf precision decade voltage dividers.



Caddock's Type 1776 Precision Decade Resistor Voltage Dividers.

When used as a 10 Megohm input voltage divider, the Type 1776 family can provide high accuracy voltage division in ratios of 10:1, 100:1 and 10,000:1.

Type 1776 Precision Decade Resistor Voltage Dividers are now available in 25 standard models with ratio TCs from 50 ppm/°C to 5 ppm/°C. Caddock's laser production techniques keep OEM quantity prices low, too.

For Type 1776 data, circle Number 205.

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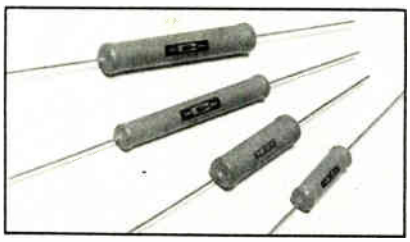

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High voltage probes and control circuits make wide use of Type MG resistors for precision high voltage regulation and high voltage measurements.

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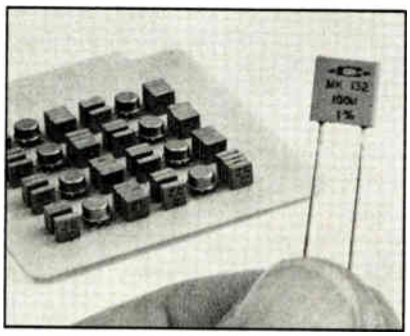
100 Megohms in a miniature package.



Caddock's Type MK Precision Film Resistors.

Precision values to 100 Megohms in a miniature CK 06 case make the Type MK ideal for low current designs.

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NEW

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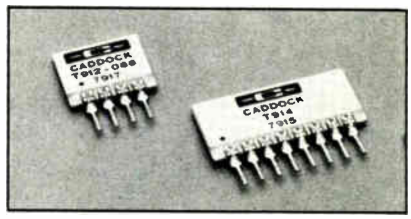

Caddock's Type T912 and T914 Precision Resistor Networks.

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Other groups have used thin films of bismuth or tellurium, but these materials tend to crystallize. What's more, the scattering of light reflected from the film's surface makes for high noise, and jagged, partially recrystallized edges around the holes also produce high noise.

As for the materials used by Hitachi, tellurium has good reflection characteristics; arsenic suppresses the tendency of the tellurium to crystallize; and selenium, though it has poor light absorption, making it hard to record on, minimizes the effects of air on the film and thus increases its stability. -Charles Cohen

West Germany

C-MOS switches, bi-FET op amps help shaft-angle encoder cover full 360°

In today's world of microprocessors and other sophisticated solid-state devices, electromechanical components seem to be leading a shadowy existence, with innovations few and far between and none too spectacular. A closer look, though, shows that significant advances are still being made. One example: a shaft-angle encoder design from Novotechnik KG, a small West German firm in Ostfildern, near Stuttgart.

It is about to go to market with a relatively inexpensive digital absolute angle encoder whose novel design results in several noteworthy performance characteristics. Operating continuously over either 360° or 2,880°—the latter corresponding to eight revolutions—the device uses a potentiometer whose life is five times longer than that of most other pots [*Electronics*, May 24, p. 224].

Also of note is the encoder's microprocessor compatibility. The device's output, processed into an uninterrupted sawtooth voltage, is fed to an analog-to-digital converter to produce straight-binary signals for a microprocessor in the control system of, say, a machine tool.

Three. Essentially, three factors are responsible for the encoder's high performance, says Ernst Gass, Novotechnik's president. One is a new potentiometer technology, another the use of highly accurate, fully integrated a-d converters, and the third the application of complementary-MOS analog switches and of operational amplifiers built with bipolar and field-effect transistors.

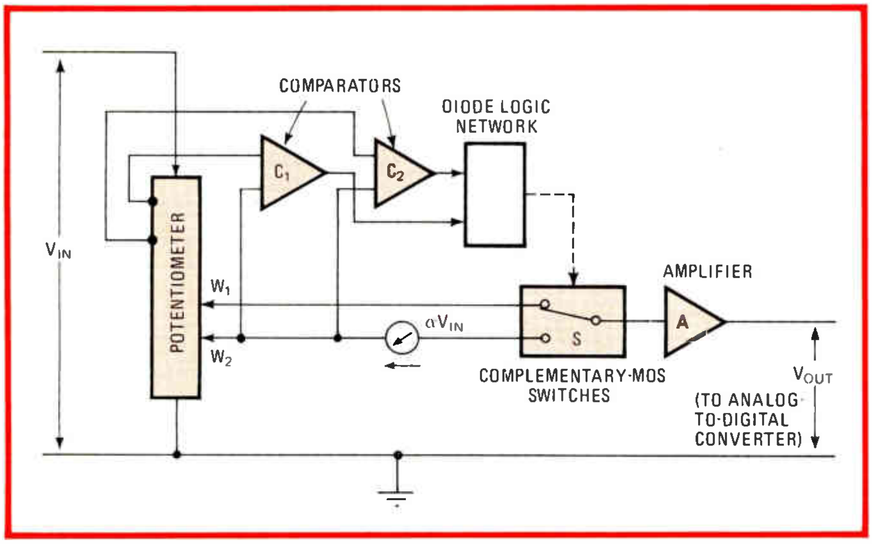
Use of C-MOS analog switches and bi-FET op amps enables the pot to operate over a full 360° and put out an uninterrupted sawtooth signal quickly and accurately. This continuous output is obtained by using two wipers that are offset by about 45° and by switching the two wiper voltages in a sequence that ensures a continuous output.

Switching. Because of the pot's high speed, the switching process must occur within 5 microseconds or so. The basic principles involved can be seen in the block diagram.

Assume that first the voltage at wiper W_1 is picked off and fed through switch S and amplifier A to the output. When wiper W_2 reaches the resistor tap of comparator C_1, this comparator, operating through a diode logic network, sets the switch such that the voltage at wiper W_2 goes to the output. The difference voltage between W_1 and W_2 is added to the W_2 voltage. When wiper W_2 reaches the tap of comparator C_2, the switch goes back to the W_1 position (up). Thus an uninterrupted output is obtained from the pot.

Employing a fully integrated a-d converter made it possible to convert the pot's output voltage into a digital output with an absolute accuracy of as high as 14 bits. A reference voltage derived from the converter feeds the potentiometer. By using a voltage ratio rather than an absolute-voltage value as the basis for voltage pickoff and measurement, the effects of temperature-coefficient problems are eliminated.

Dampened. To obtain high pot performance, Novotechnik uses a few strikingly simple design and construction techniques. The long life is achieved by partly covering the pot's multifingered wiper with silicone. That dampens the oscillations of the wiper so that it stays on the resistive element and does not bounce up and down. Consequently, pot reliability reaches about 50



Full circle. Shaft-angle encoder from Novotechnik uses a high-performance potentiometer, complementary-MOS switches, and bi-FET operational amplifiers for complete 360° coverage. Switching between the voltages of two wipers ensures a continuous output.

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France

Crystal reads back hologram instantly

No doubt holograms in coherent optical systems would be used for many more purposes if it were not necessary to expose and develop photographic plates to realize them. Consequently, researchers at Thomson-CSF's Laboratoire Central de Recherches (LCR) expect their new method of making real-time holograms to be used one day for various applications in the fields of nondestructive testing, optical computing, and adaptive optics.

The method: an electro-optical crystal registers and reconstructs a coherent object wavefront [*Electronics*, July 5, p. 68].

"For real-time holography, we looked for a material that could register interference patterns and afterward be erased without fatigue at the same energy levels used for photographic plates," explains Jean-Pierre Huignard, who heads the group working in advanced optical components and technologies at LCR in Corbeville, southwest of Paris.

The search led to bismuth silicate (usually called BSO), a material used for acoustic surface-wave devices. "Monocrystal BSO has the optical quality needed," Huignard points out, "and it has two other essential characteristics—it is photoconductive and it has a linear electro-optical effect."

The company released some details on the technique in early July at the Laser '79 Exhibition in Munich. The optical setup it uses is conventional. Light from a laser is split into two beams, with one of them reflecting off the object being "holographed" and the other acting as a reference. The two beams are directed onto a thin slab of BSO crystal and form a fringe pattern inside it.

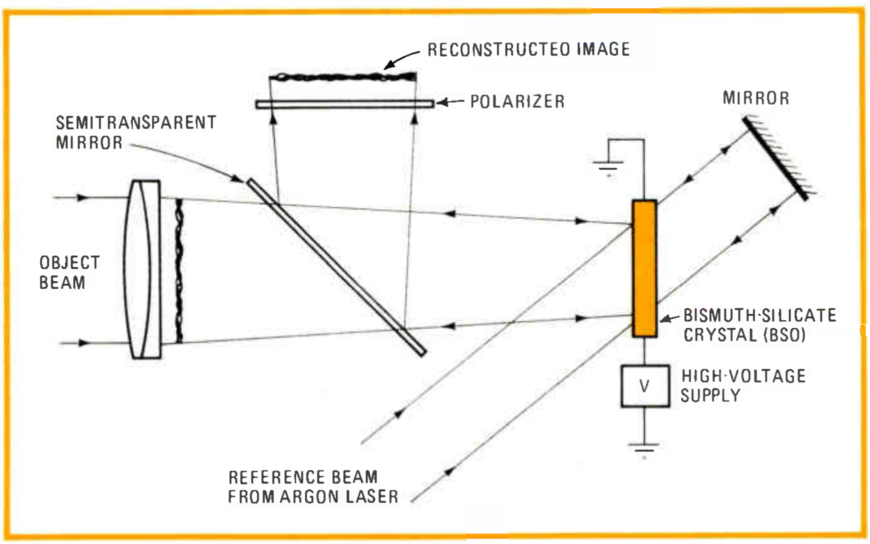
Theory. The theory that explains how the bright-and-dark pattern registers in the crystal is fairly complex. Essentially, the hologram appears because, in the bright fringes, electrons released from donor centers are driven by an external applied voltage. The electrons are trapped at sites where the crystal is less conductive—that is, where there is less incident light. These changes in the local electric field lead to a space-charge field that modulates the crystal's refractive index because of its linear electro-optical effect.

For the optimum effect, the field is applied transversely; a typical value is 6 kilovolts per centimeter. The optimum slab thickness is between 2 and 5 millimeters, and slab faces have ranged in size from 1 by 1 cm to 3 by 3 cm.

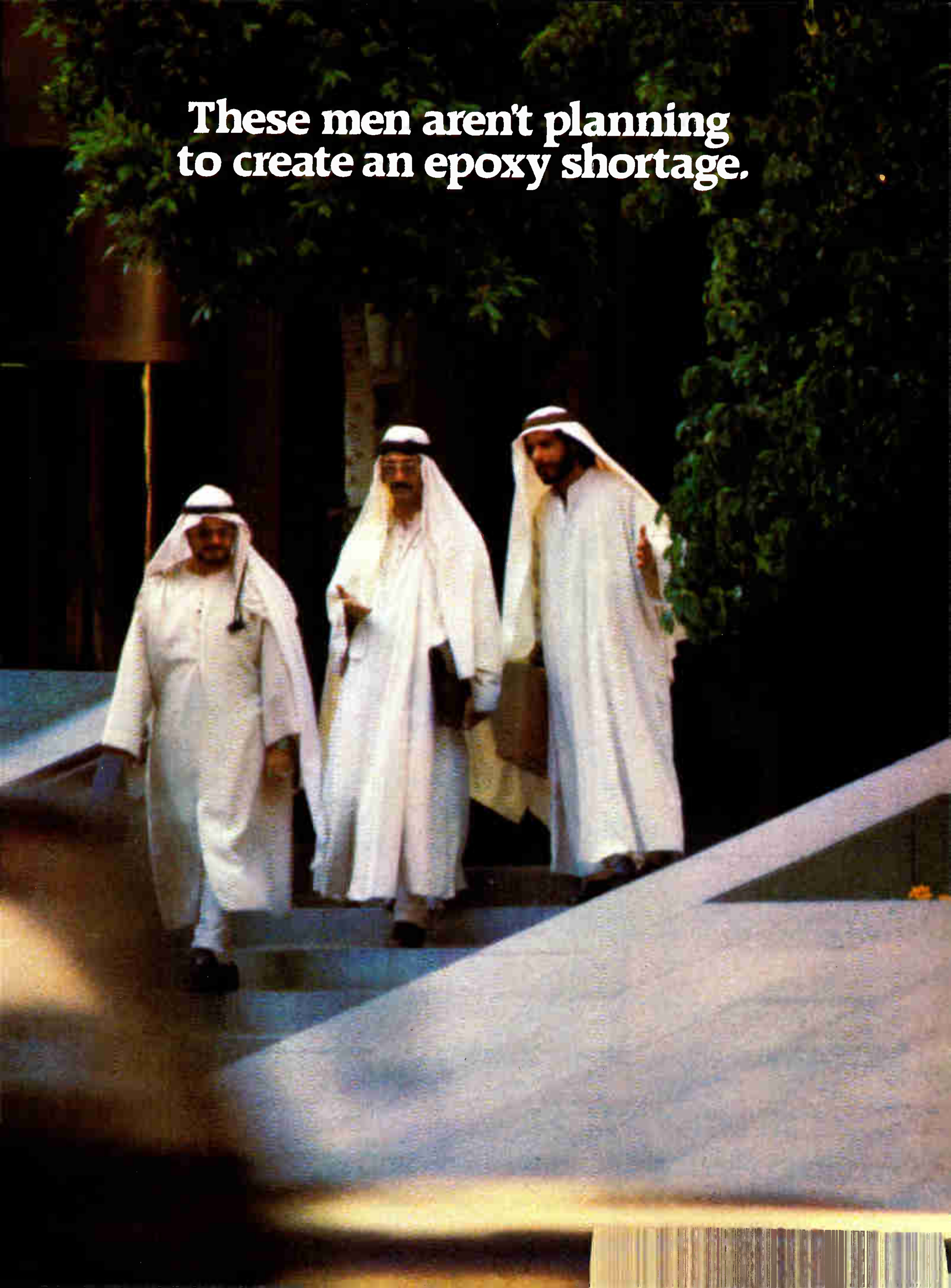
Timing. It takes about 25 milliseconds to read in a hologram, using an argon laser at a recording energy of between 100 and 300 microjoules per square centimeter. That is about the same energy needed to expose the photographic plates first used for holography, Huignard points out, but well above the 10-μJ/cm^2 ratio of the latest plates. The pattern disappears after some 40 ms if the crystal stays lit by the reference beam only; the dark storage time is about 20 hours.

To read out, the group uses a mirror placed behind the BSO slab so that it reflects the emerging reference beam back through the slab to illuminate the hologram (see figure). Since the reconstructed phase-conjugate hologram wavefront has a polarization rotated 90° from the incident object and reference beams, a polarizer blocks out any noise in the reflected beam. If the incident object wavefront has passed through a phase-disturbing medium, the distortion will be canceled out as the phase-conjugate wavefront generated in the crystal travels back through the medium.

Another possibility is to read out by a storage camera tube two holograms of the same object taken in rapid succession using a laser flash about 30 ms long followed 15 ms later by another of the same duration. The superimposed holograms show dimensional changes in the object with a resolution of about 0.5 micrometer. -Arthur Erikson



Real timing. Using a bismuth-silicate crystal known as BSO, Thomson-CSF researchers can produce a hologram in real time. Display is accomplished with the aid of a mirror placed behind the crystal to reflect the emerging reference beam back through it.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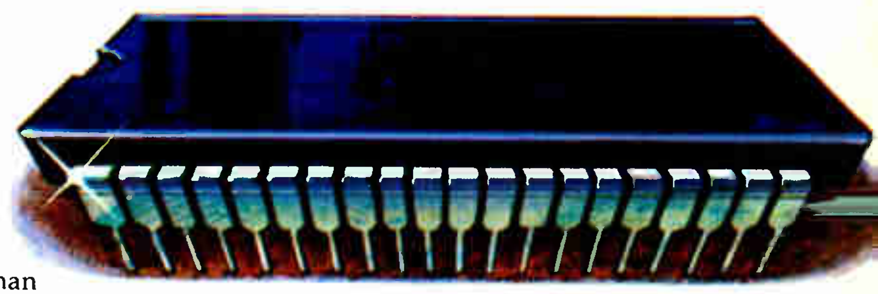

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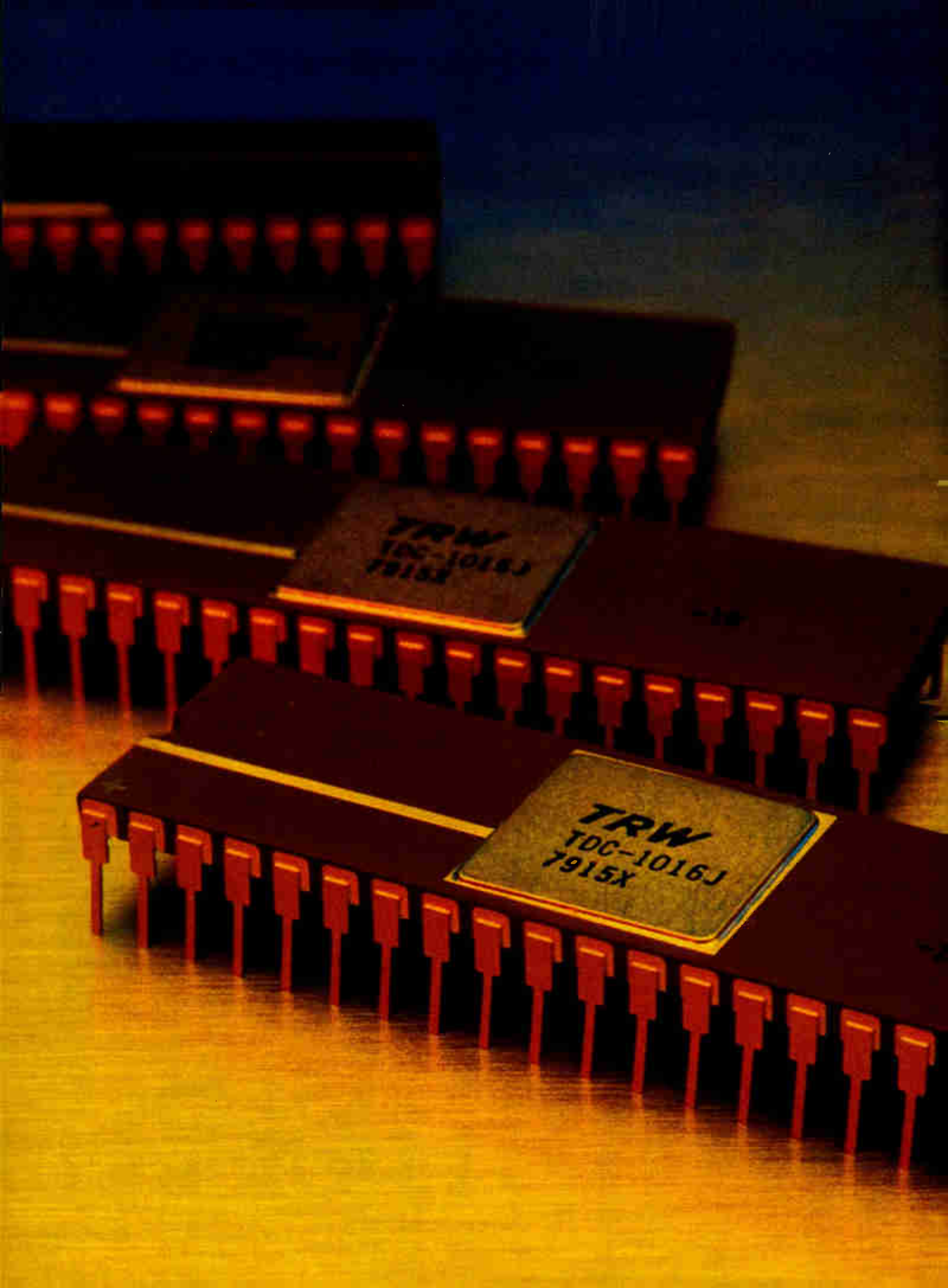
Circle 75 on reader service card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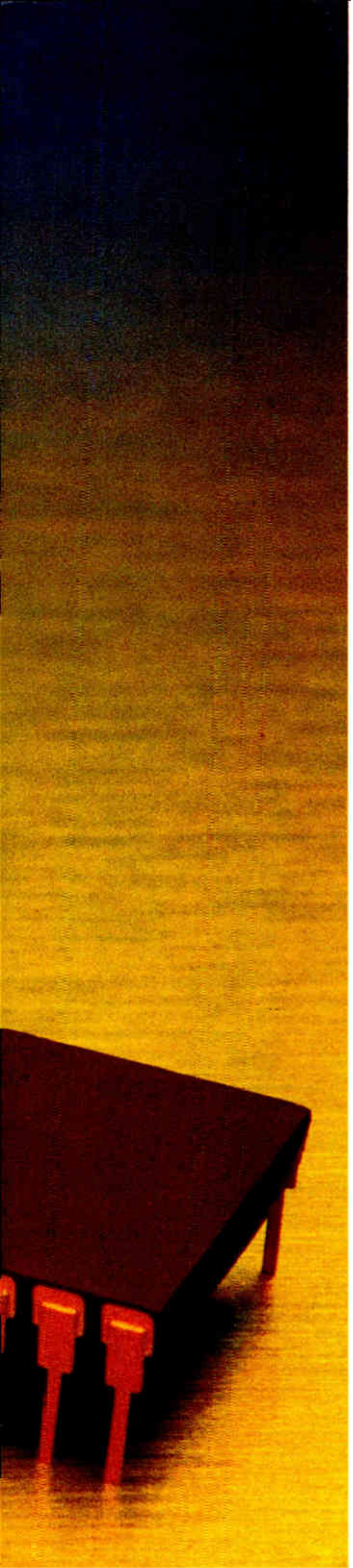

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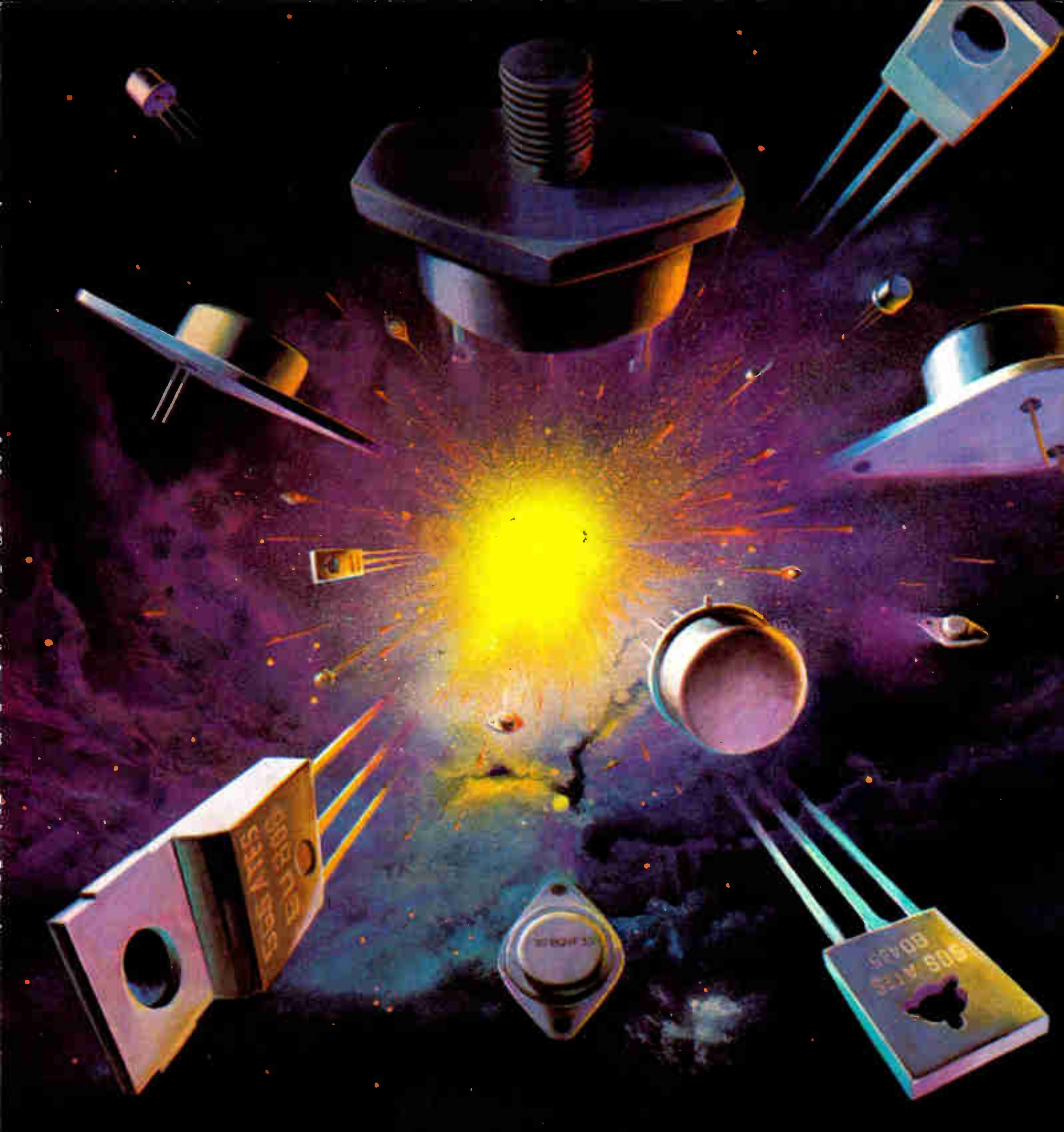

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Word and data processing merge

Not just fancy typewriters, word-processing equipment is getting more data-processing capabilities via software packages

by Gerald M. Walker, Managing Editor

The office automators are on the move again. Having bedazzled the secretarial world with an assortment of sophisticated equipment to speed the text editing of correspondence, the word-processing companies are now focusing on integrating managers into new systems that merge data processing with the generation of correspondence.

It adds up to another step toward the so-called office of the future envisioned for the past decade. But while the trend of combining word- and data-processing capability in the same equipment is proceeding, so is the controversy as major equipment vendors race to produce systems.

The competition has already increased, although industry observers concede that IBM's Office Products division, Franklin Lakes, N. J.; Xerox Corp.'s Office Products division, Dallas, Texas; and Wang Laboratories Inc., Lowell, Mass., continue to dominate the field. New in the market are such data-processing firms as Nixdorf Computer Corp. in Burlington, Mass.; Compucorp in Los Angeles; and Four Phase Systems Inc. in Cupertino. Even Digital Equipment Corp. in Maynard, Mass., has been attracted by the growing demand. Text-editing equipment alone was estimated to be worth $800 million in 1978, according to New York market research firm Quantum Science Corp. By 1983 this product category, which does not include duplicating equipment, will amount to $2.2 billion.

Automating managers. The reason for this move is the desire to get the high-priced end of the office into the system—the managers. Though most of the effort, so far led by IBM, has been lavished on text editing, an increasingly expensive part of producing paperwork, executives' time is also valuable. However, the vendors are not yet certain how to tailor programs for the boss. Thus the competition will center around software rather than hardware.

Indeed, San Jose, Calif.–based market research and consulting firm Creative Strategies Inc. in a five-year forecast of this industry predicts that no major technological innovations will radically change office organization. Instead, the firm sees increased importance for what vendors are calling multifunction terminals and an increased need to integrate word-processing and photocomposition equipment. Whether as stand-alone terminals or as part of a distributed network, the hardware will require communications ties. The main difference is that the manager, in order to be in the loop, will likely need a desktop terminal.

Probably the strongest advocate of

Office of the present. Wang's Office Information System/125 is part of the firm's all-out effort to merge word and data processing. It holds up to 2,000 text pages.

the new merger is Wang Laboratories, which has introduced machines and software with a wide range of office applications, including electronic mail. "Office management and data-processing management are not interested in typewriter replacements," comments James C. Lawlor, manager of word-processing systems marketing for Wang. "They are interested in systems to help management across the board, and that market is growing well."

To carry out its campaign to lead this market, Wang has developed a line called Integrated Information Systems that pulls together word-processing, data-processing, telecommunications, graphics, and high-speed image-printing technologies. In this group is the VS/WP, which uses the company's new virtual storage computer and various word-processing peripherals. The merger is apparent in that the computer can perform word- and data-processing tasks with up to 4.6 billion bytes of on-line storage. On the other hand, the terminals have typewriter keyboards to emphasize ease of use.

Wang also has an OIS/Basic office information system that permits concurrent operation of word processing and Basic data processing from a cathode-ray-tube display terminal. Users are able to program data-processing applications, as well as combined word and data processing, using modified Basic.

IBM, which has based its lead in word processing on magnetic-card electronic typewriters, is also in on the latest trend with its 6670 Information Distributor. It combines word- and data-processing applications, text editing and processing, and copying by laser printing. The 6670 can print multiple sets of documents at speeds up to 1,800 characters per second. And it can link terminals to data-base computers.

Skeptics. Though other word-processing companies appreciate the merger trend, some view Wang's all-out campaign as overkill. "The question of how fast this merger takes place is a matter of how simple it is," remarks Donald Roth, a product manager for Xerox's Office Systems division. "For users still at the text-editing level, using data-processing procedures is a big jump."

Agreeing, Walter Blejwas Jr., vice president of engineering for Vydec Inc., Florham Park, N. J., observes, "Producers have not really thought the thing through yet. It's going to take a learning process between the vendor and the users to get systems that fit the needs. Definition of the problem is more important at this stage than hardware design."

Vydec's two new machines, underscoring ease of software loading and communications via a fiber-optic link, point the way. Also leaning on software to make the transition from word processing to multifunctions is NBI Inc., a fast-growing firm in Boulder, Colo. Still rooted in word-processing-like functions, the NBI programs include an equation mode for scientific and technical documentation, a statistical mode for accounting, and a communications mode using an asynchronous protocol for information receipt and transmittal of up to 9,600 bits per second.

Leery of going overboard in data processing, NBI vice president for business development David Klein points out, "Data and word procession are mismatched. One operates on batches, the other on real-time information. Input speed and file size don't compare, either. But word-processing users have some data-processing needs that can be done on a software-based machine."

Also making a cautious move into the merger is Lexitron Corp., Chatsworth, Calif., a Raytheon Co. subsidiary. Pointing to a joint venture with the parent company using a minicomputer-based distributed network for word-processing chores, Joseph E. Eichberger, planning vice president for Lexitron, says that the first step in finding out what the user needs is to break down the barriers between departments. "With the Raytext system we will attempt to cut across the two users. They have different demands but need cross-coupling."

The need for merged systems has existed for some time, but because of the internal organization of companies, no one has pushed it, according to Gerald Baugh, marketing administrator for Lanier Business Products Inc., Atlanta. Although Lanier has only recently made a concerted bid to get into the text-editing side of office automation after surging ahead in dictation equipment, the firm is now planning an effort in multifunction hardware. Baugh expects that new technologies, such as voice synthesis and voice recognition, will play a part in the next generation of equipment. □

The paperless office: it works

Though everyone likes to talk about the office of the future, Micronet Inc., a management consulting firm in Washington, D. C., did something about it. Using hardware and programs provided by 17 sponsors, Micronet has redesigned its paper-handling procedures to virtually eliminate the paper.

The objective was to improve office productivity by using today's technology. All information entering the company is captured in the mailroom either on microfilm, if it is lengthy, or in computer memory, if it is shorter. Users retrieve the information from an automated microfilm system or directly from computer terminals. Outgoing correspondence leaves on paper, but "copies" are maintained on microfilm. All dictation is done on an automated system that is also capable of monitoring its use so that information is not inadvertently lost.

Does it work? Reports Larry Stockett, president of Micronet, "Benefits come at different points in the office automation cycle. If I can improve my efficiency by 5%, it can increase the bottom line by 30%. And that pays for the system."

Micronet does not sell any of the hardware, but is promoting the paperless concept. A key factor in its office is that all types of equipment are involved, including a minicomputer-based central processing system and a time-shared computer service. The company uses 16 different types of microfilm readers, for instance, depending on how and where the user wants to display the information.

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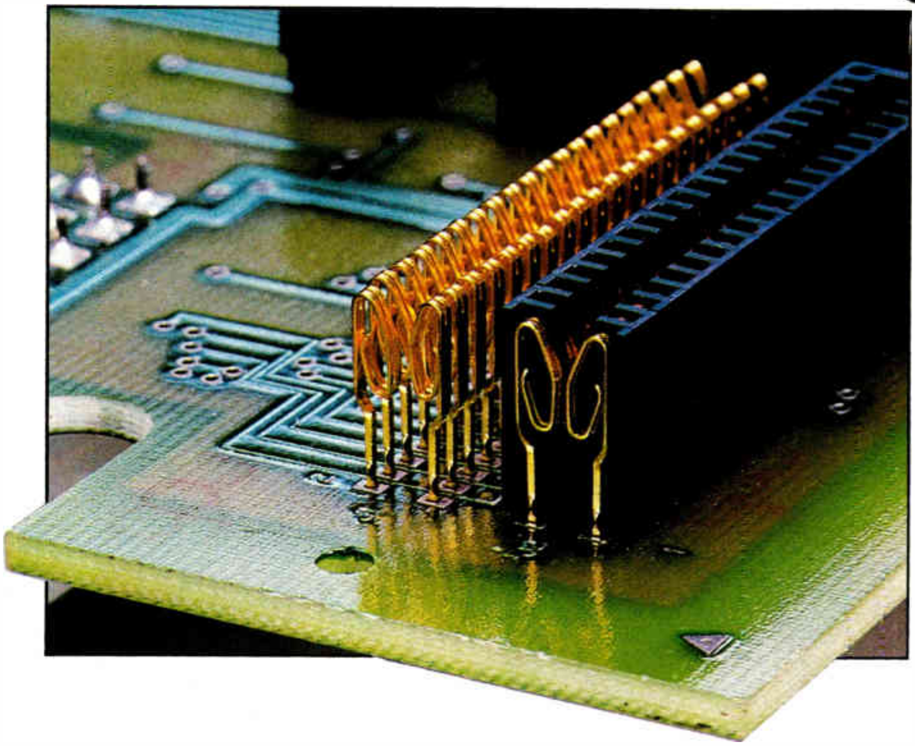

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Circle 84 on reader service card

Peripheral chips

Chip makers ride CRT controller wave

Rush to fill sockets with LSI starts as forecasts indicate market will double to 2 million units a year by 1981

by William F. Arnold, San Francisco regional bureau manager

A worldwide expansion in demand for cathode-ray-tube terminals, sparked by the growing number of data- and word-processing systems, is creating another bonanza for semiconductor manufacturers. The reason is that CRT terminal makers are turning to large-scale integration for the control functions so that fewer components will lower manufacturing costs and hike the number of features easily put into products.

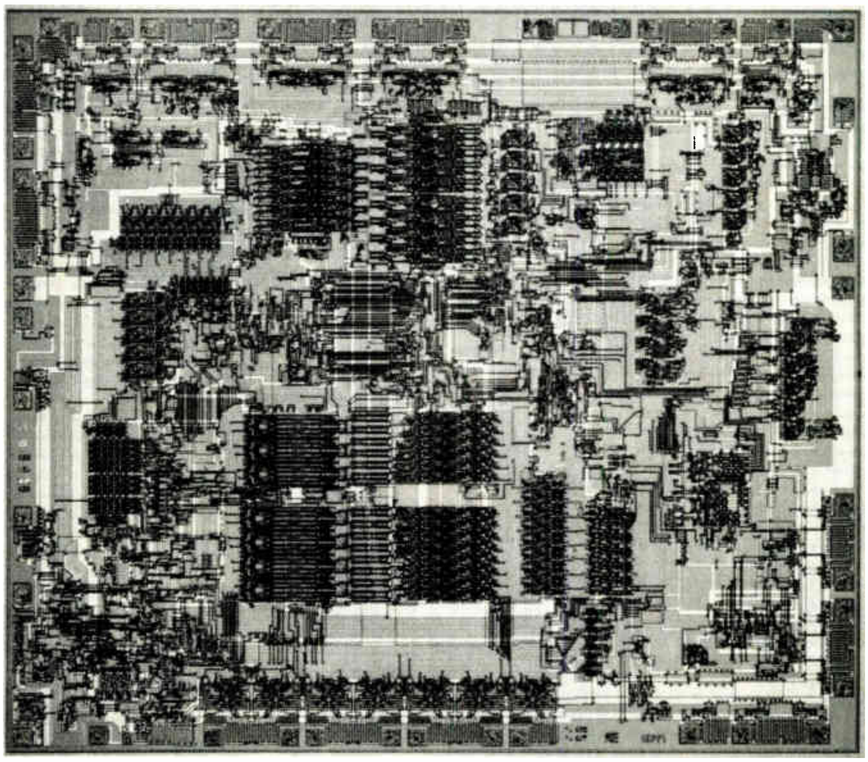
Helping this trend is the need of terminal makers to differentiate their products from those of the competition in an international market that will grow from 750,000 units last year to 1.2 million this year, 1.6 million in 1980, and more than 2 million in 1981. Obviously, using LSI saves a lot of component costs in a marketplace where, for example, a low-end terminal can have 50 or more small- and medium-scale integrated parts and less than half that made with LSI.

Also fueling the fever are emerging markets in replacements for teletypewriters, ticker tape, and almost any device in which paper is now used, according to James J. Ferrell III, strategic product marketer at Motorola Semiconductor Group. "Any type of communication can be done with a CRT," he says. "It's much faster and saves paper."

Newcomers. This kind of action attracts competitors for the early leaders in CRT controller chips, Intel Corp., Motorola Inc., National Semiconductor Corp., and Standard Microsystems Corp. For example, Synertek Inc. and American Microsystems Inc. are joining Hitachi Ltd. as an alternative source for Motorola's n-channel MOS MC6845 CRT controller. In a somewhat novel twist, Rockwell International Corp.'s Microelectronic Device division will second-source Synertek's version of the Motorola part. Texas Instruments Inc. already second-sources SMC's 5027 device, and Signetics Corp. plans a proprietary n-MOS 2672 programmable video-timing controller chip later this year.

Also aiding interest in CRT controllers is that they help support a company's microcomputer line. That is underlined by Advanced Micro Devices Inc.'s intention to have an AmZ8052 controller chip for the 16-bit Z8000 in early 1981.

But satisfying the market is not easy. For one thing, "there's no one way to build a CRT terminal," observes Alan Goldberger, Signetics' manager of MOS microprocessor applications. That is a point with which Donald Phillips, marketing manager of peripheral products for Intel's Microcomputer Components division, agrees. They mean that, because each terminal manufacturer tends to have its own circuit design and specifications, it is hard to equip a chip with everything everyone wants. Conversely, sometimes the semiconductor technology determines functions. For instance, AMI



In control. This 6545 CRT controller chip from Synertek allows much easier transparent addressing of the refresh RAM. It is compatible with the 6500 and 6800 microprocessors.

omits a dot generator from its upcoming 68045 because "you can't do it in n-MOS," according to Mitch Gooze, marketing and applications engineering manager.

Moreover, the market, supplied by several major terminal makers and numerous smaller ones, is composed of three basic types of products—although the lines separating them are admittedly fuzzy. The low end are dumb terminals: teletypewriters with no internal intelligence and limited control features. Smart terminals have some intelligence, maybe for internally editing, storing, and rearranging data and for some control over the display and cursor. The high-end—intelligent—terminals are almost small computers with floppy-disk peripherals, internally programmable functions, and such display features as scrolling, full cursor control, and upper- and lower-case characters.

Thus, as CRT terminals become more intelligent, the user is apt to find more combinations of such features as programmable screen formats, split screen, page or scroll operation, interlacing, and capabilities for light pen, forms, and graphics, plus a variety of visual attributes, including blinking, underlining, and reverse video.

Money talks. For terminal makers, LSI is about 20% of the total material cost, a significant but not overwhelming proportion. That makes "cost No. 1 in buying LSI," according to George M. McFadden, vice president of engineering for Lear Siegler Inc.'s Data Products division in Anaheim, Calif. His definition of an intelligent terminal is simple: "The customer can program it himself." Lear Siegler does not have an intelligent terminal yet but is looking hard at it, McFadden says.

In designing CRTs, Lear Siegler holds that "the communications line always has the highest priority, handling the incoming data." So in looking at prospective chips, its designers focus on data-interrupt handling and select chips that perform best. They sketch out the architecture around this feature and "then go out for bids." Lear Siegler is constantly looking at offerings from Motorola, Zilog, and Mostek, among others, and "assumes all their parts will do the job." But there are always tradeoffs to be considered, since there is no ideal chip set now and none coming, McFadden says.

At Digital Equipment Corp. in Maynard, Mass., Edward R. Lazar Jr. points to the VT-100 series of terminals. Lazar, corporate product manager for video terminals and small systems, says, "The VT-100 shows the trends toward intelligence and the use of custom LSI chips. In the VT-100, LSI has allowed a 5-to-1 reduction in chip count."

Typical of the upward progression of terminals is Data General Corp.'s new Dasher D-111. Says Martin L. Cooper, product manager for character peripherals at the Westboro, Mass., firm, "The D-111 uses an LSI approach to keyboard encoding that allows us to get international character sets just by changing one chip and the appropriate keypads."

With this much spread of functions and designs, how do chip makers approach design? "We see it as a low-end problem," declares Charles Carinelli, design section leader in interface circuit development at National's facility in Santa Clara, Calif. The firm took an unusual tack by designing mask-programmable–read-only-memory controllers with a bipolar technology, combining integrated injection logic, Schottky TTL, and standard linear circuitry on one chip.

Also going the mask-programmable route is AMI, whose Mitch Gooze claims its 68045 will be "the first and only MOS mask-programmable CRT controller." In second-sourcing Motorola, AMI feels it is backing a very good part but believes it may have a price advantage by leaving the light-pen registers off the chip. That more than halves the die size, even with conservative 5-micrometer geometries, and drops the price to well below $10, Gooze says.

Some extras. Synertek takes another approach to second-sourcing Motorola's part by coming out with a plug-compatible controller that has extra features, according to Gary J. Summers, formerly director of the Microprocessor Group and now vice president of engineering with Commodore Business Machines Inc. in Palo Alto, Calif. Directly compatible with Motorola's device, Synertek's 6545 does not need memory contention circuits; it has an internal status register so that the central processor can check on the CRT controller's status; and refresh memory address can be either binary or row and column.

Motorola and Texas Instruments, which second-sources SMC's 5027, take a more elaborate approach by incorporating various on-chip registers users can program with characters, line width, and so on. □

Is Superchip the answer?

Some terminal makers wonder whether what they call a super chip might be the answer to the increasing sophistication of cathode-ray-tube controllers. The technology exists to build it, observes Brian Cayton, applications manager at Standard Microsystems Corp. in Hauppauge, N. Y., but it is not yet economical to produce it. And John F. Jacobs, director of systems hardware development at neighboring Applied Digital Data Systems Inc., comments that "the problem with one big chip is that eventually you become pin-limited in the number of functions you can get in and out simultaneously," which would have to be solved by multiplexing input/output lines. But given the trend toward increasing integration, Motorola Semiconductor's James J. Ferrell III, strategic product marketer, and Texas Instruments Inc.'s James Huffhines, MOS microcomputer marketing manager, foresee one chip with controller and microprocessor on board.

Does that mean the end of the dumb terminal? Lear Siegler Inc.'s George M. McFadden, vice president of engineering, thinks not, because many users simply do not require computing power in their products, and Intel Corp.'s Donald Phillips, a marketing manager, agrees. But the prospect of magnetic-bubble memories raises questions for McFadden. "What's going to happen to the price of bubble memory? And if it does come down, what do we do with it?" he asks. He thinks it may usher in another era of CRTs.

Electronics abroad

Tories changing rules of the game

Britain's electronics industries could be deeply affected by Thatcher government's determination to cut state's role

by Kevin Smith, London bureau manager

When Mrs. Margaret Thatcher, Great Britain's first woman prime minister, moved into No. 10 Downing Street, it marked the beginning of an economic experiment that could determine the relative roles of the state and free enterprise in the promotion of thriving, technology-based industries in her nation. Electronics would be especially affected. For Mrs. Thatcher's plan is to arrest Britain's long-term decline by disengaging state and private sectors, whose alliance she says has stifled enterprise.

Some results of her Government's resolution are:

- Immediate cuts in personal and corporate taxes, with more cuts promised.
- More government purchasing to encourage innovation.
- Review of the post office monopoly on terminal equipment.
- Gradual phasing out of government investment grants and support plans. (Under the Labour government, such support to the microelectronics industry climbed, with a total of $800 million envisaged.)
- Selective phasing out of regional development grants, which, if strictly implemented, could hurt efforts to attract U. S. electronics firms.
- Most controversial of all, a possible bleak future for the National Enterprise Board, best known in electronics circles for backing Inmos, the semiconductor maker. The NEB has already been asked to sell $200 million worth of assets in such firms as Ferranti Ltd. and ICL Ltd.

Mrs. Thatcher's plan is being steered by her Minister of State for Industry, Sir Keith Joseph, who is also the Conservative Party's chief theoretician, and the Chancellor of the Exchequer, Sir Geoffrey Howe.

No welshers. Whatever occurs, says Sir Lesley Murphy, NEB chairman, the new government will not go back on funding commitments already made to Inmos—although, when prodded, he says, "Of course, they could renege, but I am confident they won't—they're honorable people."

This also means that the other NEB startups, such as Insac, the software marketing organization that has sold video-text software to GT&E in the U. S., and Nexos, a consortium of companies attacking the word-processing and office-equipment market, should also be secure.

One deal that managed to slip under the wire after the Conservatives came to office was a joint venture between disk maker Data Recording Instrument Co. and America's Magnetic Peripherals Inc. [*Electronics*, June 7, p. 70]. But will the Conservatives forbid future venture capital exercises? Despite Sir Lesley's optimism, that remains to be seen. One ray of hope is Sir Keith's stated intention of helping the small-business man.

But the state will not simply stand aside and watch. Sir Keith will also be preparing his own formula for assisting industry in its free-enterprise task. In particular, he wants to use the government's huge purchasing power to support new technology; he has great praise for Sir William Barlow of the British Post Office for the changed attitude that has seen the System X program given top priority, and for a $10

Holding the purse strings. Sir Geoffrey Howe offers a private-enterprise budget.

Eyeing the NEB. Sir Keith Joseph, industry minister, has no love for Labour's NEB.

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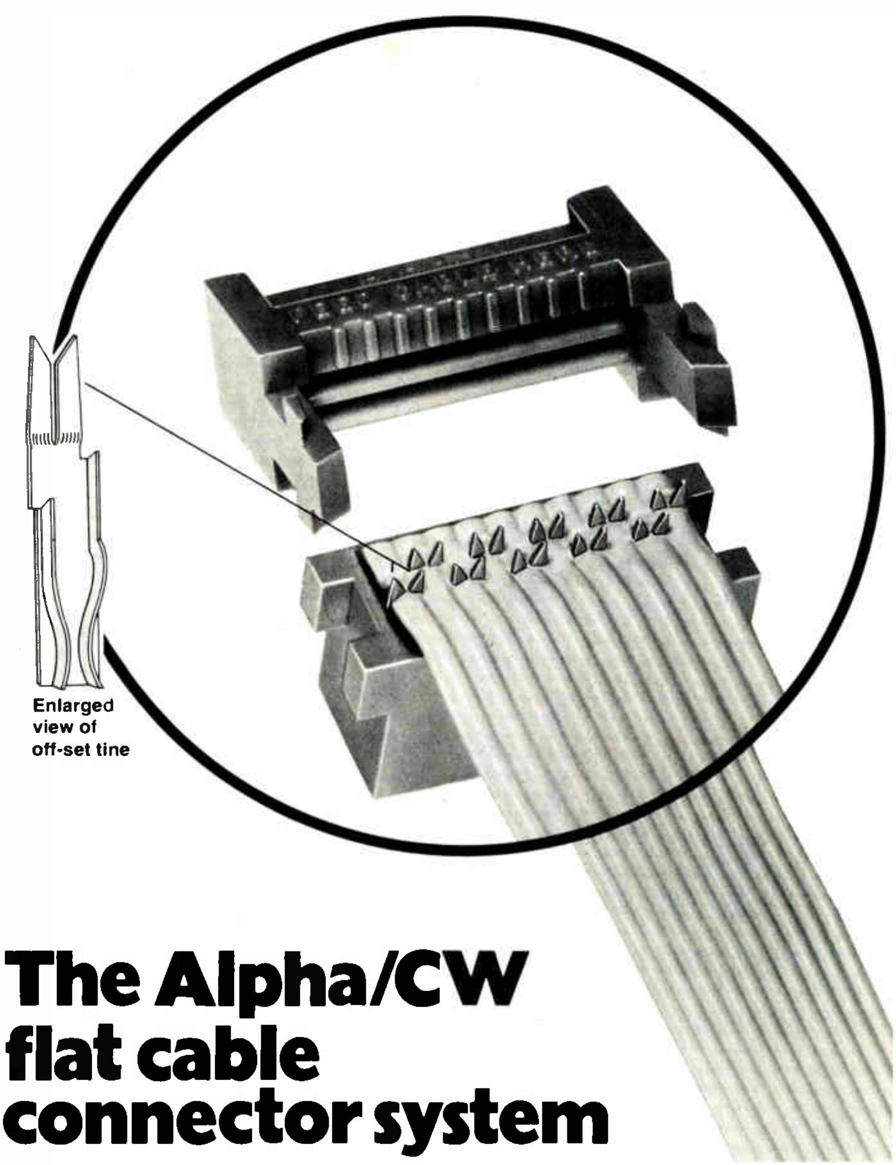


Enlarged view of off-set tine

The Alpha/CW flat cable connector system

million order for 450 kilometers of fiber-optic transmission equipment. But another Joseph proposal under consideration—to break the BPO monopoly on terminal equipment the way the Carterfone decision in the U. S. opened up its phone system—may not be so warmly greeted at the post office.

Use of the government's purchasing muscle finds a sympathetic ear with Mullard Ltd.'s new managing director, Ivor Cohen. He argues that state purchasing of private videotext systems or of systems for programmed learning could help launch a major industry around the technology. The Japanese, Cohen says, work this way, "building a concept of a united industry."

But even the industry minister's proposals call into question the free play of market forces. U. S. computer companies, for example, complain that buy-British policies lock them out of the state sector. While Sir Keith may overlook this breach of purist, free-market dogma, the role of the NEB gives him some difficulty.

Sir Keith will also find it difficult to remove regional investment grants to industry—something he is not rushing—as in the electronics sector it would handicap Britain in the international game of attracting U. S. electronics companies to Britain's shores. The Republic of Ireland, for example, has achieved enormous success in building a local electronics presence with tempting tax concessions and investment grants to selected U. S. companies. Most recently, Mostek Inc. announced plans for a new plant in Ireland after a careful evaluation of sites there and in Scotland, and Rockwell International Corp.'s Microelectronics division as well as Siliconix Inc. are looking for European sites.

Union block. But the Thatcher Government's free-enterprise horse could well be halted before it reaches the stable door by the depressive effects of higher interest rates (up to 14%) and a wage free-for-all promised by the unions' instant rejection of a budget that they see as perpetuating the class struggle.

At the helm. Prime Minister Thatcher is steering away from state ownership.

Also up for review in the bag of interventionist machinery inherited from the Callaghan administration will be regional investment grants aimed at attracting British and overseas companies to deprived regions and industry support schemes aimed at boosting British industry into the microcircuit age. The role of the National Economic Development Office (an agency involving the government, management, and labor) in drawing up national plans for specific industry sectors will also be scrutinized.

On the prowl. Yet another interventionist dilemma is posed by moves to sell off successful NEB-backed companies like ICL and Ferranti. Ernest Harrison, chairman of Racal Electronics Ltd., who has ambitions to turn his fast-growing company into one of the world's electronics giants, has long eyed Plessey Ltd. and has stated an interest in Ferranti when it comes up for sale. Such a move could trigger a dominolike round of takeover bids in Britain's fragmented electronics industries. But Sir Geoffrey in his budget speech said that the stock sale "forms an essential part of our long-term program for promoting the widest possible participation by people in the ownership of British industry." So the Tories could be planning a form of sale that would prevent Racal and other UK companies from dividing shares. □

Consumer electronics

Microcomputers to run test house

Motorola's experimental residence in Arizona will contain unobtrusive system of off-the-shelf micromodules

by Larry Waller, Los Angeles bureau manager

Tucked away in a housing development near mountains south of Phoenix, Ariz., sits an eye-catching house that is bound to capture world attention when it is finished this fall. Not only does the prism-shaped abode use new materials designed by architects famed for innovations—the Frank Lloyd Wright Foundation of Taliesin West, in nearby Scottsdale—but it represents an ambitious technological goal: to make microcomputers an unobtrusive but integral part of family life.

In charge of this task is a pair of engineers from Motorola Inc.'s Phoenix-based Semiconductor Group. The two have devised a prototype five-microcomputer network that controls and manages all the home's electrical, environmental, and security requirements. Already proved in the laboratory, it will be installed in mid-September for an October opening, if present plans hold. The home's name, "Ahwatukee," also given to the entire development, is Crow Indian and translates as "shining home of dreams."

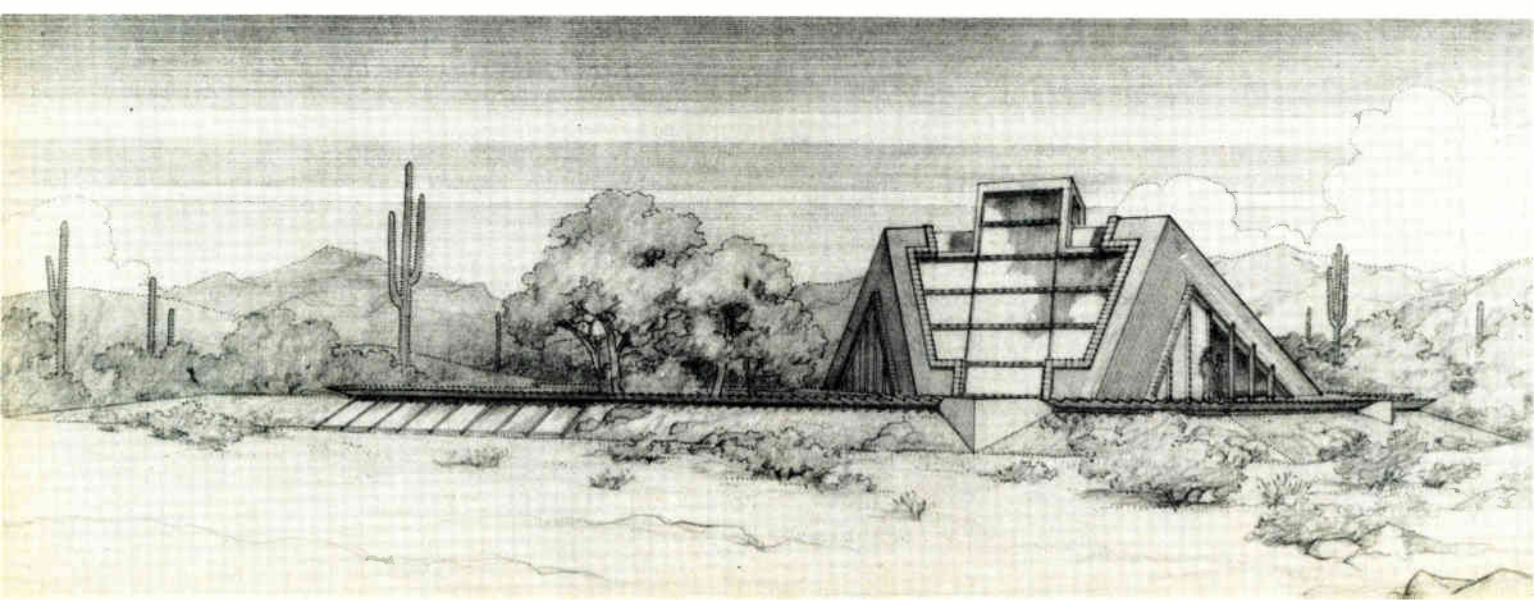
The two engineers in the consumer strategic marketing area have been working on this home computer system since September 1978. In their early 30s, Patrick O'Malley, systems engineer, and William D. Pierce, applications specialist, believe their handiwork breaks new ground in concept and hardware configuration.

Just an appliance. "The philosophy behind the system is that it is a home appliance," says O'Malley. "But in keeping with the nature of computers, it is a general-purpose home appliance. It will make life in the home simpler and more comfortable and at the same time make the house more responsive to the needs of its occupants than any other building ever built. However, the system must always remain subservient to the homeowner. The controls merely execute the homeowner's decisions automatically."

In computer parlance, the Ahwatukee project is transparent—the user never knows it is there. What the Motorola duo strained especially to avoid is the "spaceship console control-board look" so often portrayed in futuristic home concepts. "This scares off a nontechnical person," Pierce explains. Instead, they hope the homeowner will come to regard their network of computers, displays, sensors, and keyboards as a common "shoebox in the closet," as he puts it.

For hardware, the designers used as basic building blocks Motorola's off-the-shelf micromodules, which are commercially available boards built around the 6800 processor. They assembled these modules into five microcomputer nodes, connected into a network. Although there also are five major jobs overseen by the control system, the nodes are not dedicated to each one separately—each can do all jobs. Rather, they are linked in this way for redundancy, to offer maximum reliability. The functions are environmental control, security, load switching,

House of future. Architect's sketch shows Ahwatukee, Motorola's partly underground test residence. Its five microcomputer nodes, linked by MC6800-controlled communications boards, will jointly cover environment, security, load switching, energy management, and data handling.



energy management, and information storage and retrieval. "Different nodes take care of different sections of the house," says O'Malley.

Tying the nodes together are communications boards, each with an MC6800 processor that drives an MC8854 advanced data-link controller. The only piece of the system that had to be built from scratch is the video display, but since it uses circuitry first designed to interface Motorola's MC6847 video display generator, it was easily done, the designers say. On the display are choices of action; by means of a keyboard, a person can give instructions to the system.

Simple orders. No knowledge of computer programming is needed, says Pierce, since the software takes care of everything with simple keyboard commands. Menus of possible choices of such things as temperature settings or the time the lights should be turned on are displayed in an interrogatory fashion on the screens, to guide the user.

The software, in fact, probably advances the state of the art in home computers more than the hardware does, in Pierce's opinion. Until the availability recently of improved high-level languages, software was not adequate to deal with a system of such complex interactions. "Fortran or Basic wouldn't do it," he says. Software was written in the MPL language developed at Motorola to support structured programming techniques; it is similar to PL/1.

Rounding out the hardware are the input devices, with the digital ones largely being switches of all types. Analog value measurements, such as temperature and humidity, are monitored and determined by a 32-channel analog-to-digital converter. Digital inputs, such as those from wall switches and motion detectors that monitor a room's occupancy, are sensed through contact closures that are in turn connected to a microcomputer through opto-isolators. Outputs are all contact closures, with relays located in the computers.

In unburdening the future owner of Ahwatukee of tedious everyday decisions, the Motorola computer network's biggest chore is to regulate the total internal environment. By balancing temperature, humidity, and other parameters against the output of energy-using equipment, the system is performing perhaps its most vital task, especially in the fiercely hot Arizona summers. It even automatically opens and closes doors and windows.

Turning on. But the designers constantly emphasize the system's transparency, to make the homeowner realize he is in control. Conventional wall switches, for instance, still can turn on lights, even though the computer could do it by sensing motion in the room. But instead of being wired directly to a fixture, each supplies an input to the computer network, which then activates it when it is switched.

Of all features, security is perhaps the least conventional: there are no keys at Ahwatukee. The doors will have calculator-style keyboards; the computer permits them to open when the right access code is punched in. Also, the rooms have smoke and motion detectors that can sound an alarm by telephone to the proper agency, as well as turning on audio alarms and lights.

Finally, with this home computer system, an occupant can throw away all address books, recipes, and other vital records after entering them into the data storage and retrieval portion contained in a disk memory.

For now, Motorola says the home computer system, which has some 1,200 integrated circuits and 750 discrete components, is not a product for sale, since total cost is $30,000 or so and rising. But the payoff comes when engineers get enough operating experience under their belt to start partitioning the functions into about 200 large-scale integrated chips, which will bring the cost down eventually to the $200 to $300 range. "But below $10,000 it could start to get interesting to buyers," thinks Pierce. The entire home will cost about $750,000.

In the meantime, they keep adding features taken from their "ideal wish list": these include the likes of remote programming and voice synthesizers for interfaces. There is, however, one odd omission: even though Motorola has interests in photovoltaic energy, the house has no provision for using it. □

Communications

World waits for sunspots

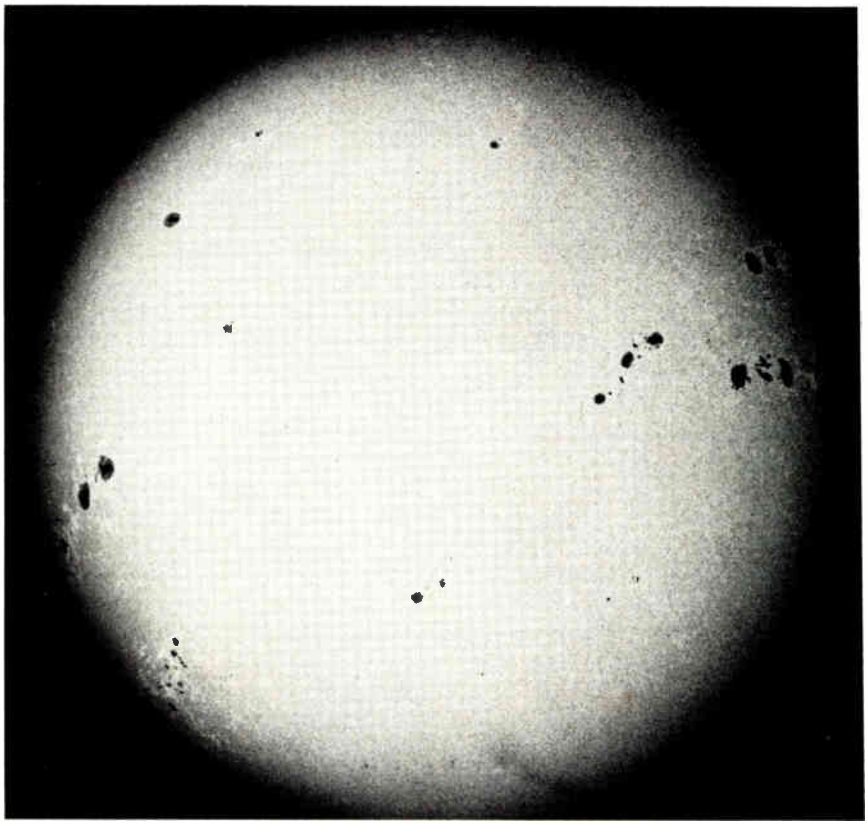
Major disruptions, particularly in 3-to-30-MHz band, are expected next year, with satellites also affected

by Harvey J. Hindin, Communications & Microwave Editor

The sunspots are coming, and for users of a good portion of the civilian, commercial, and military radio bands that means communicating in another way or learning to work with different frequencies.

Actually, there are always sunspots, and they intensify periodically. The profound influence these dark areas in the sun's photosphere have on the earth's communication systems makes it significant that the National Oceanic and Atmospheric Administration predicts major disruptions in early 1980. The activity, most of it in the 3-to-30-megaherz range, is expected to peak in March.

The disruptions in communications will benefit some and hinder others. The more than 350,000 amateur radio operators in the U. S., for example, will be able to make extremely consistent, long-distance contact frequently and with relatively low power, says H. H. Sargent III of NOAA's Space Environment Laboratory in Boulder, Colo. But operators confined by law to specific frequencies may find them more heavily congested than usual. Such



Blacked out. Dark areas on the sun, or sunspots, wipe out much radio communication in the 3-to-30-MHz range. The upcoming intense period of sunspots should peak early in 1980.

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reduced efficiency often accompanies increased solar activity, he adds.

Worse yet, if the cycle, the 21st since 1755, is as severe as Sargent and his colleagues—using a sophisticated statistical procedure called multiple regression analysis—predict, then related geophysical disturbances such as solar flares and ionospheric storms will occur. These will disrupt radio communications in both the 3-to-30- and 30-to-300-MHz bands for periods of time ranging from minutes to days.

Second worst. If the prediction is accurate, the 1979–80 cycle will be equal to the second most severe cycle observed over the past century. This disturbance, the 18th since 1755, occurred in 1947. Because of their serious effects many investigators have studied all available records of sunspot cycles, which average around 11 years each, in an effort to predict the impact of the phenomenon. However, the predictions by no means agree, and the lack of a reliable, long-term data base using modern measurement technology contributes to the disparity.

The present sunspot disturbance is in part responsible for the untimely demise of the Skylab satellite, as it caused molecules in the earth's atmosphere to rise, creating increased drag on the spacecraft. If opinions on the severity of sunspot activity had not varied so widely, it might have been possible to pinpoint Skylab's reentry more accurately. As it was, the National Aeronautics and Space Administration's estimates suggested less disruption than those made by the NOAA group.

Sargent's estimate is based on the work of a Russian physicist, A. I. Ohl, who predicts an extremely severe cycle ahead. Sargent's colleague, Joseph Hirman, thinks that Ohl's method of calculation should be taken seriously because it takes new factors into consideration, relying "not only on past sunspot cycles, but adding magnetic disturbances on earth caused by sunspots as a source of additional information. Statistically, this is very important because it takes into account something besides the sunspots themselves." □

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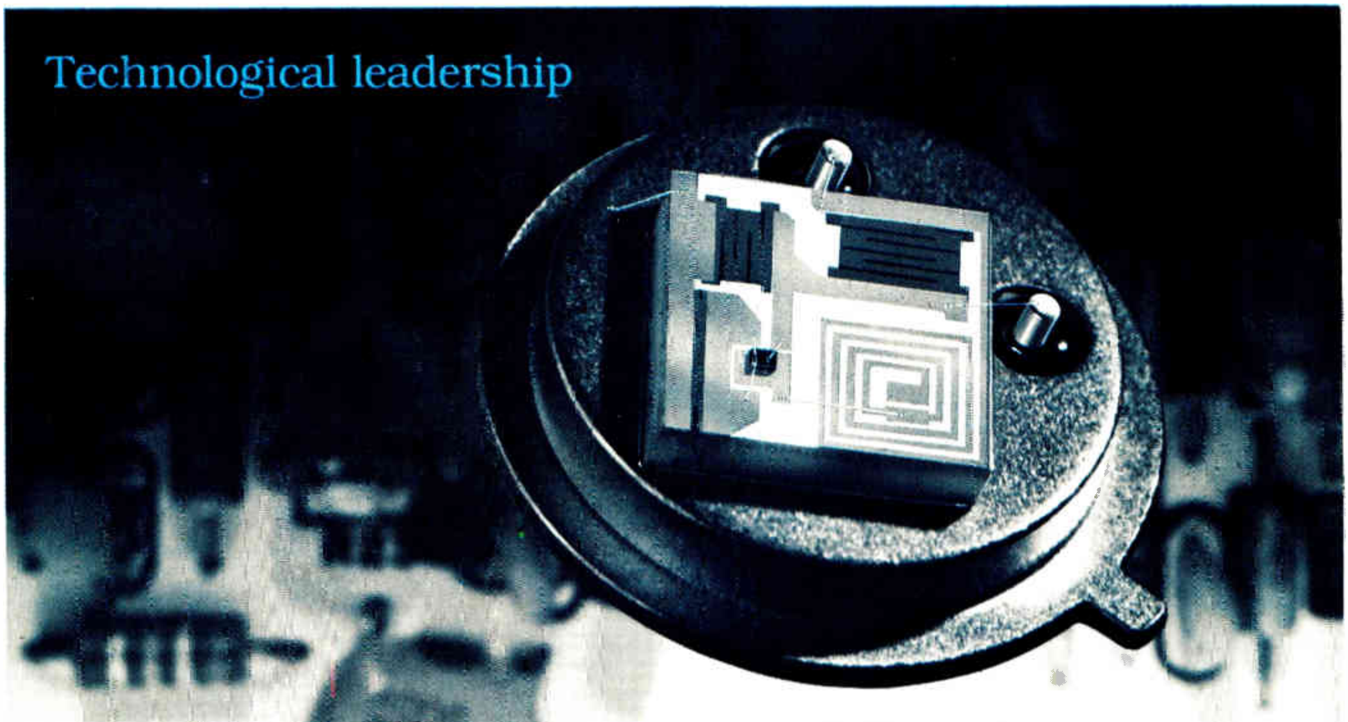

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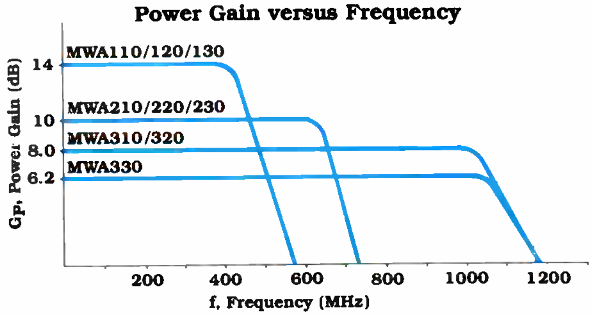

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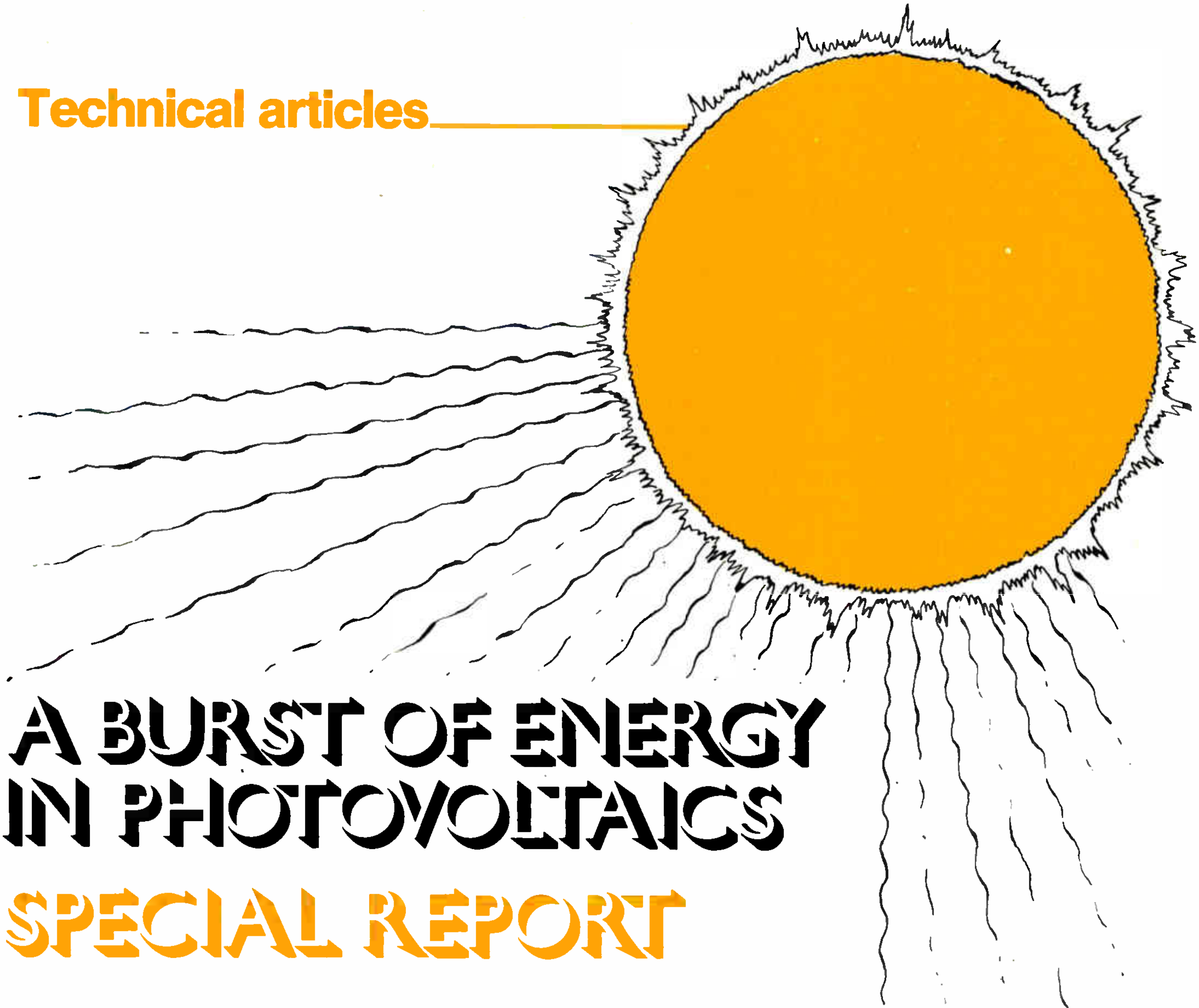


A BURST OF ENERGY IN PHOTOVOLTAICS

SPECIAL REPORT

by John Javetski, *Consumer and Industrial Editor*

☐ Solar cells seem more and more likely to supply part of the world's future energy needs—and to open up a major new electronics market as well. Ever since 1973, when the Arab oil embargo underscored the world's dependence on petroleum, researchers have redoubled their efforts to build a photovoltaic device that can extract electricity from sunlight more cheaply than conventional generators produce it from fossil fuels. Although that goal has yet to be achieved, except for applications in remote locations, photovoltaic cells today are more efficient and inexpensive than ever and promise to become even more so in the future.

To summarize the progress of the last six years:

■ The price of a typical commercial solar-cell array has been halved. In 1973, a module that produced 1 watt of electricity under peak illumination at noon cost $20 to $30. Today, a module with identical performance and better reliability sells for about $10 to $15.

■ Conversion efficiencies of cells based on "mature" technologies—single-crystal and polycrystalline silicon, cadmium sulfide, gallium arsenide, and concentrators—have risen dramatically and are now nearing their theoretical maximum.

■ The U. S. and other governments have stepped up funding for research programs aimed both at reducing the production cost of today's cells and at identifying new technologies that could eventually become the bases of even cheaper arrays.

Thanks to falling costs, the worldwide market for photovoltaics is beginning to expand. Estimates of its growth rate vary widely, but experts generally agree that annual installed capacity will slowly gather steam and rise from last year's level of about 1 megawatt to at least 5,000 MW by 2000. There is absolutely no argument, however, that, when the market becomes large enough to justify automated mass production of cells, costs will really plummet. That will open up new markets, accelerate sales, and drive prices even lower.

Despite the progress to date, solar cells still have a long way to go before they can begin to satisfy more than a trivial percentage of the world's appetite for electricity. This report will survey the work being done today by researchers in the U. S. and around the world. Their efforts are as diverse as estimates of photovoltaics' potential viability as an alternate energy source, but they do have a common denominator—hope.

PART I
GOVERNMENTS LOOK TO THE SUN

Of all the programs of solar cell development, the most ambitious is the U. S. Department of Energy's Photovoltaic Systems Program. Its long-range goal is to ensure that photovoltaic systems supply a "significant" amount of electrical energy to the nation by the year 2000.

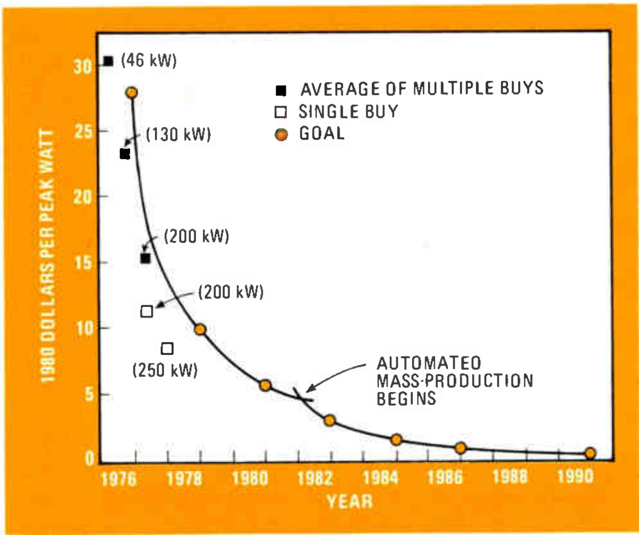
Washington began funding solar-energy research in earnest in 1973. Since then, although the agency in charge of administering the work has changed several times (from the National Science Foundation to the Energy Research and Development Administration to DOE), the program's intermediate targets between now and the end of the century have not.

Figure 1 shows these DOE targets in 1980 constant dollars, namely, to lower the price of solar-cell modules to \$2.80 per watt by 1982, 70¢/W by 1986, and 15¢ to 50¢/W by 1990. At those prices in those years, DOE expects photovoltaics to put large dents in the stand-alone, residential, and utility markets, successively.

Ahead of schedule

What are the chances that the goals will be achieved? In Washington, bureaucratic "cautious optimism" is running high. "There's a better probability than ever of meeting the 1982 and 1986 goals," reports Paul Maycock, who has headed the energy technology program since 1977. "In fact," he adds, "we're about one year ahead of schedule," estimating that several soon-to-be-announced Federal buys of arrays should cost an average \$5.50/w.

Besides being pleased with this technical progress, Maycock, who formerly handled marketing and product development for Texas Instruments Inc., is also elated



1. Racing with the sun. DOE hopes to cut the cost of solar-cell arrays to \$2.80 by 1982 and 15¢ to 50¢ by 1990. Besides technical progress, the timetable assumes annual photovoltaics sales will grow to 20 MW by 1982, 500 MW by 1986 and 5,000 MW by 2000.

that DOE recently recognized the importance of other aspects of photo-voltaic cell technology. First, it added price goals for systems (\$6 to \$13/w, \$1.60 to \$2.20/w and \$1.10 to \$1.30/w, respectively) to its 1982, 1986, and 1990, prices for arrays. Then, late last year, it assigned to its Conservation and Solar Applications branch responsibility for assuring that photovoltaic systems penetrate the various sections of the power market as they become cost-effective.

The Conservation and Solar Applications branch is initially authorized to spend \$98 million over the next three years on administering the Federal Photovoltaics Utilization Program, which is totally separate from the Photovoltaic Systems Program. FPUP has two immediate goals: to develop the Federal market by encouraging Government agencies to buy photovoltaic systems, and to provide marketing support to commercial solar-cell manufacturers, whose growth is crucial to the ultimate success of photovoltaics.

Those manufacturers, in particular the growing number of wealthy oil companies that now own or subsidize cell manufacturing plants, were undoubtedly in mind when Congress passed Public Law 95-590 last year. The National Photovoltaics Act authorized expenditure of \$1.5 billion over the next 10 years for photovoltaic research, development, and demonstration—a long-term program that is viewed by industry observers as an invitation to companies to make a marketing commitment to photovoltaics by investing in much-needed mass-production capacity.

Funding through the act, which becomes the authorizing legislation for the Photovoltaic Systems Program, will heavily favor the development of technology for the next few years and then gradually shift to emphasize demonstration projects in the field. Although that weighting irks commercial suppliers a bit, it delights research workers.

Small-scale integration

Whatever the act's eventual implementation, its philosophy parallels DOE's recent administrative decentralization of its photovoltaic effort—the creation in effect of a new middle level of management that will be responsible for integrating related parts of the program. Figure 2 shows the result: the inclusion in the organization of two supervisory, or lead, centers, the Solar Research Institute (SERI) in Golden, Calif., and the Jet Propulsion Laboratory (JPL) in Pasadena, Calif.

Roughly speaking, SERI oversees program elements involving advanced (and on occasion esoteric) R&D, while JPL is in charge of developing mature technologies. Day-to-day management of the program elements will continue under research organizations like Sandia Laboratories, Albuquerque, N. M., the National Aeronautics and Space Administration's Lewis Research Center in

Foreign governments are banking on sun power, too

The expenditures of overseas governments for photovoltaics development look like small-scale versions of Washington's—with one important difference. Until the passage last year of the 10-year National Photovoltaics Act, the U. S. was the only country with a long-range solar-energy plan not backed by a multiyear funding authorization.

The following list provides an update of the directions and financial support that various nations are giving to photovoltaics activities:

The European Economic Community. Beginning this month, the Commission of the European Economic Community will spend about $24 million over a period of four years on promoting the development of solar cells in its nine member countries. In accordance with usual EEC policy, that sum will be matched by funding from local sources, mainly national governments.

The $24 million will sustain projects now supported by the $10 million injected into photovoltaics by EEC during the last 20 months. That work includes 50 contracts for research and development of technologies that range from placing single-crystal silicon on graphite ribbons to raising the efficiencies and lowering the costs of cadmium-sulfide, cadmium-telluride, and amorphous-silicon cells, as well as cells used in concentrator systems.

More pragmatically, between now and 1983 the commission hopes to build three or four generating plants that will produce 300 to 400 kilowatts of electricity each. Wolfgang Palz, the commission's director-general, sees France and Italy as strong candidates for the new plants, but hopes a northern EEC member like the UK, West Germany, or Denmark will get a shot at one, too.

France. At mid-year, planners at the year-old French Commissariat à l'Energie Solaire (COMES) were busy putting together a long-range program aimed at reducing the costs of solar cells to $1.60 to $2.50/W by 1985, a less ambitious target than the U. S. Department of Energy's. Although the path to that goal has yet to be plotted, the commissariat already has a rough idea of what it will cost to get there. It estimates total funding—including government money, private investment, and help from the European Economic Community—at $115 million. Still to be decided is how much of that sum the French government will contribute.

This year, COMES is spending $4.7 million on photovoltaics, almost triple the $1.7 million it distributed during 1978. And it is not the only French government agency interested in power from sunlight; the Centre National de la Recherche Scientifique (CNRS) and others have budgeted another $4.5 million for 1979.

Over the last three years, the French have shifted their R&D emphasis from programs with long-range goals to those that show greater practical potential in the next few years. These short-term programs include systems studies and work on single-crystal-silicon cells and concentrators. Not to be overlooked, however, is their continued development of less mature cell technologies and low-cost production of silicon ribbons and cast crystals.

West Germany. Bonn's Ministry for Research and Technology, which began supporting the development of terrestrial photovoltaics in 1974, is today aiming the lion's share of its support in one direction, the Bavarian town of Burghausen. There, Wacker-Chemitronic GmbH and AEG-Telefunken are together developing a polysilicon crystallization process that they hope will reach the stage of yielding large quantities of cheap efficient solar cells by the year 1985.

Two years ago, the ministry was so impressed with the cells' export potential that it decided to pick up 80% of the cost of refining the process and building production facilities. Its eight-year bill will be $76 million, a sum that dwarfs its expenditures on other ongoing R&D projects.

Although insignificant by comparison, the German government's funding for other than polysilicon research covers a broad spectrum, including work on amorphous silicon, cadmium-sulfide cells, cadmium-selenide thin films, and cadmium-telluride concentrator cells. Reportedly, Bonn is now considering a post-1985 program of yet unspecified proportions.

Japan. "Mysterious," as in the phrase, "the mysterious East," aptly describes Japan's Sunshine Project, a comprehensive, multibillion-dollar program begun in 1974. For today, the Ministry of International Trade and Industry (MITI), which shepherds the project, will not say how things are going and essentially forbids its contractors to publicize their efforts.

Observers interpret this silence as a sign that the project is progressing slowly. They note that Sunshine's photovoltaics program began in 1974 with the vague goal of "reducing costs to one hundredth or less" and an equally vague timetable: basic research through 1980, design of a pilot production facility from 1981 to 1985, and low-cost power generation sometime during 1986–90. As a result, profit-motivated companies not participating in the project are today considered ahead of the MITI-industry team.

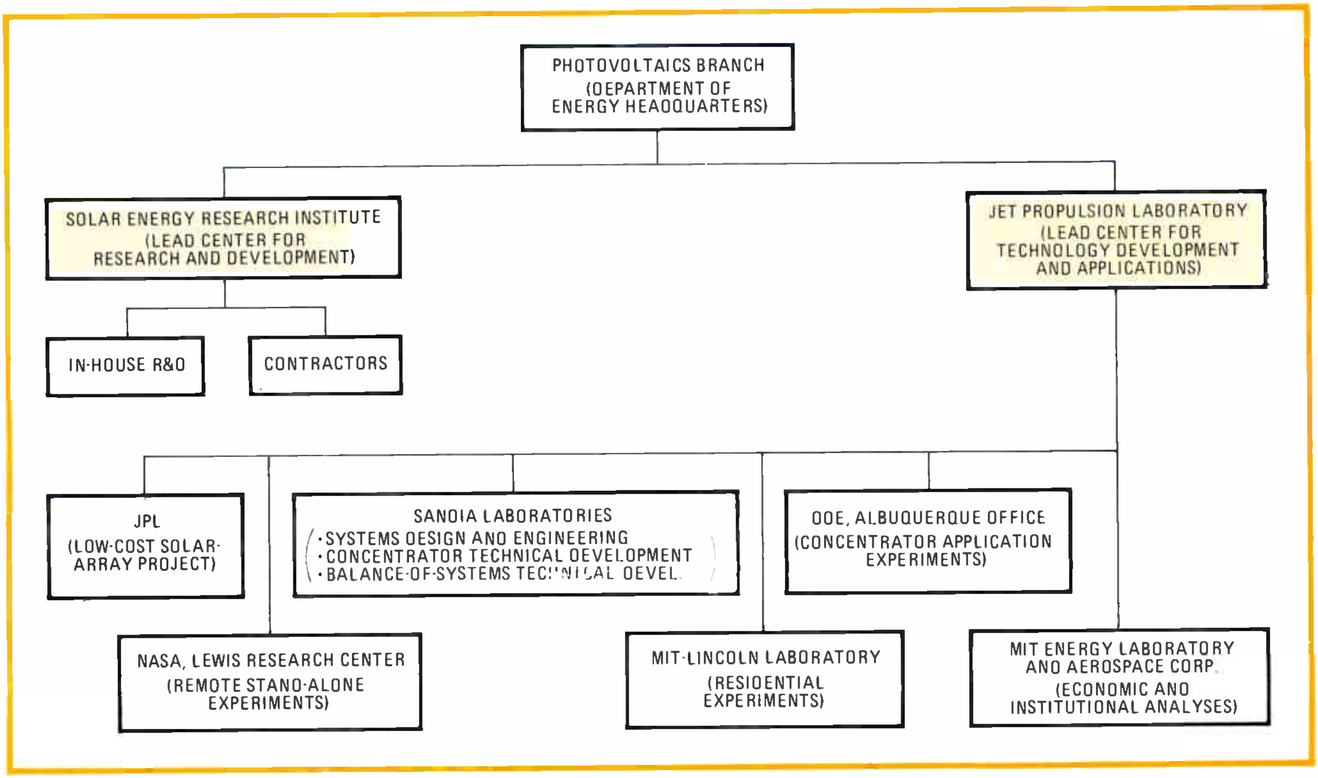
All Sunshine spokesmen will say is that they plan to model a 3-kW station with a mock power source and begin studying its static characteristics this year. Dynamic studies, with real cells, will follow in 1980.

Italy. Rome has been characteristically slow to move on a national solar-energy scheme. Now awaiting the reconvening of parliament is a modest plan, drawn up by the Ministry of Industry, that calls for the total subsidy of rural photovoltaic installations that would not be tied to an electrical grid. According to the plan, 80% of the cost of any such project would be picked up by the government, the remainder being paid for by ENEL, the state-owned utility company.

Great Britain. Unlike Italy, the government of the UK at least has the excuse of perennially clouded skies for its lack of a significant photovoltaics program to compare with DOE's. The British Department of Energy does have a $12 million solar program, but its chief aim is to develop thermal heat-exchange panels. Limited funding for solar-cell R&D in Britain also comes from the Department of Industry, the Science Research Council, and the European Economic Community.

Canada. Its northern latitude is the reason that Canada's solar-energy program is lukewarm toward photovoltaics. But, according to John Simpson of the National Research Council, federal spending for photovoltaic R&D this year amounts to about $1 million. Included in the latter is development of several cells based on polysilicon.

Like the U. S., Canada is now beginning to steer its funding toward more demonstration projects. By 1982, Simpson expects two or three types of polycrystalline cells to be in production. Two years later, with a viable industry in place, Canada should be better able to predict its future in photovoltaics.



2. Decentralization. Research-oriented institutions manage the various elements of the Photovoltaic Systems Program on a day-to-day basis. New to the hierarchy are the lead centers at JPL and SERI, which aim to integrate the work of the projects that they oversee.

Cleveland, Ohio, and the Lincoln and Energy Laboratories of Massachusetts Institute of Technology.

For fiscal year 1980, which begins this October, DOE needs a $130 million appropriation to allow the existing program to continue. But that amount, a modest increase over the $103.5 million being spent in fiscal 1979, is by no means certain to remain intact in next year's Federal budget, which is now in the process of being made final in Congress.

Regardless of the sum finally budgeted for next year, Uncle Sam's financial support for photovoltaics puts other governments' expenditures in the shade (see "Foreign governments are banking on sun power, too," p. 107). However, despite smaller Federal and private outlays overseas, foreign photovoltaic technology is considered serious competition by American solar experts. DOE's Maycock attributes the successes of the West Germans, for example, to their decision to put their eggs in fewer well-chosen technological baskets, a gamble that seems to be paying off, at least in promise.

But, in general, American cell technology still shines brightest internationally, especially in terms of diversity. A good example of that sophistication is the work being done at and for JPL to advance the state of the art of the oldest, most understood solar cell technology: single-crystal silicon.

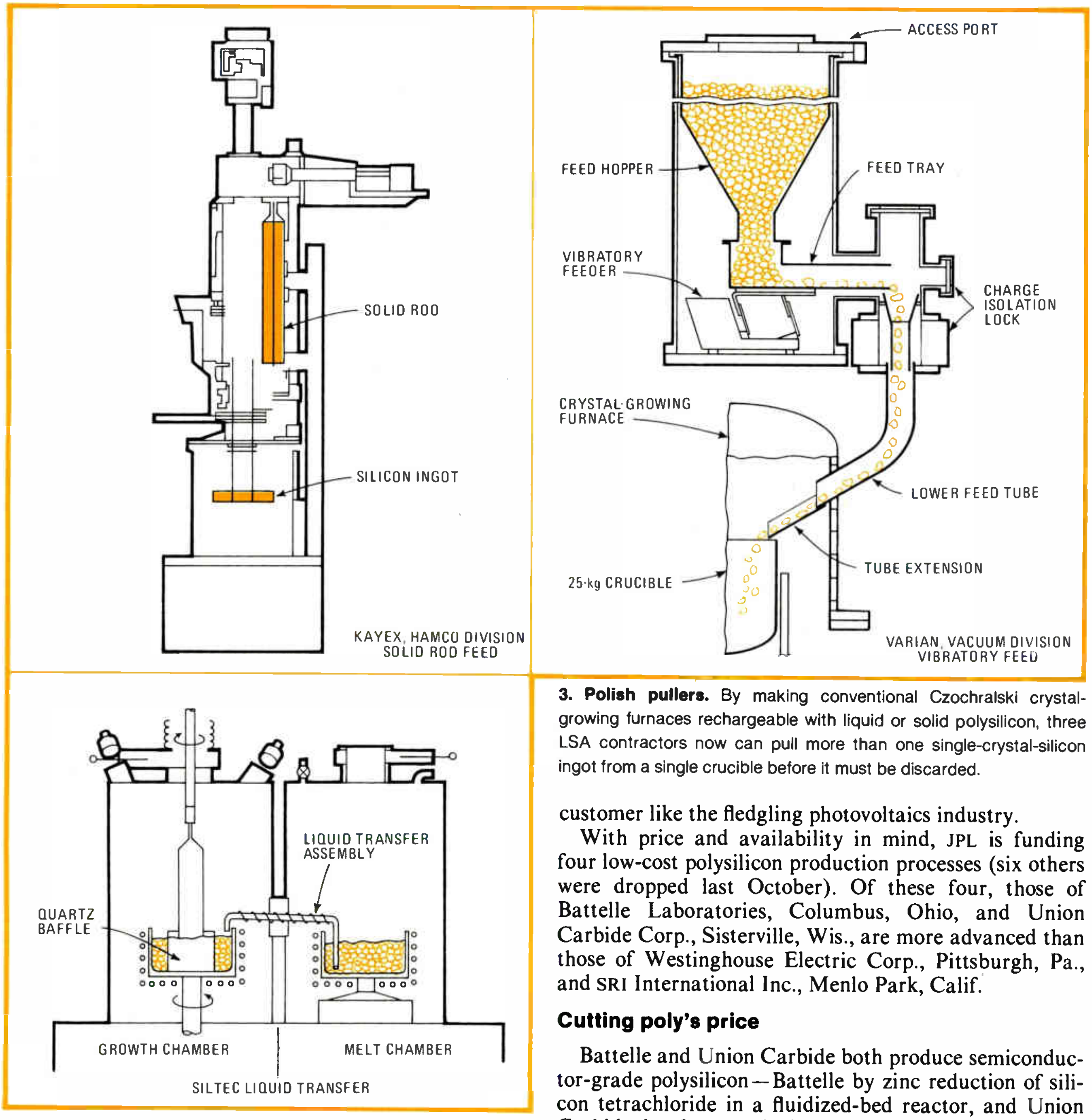
PART 2
THE PUSH TO PRODUCTION IN SILICON

The obstacles to the large-scale manufacture of solar cells are being attacked on every level. The material, its shape, the transparent encapsulant, and the final module, complete with pn junctions and electrical contacts, are all undergoing intense development. In the U. S., the main focus is on conventional crystalline silicon. Elsewhere, amorphous silicon is also coming in for a lot of attention.

The Jet Propulsion Laboratory in Pasadena, Calif., manages the Department of Energy's Low-Cost Solar Array (LSA) project. LSA is grooming one type of cell—single-crystal silicon—to meet the 1982 and 1986 price targets for modules. Since it began in 1975, the project has received consistently strong support from the Photovoltaic Systems Program, reflecting DOE's feeling that the well-understood silicon technology has the best chance of becoming cost-effective in the short term.

Like Gaul, LSA is divided into parts—four, to be exact. These parts, which JPL calls tasks, each aim to reduce the cost of one phase of the evolution of sand into sunlight converter. The four LSA tasks are: the production of polysilicon material, the formation of large crystalline sheets, cell encapsulation, and fabrication.

Task 1, reducing the cost of polysilicon, is considered a



3. Polish pullers. By making conventional Czochralski crystal-growing furnaces rechargeable with liquid or solid polysilicon, three LSA contractors now can pull more than one single-crystal-silicon ingot from a single crucible before it must be discarded.

crucial link in the production chain. Semiconductor-grade (99.999% pure) polysilicon, the feedstock for today's solar cells, now sells for about $65 per kilogram, or about $2.80 per watt in 1980 dollars. DOE hopes to cut that cost to $10/kg by 1982 and, along the way, discover whether so-called solar-grade polysilicon—polysilicon with impurity concentrations below the semiconductor but above the metallurgical grade—could be used to make cheaper cells with acceptable performance.

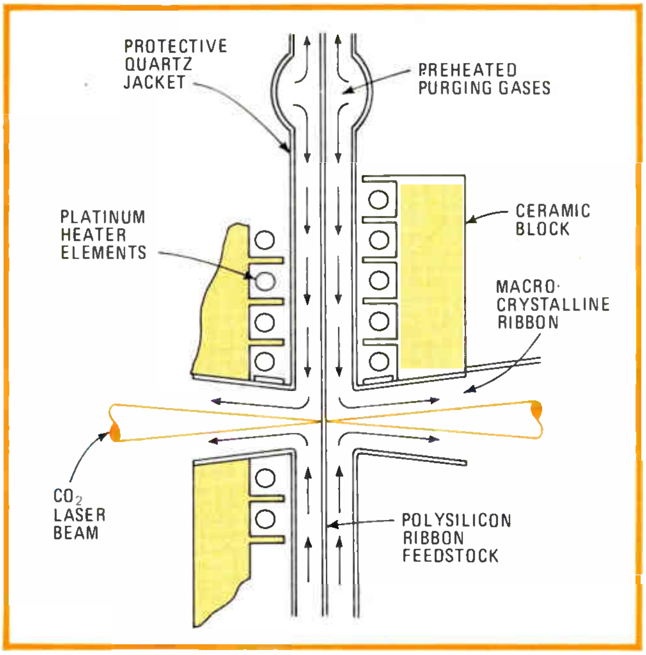
The price of polysilicon is not all that worries DOE. Industry observers say that today's tight market for the material may develop into shortages in the near future. That, they add, will hurt solar cell makers because polysilicon producers will be reluctant to invest $20 million to $40 million in a new plant just to serve a small customer like the fledgling photovoltaics industry.

With price and availability in mind, JPL is funding four low-cost polysilicon production processes (six others were dropped last October). Of these four, those of Battelle Laboratories, Columbus, Ohio, and Union Carbide Corp., Sisterville, Wis., are more advanced than those of Westinghouse Electric Corp., Pittsburgh, Pa., and SRI International Inc., Menlo Park, Calif.

Cutting poly's price

Battelle and Union Carbide both produce semiconductor-grade polysilicon—Battelle by zinc reduction of silicon tetrachloride in a fluidized-bed reactor, and Union Carbide by first producing silane from metallurgical-grade (98% pure) silicon and then depositing silicon from it. According to Lamar University of Beaumont, Texas, which JPL uses to evaluate the commercial feasibility of such processes, both approaches stand a good chance of meeting the $10/kg goal when scaled up into plants producing 50 to 100 metric tons a year.

Meanwhile, Westinghouse and SRI International are developing processes that yield solar-grade material. Both rely on sodium reduction of silicon halides and now show preliminary cost estimates of $9.40/kg and $6.20/kg, respectively. To get a better handle on the feasibility of using solar-grade polysilicon for cells, JPL has five contractors looking at the tradeoffs between purity and cell performance. They are: Aerospace Corp., Los Angeles; the National Bureau of Standards in



4. Ribbon to ribbon. Motorola converts fine-grained polysilicon feedstock into large-grained, macrocrystalline ribbons by heating and then recrystallizing them with a gas laser. This process requires no crucible or die and has a high throughput rate of 55 cm²/min.

Gaithersburg, Md.; C. T. Sah Associates, Urbana, Ill.; Lawrence Livermore Laboratory in Lawrence, Calif.; and Solarex Corp., Rockville, Md.

Task 2 of the LSA project is to reduce the cost of transforming purified polysilicon into large sheets of single-crystal material suitable for cell fabrication. DOE sees this step as having great potential for cost reduction—from a whopping $5.85/W in 1976 to a hoped-for 94¢/W by 1982.

Ingots versus film

Today, JPL is funding several different processes [*Electronics*, Sept. 28, 1978, p. 97] that yield single-crystal silicon in one of three forms: ingots, shaped ribbons, or sheets. Although "pleasantly surprised" that Czochralski crystal growing—the technique used to make ingots for semiconductor manufacturers—continues to show progress, JPL expects that in the long run ingot technologies will cost a few cents more per watt than the newer ribbon and film processes.

The ingot growers—Kayex Corp.'s Hamco division in Rochester, N. Y., Siltec Corp. in Menlo Park, Calif., and Varian Associates' Lexington (Mass.) Vacuum division—are all modifying conventional Czochralski crystal-pulling furnaces to make them rechargeable with molten silicon (Fig. 3). That would allow extraction of more than one ingot before cooling the furnace, a procedure that inevitably cracks and destroys the expensive crucible in which the crystal grows.

Crystal Systems Inc., Salem, Mass., also makes ingots, but by casting them [*Electronics*, July 20, 1978, p. 44]. Its heat-exchanger method now yields 15%-efficient square ingots that, when sliced into cells, greatly improve the packing density of finished arrays. President Fred Schmid adds that their shape is not his ingots' only selling point: "Our process requires one third less power, material, and labor than Czochralski," he claims. Now producing 4-in.² ingots, Schmid hopes eventually to increase their cross section to 12 in. on a side.

Crystal Systems also has a Task 2 contract to reduce the considerable (typically 50%) waste incurred in slicing ingots into wafers and then polishing or etching them to remove surface damage. It is using a multiwire sawing technique that yields up to 64 4-mil-thick wafers per linear inch of ingot and should eventually be able to reduce ingot waste to 33%. Other companies with ingot-wafering contracts are Varian, for multiblade slicing with an abrasive slurry, and Siltec Corp. and Silicon Technology Corp., Oakland, N. J., for inner-diameter sawing with fixed-diamond abrasives, today's prevalent sawing technique.

One way to eliminate the ingot-wafering step completely is to grow the crystalline silicon directly as thin ribbons or films. JPL is backing the work of four contractors in this promising area: Mobil Tyco Solar Energy Corp., Waltham, Mass.; Motorola Inc.'s Semiconductor Products group, Phoenix, Ariz.; Westinghouse Electric Corp.'s Research Center, Pittsburgh, Pa.; and Honeywell Inc.'s Corporate Technology Center, Bloomington, Minn.

Mobil Tyco, Motorola, and Westinghouse use different techniques to grow ribbons, but all three need to boost the throughput of their process and the conversion efficiency of their product before they can meet DOE's 1982 and 1986 cost goals. Last year, Westinghouse set a new record of 16% for ribbon efficiency with its dendritic-web process, while Motorola raised the growth rate of its ribbon-to-ribbon (RTR) process (Fig. 4) to 55 cm²/min. Mobil Tyco, which already licenses its edge-defined film-fed growth (EFG) process to Japan Solar Energy Corp., can now pull five 2-in.-wide ribbons simultaneously from a single crucible.

Rather than make ribbons, Honeywell produces its films by dip-coating inexpensive carbon-coated ceramic substrates in molten polysilicon. Since its process consumes very little silicon, its target throughput rate for cost-effectiveness (0.15 cm/s) is lower than that for ribbon-growing techniques. To date, Honeywell has produced 2-cm² cells with an efficiency of 5.5%.

The crucible

As all of the processes described so far require either a refractory crucible to hold the molten silicon or a refractory die to shape it, JPL has also let several Task 2 contracts for the development of suitable die and container materials. These materials have to be: low-cost; mechanically stable at temperatures above 1,400°C, the melting point of silicon; not contaminating to silicon; and malleable with close tolerances. One material with all four of these properties is silicon nitride, so Battelle Labs, RCA Laboratories, Princeton, N. J., and Eagle-Picher Industries Inc., Miami, Okla., are working on it.

Unlike the solar cells used to power satellites in space, a relatively benign environment, terrestrial photovoltaics must survive moisture, salt spray, animals, vandals, ice, and snow. The objective of Task 3 of the LSA project is to develop a low-cost module-encapsulation system that can be expected to last for a period of at least 20 years.

JPL expects that the most difficult problem in this area will be protecting the module's sunlit side while maintaining transparency. It is keeping its options open as to what form the transparent element will take, but several candidate materials—glass and various polymers—already look promising. Nine contractors now are working on encapsulants, notably Motorola, on an anti-reflective coating for soda-lime glass, and MB Associates Inc., San Ramon, Calif., on development of glass-reinforced-concrete substrates.

Low-cost production

The final step in any solar cell's evolution is its conversion from wafer, ribbon, or film form into a finished multicell module that is ready for installation. That process, which includes creation of the photovoltaic pn junction, addition of electrical contacts, assembly and encapsulation, represents about 35% of the cost of a finished array and cost $8.36/W in 1976.

Today, JPL, backed by studies of mass-production techniques from Motorola, RCA, and Texas Instruments, thinks that this figure can be reduced to a mere 81¢/W by 1986 if plants can be built that can produce 5 to 30 MW of cells annually. Task 4 of the LSA project therefore aims to identify, develop, and demonstrate the feasibility of those processes that can be automated and incorporated into a mass-production sequence.

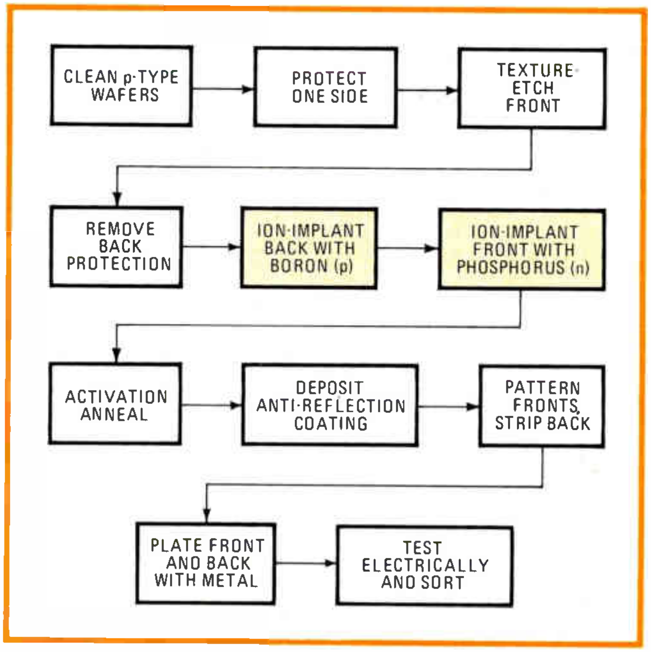
In September 1977, Task 4 went into phase 2, process development. Since then, nine firms have been busy refining their concepts of what the solar-cell production line of the future (Fig. 5) should look like. Included among them are such semiconductor giants as Motorola, RCA, and Texas Instruments, as well as commercial cell suppliers Solarex, Spectrolab Inc., Sylmar, Calif., and Sensor Technology Inc., Chatsworth, Calif.

All the phase 2 contractors report that JPL has made their difficult task a lot easier by developing Samics, the Solar Array Manufacturing Industry Costing Standards computer program. To use it, they phone in their preliminary cost estimate for any step in the process and receive back a detailed analysis, in cents per watt, of what the computer thinks that step will add to the price of a finished array.

JPL itself has used Samics to model a factory of the future, which it calls a "strawman" factory. Results indicate that solar cells with 12% to 14% efficiencies and priced at 56¢ to 69¢/W could be manufactured in such a factory having a capacity of 50 to 250 MW annually.

In the future, Task 4 work will focus on replacing two techniques used to form semiconductor junctions: diffusion of impurities and furnace annealing. Their replacements, ion implantation and laser- or electron-beam annealing, seem promising ways of cutting manufacturing costs, but only if their throughputs can be scaled up. Spire Corp., Bedford, Mass., has already developed a 100-milliampere ion implanter that, according to Samics, should add no more than a penny to the cost of a 1-watt cell.

Meanwhile, overseas cell producers are improving their production processes. In France, the Centre de Recherches Nucléaires in Strasbourg has been working with RTC-La Radiotechnique Compélec, which is based in Paris and is a leading European supplier of single-crystal arrays. Together they are developing a technique that uses pulsed lasers to improve the diffusion of phosphorus into p-type substrates.



5. Factory of the future? Once the size of the market for photovoltaics justifies it, companies will begin to mass-produce solar-cell arrays. This typical processing sequence employs ion implantation, rather than diffusion, of impurities to form the cell junctions.

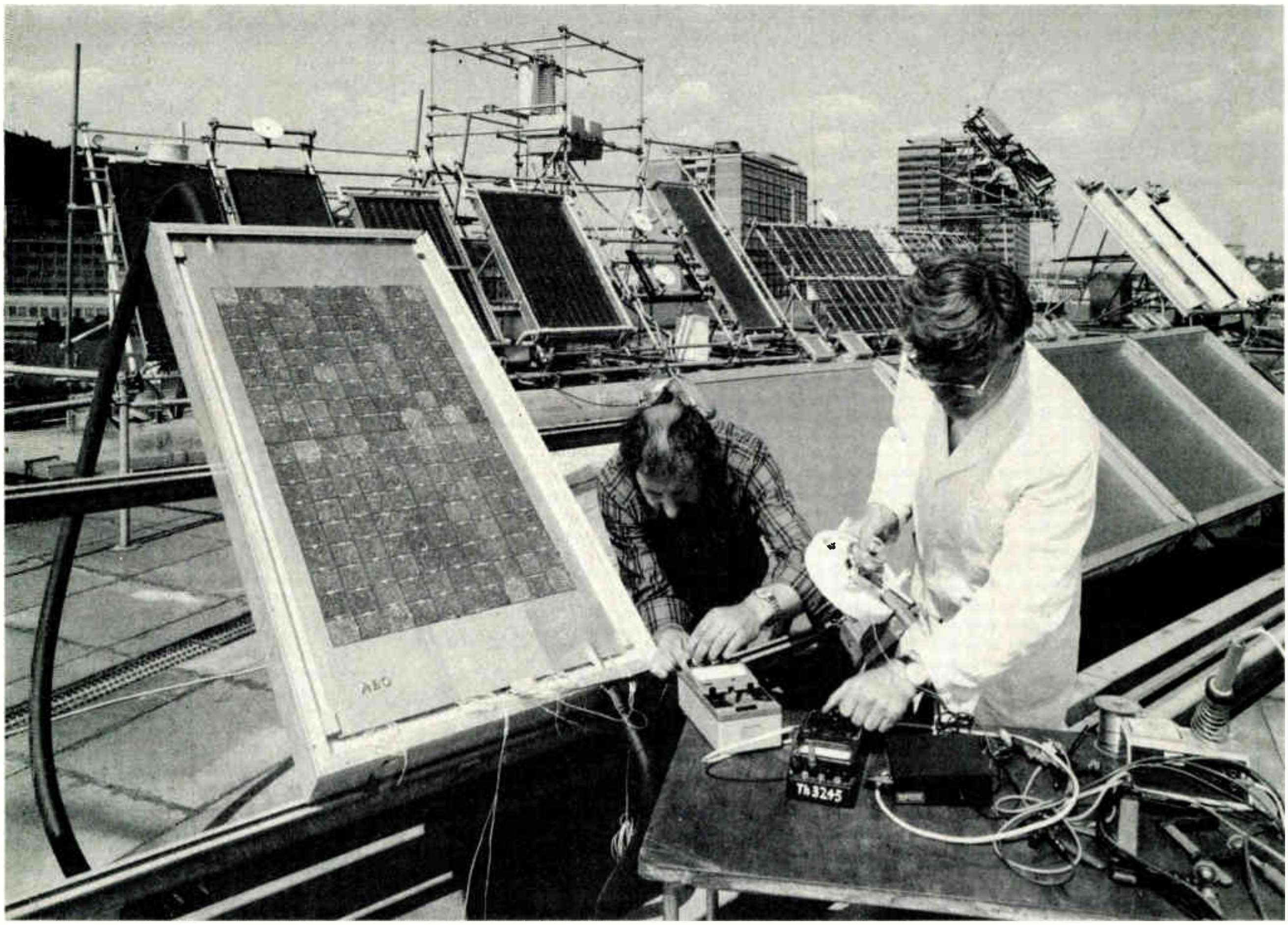
Another French supplier looking into low-cost diffusion techniques is Laboratoires d'Electronique et de Physique Appliquée (LEP), based in Limeil-Brévannes. LEP is depositing indium-tin-oxide (ITO) layers on wafers, and then forming pn junctions with a high-temperature diffusion process. The ITO layers then serve as both electrodes and antireflective coatings.

Poly looks promising

Rather than grow expensive, 0.1-to-0.2 mm-thick single-crystal silicon sheets for solar cells, several companies are investigating placing 20-to-30-micrometer-thick films of polycrystalline silicon on low-cost substrates like graphite. Today, research efforts are focusing on increasing the efficiency of such cells by orienting their crystalline grains vertically, perpendicular to the substrate. This minimizes recombination losses of photogenerated charge carriers, but requires that the grains be at least 100 μm on a side to maximize absorption.

Two firms that seem to have solved the problem are Solarex Corp. and Heliotronic GmbH [*Electronics*, Oct. 26, 1978, p. 68]. Both cast the material for their cells into bricks, a technique that requires less energy than Czochralski crystal growth, has a higher throughput, and lends itself better to automation.

Solarex, which also produces single-crystal silicon arrays, has already set up a production subsidiary, Semix Inc., near its headquarters in Rockville, Md. Within a year, Semix should be ready to make 15%-efficient, 10-by-10-cm semicrystalline cells for $4 to $6/W.



6. Poly panel. German technicians check the performance of an array of polysilicon solar cells. The finished array, made by AEG-Telefunken from semicrystalline wafers cast by Wacker-Chemitronic's Heliotronic subsidiary, comprises 180 5-by-5-cm cells that are 10%-efficient.

Heliotronic, the Burghausen subsidiary of Wacker-Chemitronic GmbH, will produce an inexpensive, fibrous polycrystalline material called Silso, which AEG-Telefunken, Europe's leading supplier of solar cells for space vehicles, will then turn into finished arrays (Fig. 6). Now supplying samples of 10-by-10-cm wafers with efficiencies greater than 10%, Heliotronic hopes to cut prices to 25¢/W within five to eight years by boosting volume.

Elsewhere, work on polysilicon cells remains still in the research stage:

- At Southern Methodist University in Dallas, Texas, chemical-vapor deposition has been used to grow thin films of silicon on recrystallized metallurgical-grade polysilicon substrates. To date, this process has yielded 9-cm^2 cells with efficiencies of 9.5%.
- Motorola in Phoenix uses electron beams to deposit thin polysilicon films on temporary substrates of molybdenum and tungsten. By thermal-shear techniques, it then separates large-area (3.8-by-4.5-cm) films from the substrates and recrystallizes them using lasers.
- In France, LEP deposits polycrystalline-silicon layers on carbon ribbons by pulling the ribbons through zones of molten silicon. However, it is still unsure whether this process will be feasible on an industrial scale.

If single-crystal and polycrystalline silicon are favorites in the solar-cell materials derby, amorphous silicon, which has no crystalline structure at all, is a sleeper. That is because, in the words of Donald Feucht, manager of SERI's Photovoltaic Program office, "amorphous silicon might in the long run be the ultimate low-cost photovoltaic material."

Crystallizing the amorphous future

A relatively new semiconductor material, amorphous silicon has optical and electrical properties that are far different from those of crystalline silicon. For one, amorphous silicon is a strong absorber of light. Cells made from it need be only 1 μm thick, which spells savings in material costs and processing times. And its amorphous structure makes it insensitive to the substrate on which it is deposited, allowing the use of inexpensive materials like glass or plastic.

But, unfortunately, today's amorphous-silicon cells are notoriously inefficient. Despite estimates that conversion efficiencies as high as 15% are possible, the highest reported to date is 6%, by RCA Labs in Princeton, N. J.

RCA produces its amorphous cells, which include metal Schottky barriers on their tops, by using a glow-discharge technique and introducing hydrogen during deposition. Although details of the mechanism are not well understood, the hydrogen atoms apparently attach themselves to the silicon atoms' broken covalent bonds, which are characteristic of any amorphous substance. Thus they reduce recombination of photogenerated carriers that would otherwise occur at those sites.

Today, amorphous-silicon researchers are focusing on two ways to boost conversion efficiency. One is the addition of gases other than hydrogen during deposition to further reduce entrapment of carriers by dangling bonds. A notable proponent of this approach is Stanford Ovshinsky of Energy Conversion Devices Inc., who has used fluorine as a process modifier. Incidentally, Ovshinsky's work recently attracted the attention of Arco Solar Inc., Chatsworth, Calif., an oil-company–backed supplier of single-crystal silicon arrays. Arco Solar has agreed to pay $3.3 million to the Troy, Mich., firm for a nonexclusive license to develop Ovshinsky's technology into a marketable product.

The other efficiency-raising technique is rf sputtering, an alternative to glow-discharge that is well understood and adaptable to automation. Among the researchers in this camp is the Department of Electrical Engineering at the University of Sheffield in Great Britain.

The UK has another proponent of amorphous silicon in Walter E. Spear of Dundee University. Spear's group is now achieving efficiencies of 5%, but he cautions that their work should still be considered experimental because scaling up has yet to be tackled.

Spear also has his own idea of why RCA's progress has not been equalled by other laboratories. "RCA's Schottky-barrier diodes are but a fraction of a square millimeter in size," he says. He also argues that the metal electrodes in Schottky-barrier diodes absorb 75% of the incident light, so such devices can never attain maximum theoretical efficiencies.

Work in Japan

However, low efficiency is not stopping the Japanese from getting on the amorphous bandwagon. Sanyo Electric Co., for example, intends to put amorphous-silicon cells in consumer products like digital clocks and desktop calculators by the spring of 1980. Although its parts convert only 2.5% of the energy from a fluorescent lamp into electricity, the Osaka City–based firm claims that they already are on a par with single-crystal-silicon cells for cost-effectiveness. Eventually, Sanyo hopes to slash production costs to 1% of what it now costs to make a single-crystal cell.

A second Japanese company high on amorphous silicon is Fuji Electric Co., another nonparticipant in its country's Sunshine project. Fuji has developed 7-by-7-cm amorphous-silicon cells that are four times the area of Sanyo's, but comparable in efficiency (2%). Its Schottky-barrier prototypes contain two layers of amorphous silicon, with different percentages of impurities, that rest on a stainless-steel substrate.

PART 3
ALTERNATIVES TO SILICON

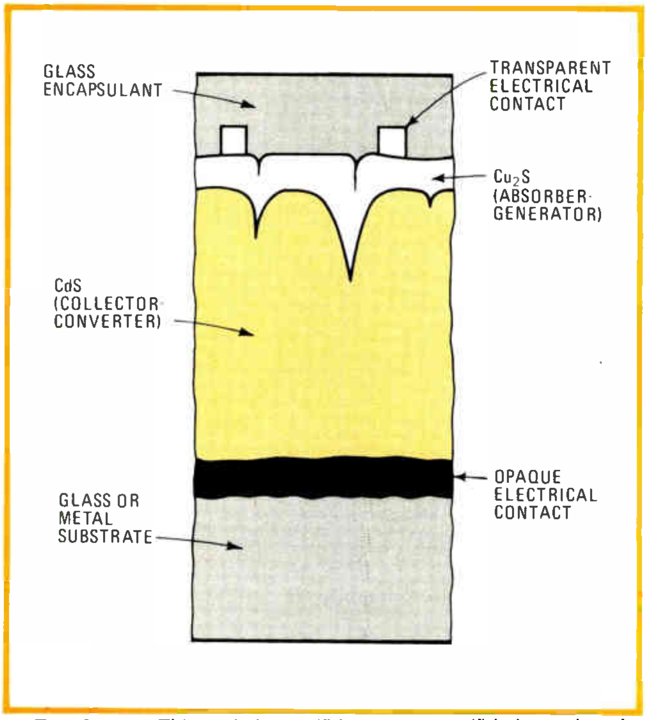
Silicon is not the sole source of solar cells. Many combinations of dissimilar materials, called heterojunctions, and even differently doped layers of the same material, called homojunctions, also exhibit the photovoltaic effect to varying degrees.

Cadmium-sulfide (CdS), for instance, when joined to one of several other materials, forms a solar cell with a theoretical conversion efficiency as high as 16%—and with the potential for low-cost production. Like amorphous silicon, CdS is a strong absorber of light, so that productive cells as thin as 8 micrometers can be made from very little material. But, also like amorphous silicon, most of today's CdS cells generally fall far short of theoretical conversion efficiencies.

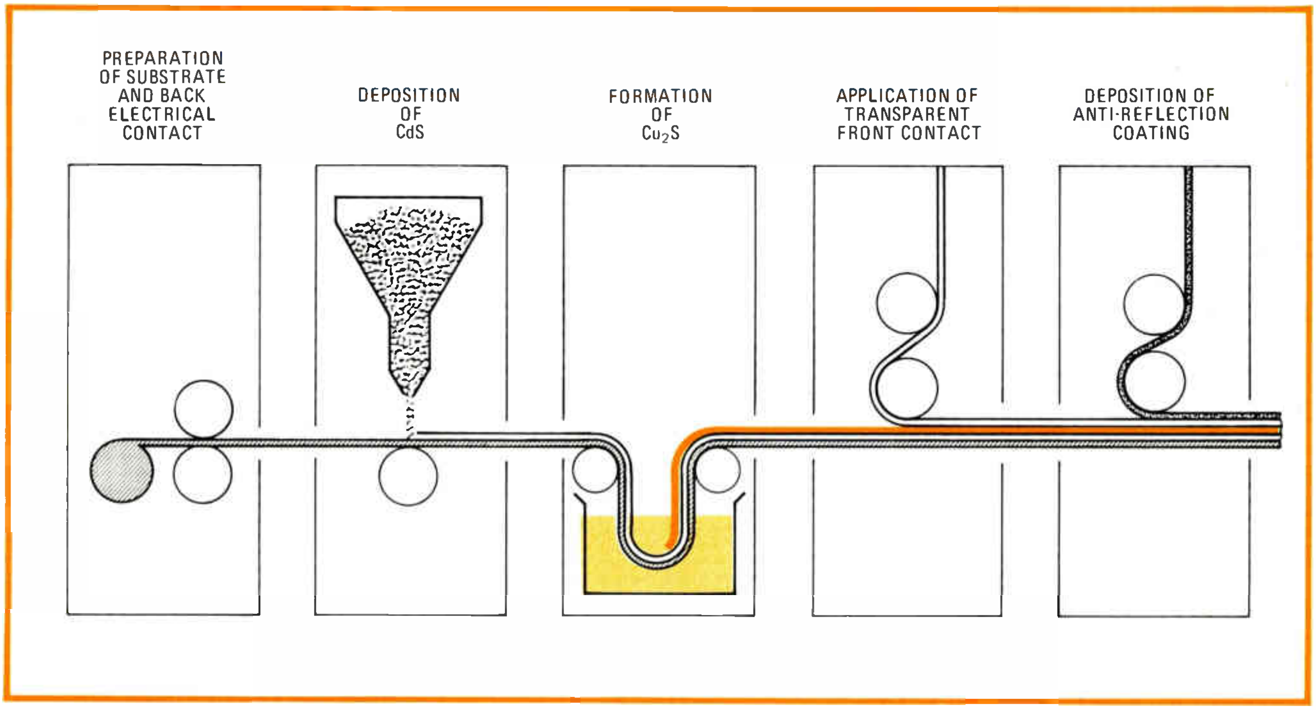
An exception is a cell based on cadmium sulfide and cuprous sulfide (Fig. 7). CdS/Cu_2S cells have attained efficiencies greater than 9%, and several organizations say 14% to 16% looks possible. What's more, these same researchers predict that techniques borrowed from the chemical process industry will make it possible to produce such cells for 10¢ to 30¢/W by 1990.

The two organizations that continue to do the best work with cadmium sulfide are the Institute of Energy Conversion, an independent development group set up at the University of Delaware at Newark, and the University of Stuttgart in West Germany.

Last June, IEC director Allan M. Barnett announced he had reached 9.15% efficiency. He also shocked some



7. Two in one. This cadmium-sulfide/cuprous-sulfide heterojunction is typical of thin-film photovoltaic cells. It is made up of two active layers: an absorber-generator, and a collector-converter that have a matching lattice structure but opposite conductivity.



8. Continuous CdS. Pilot production process for CdS/Cu_2S solar cells includes five basic steps that build the device from bottom to top. Analyses show continuous production of 10%-efficient cells becomes cheaper than batch processing once annual output exceeds 20 MW.

silicon specialists by predicting that thin-film CdS/Cu_2S cells could be selling for 35¢/W as early as 1982, easily beating DOE's 1986 price goal of 70¢/W [*Electronics*, June 22, 1978, p. 42]. Barnett expects to pass 10% "within a year" by adding zinc, in concentrations of about 25%, to the cadmium sublattice. The zinc reduces the mismatch between the CdS and Cu_2S lattices and raises the cell's open-circuit voltage.

Meanwhile, the Institute is slowly lining up five independent companies to license its CdS technology and set up pilot-production plants based on the process shown in Fig. 8. SES Inc., a Shell Oil subsidiary also located in Newark, Del., already reports limited production of 6.5%-efficient CdS/Cu_2S cells from a plant, still under construction, scheduled eventually to produce 1 MW of cells per year.

Another firm setting up a CdS pilot plant is Photon Power Inc. of El Paso, Texas. Photon Power is also working with Libbey-Owens-Ford on ways to feed a glass-manufacturing plant's output directly into the cell production line as the CdS cell substrate, in order to slash prices to 5¢ to 15¢/W. Its major challenge is to speed up cell production from its present 2-cm/min rate to the 20 cm/min of the float-glass facility.

The University of Stuttgart also has set up a small production line and now makes 7-by-7-cm CdS/Cu_2S cells that are 6.7%-efficient. Stuttgart produces its cells by evaporating a CdS film onto a glass substrate, dipping the film in a cuprous-chloride solution for a few seconds, and then encapsulating the cell between glass plates. (In contrast, IEC creates its junctions on a metal substrate by reacting evaporated CuCl with CdS.) German scientists are now investigating the use of reactive-sputtering techniques to improve control of the CdS and Cu_2S depositions, as are groups in California at Lockheed's Palo Alto Research Laboratories and Lawrence Livermore Laboratories.

One other CdS-based cell that shows promise is the heterojunction of cadmium sulfide and copper indium selenium. With SERI funding, Sperry Univac's Defense Systems division in St. Paul, Minn., and Boeing Aerospace Corp. in Seattle, Wash., are both trying to develop a $CdS/CuInSe_2$ cell that is at least 4 cm^2 in area and has a minimum conversion efficiency of 8%.

Market acceptance of any CdS-based cell will require careful attention to its handling and encapsulation, since cadmium is a toxic substance that could contaminate personnel and the environment. That is not seen as an insurmountable problem, however, nor is the fact that cadmium is not as abundant as silicon. Domestic supplies of cadmium will be sufficient to supply annual production rates greater than several thousand megawatts through the end of the century, but production beyond that level could cause shortages.

Concentrating on gallium arsenide

Another promising type of solar cell utilizes gallium arsenide. GaAs devices are more expensive to manufacture than single-crystal silicon cells, and they also contain a toxic substance (arsenic), but they absorb light even better. Single-crystal GaAs cells hold the record for photovoltaic efficiency—26%, with single-crystal silicon in second place at 22%.

One way to offset gallium arsenide's high cost is to use small cells and concentrate sunlight on them through lenses and mirrors. Unlike silicon cells, whose efficiencies deteriorate rapidly at the high temperatures produced by concentration, the theoretical maximum conversion efficiency of gallium-arsenide cells remains fairly constant as temperatures rise: it is still 20% at

100°C. This property of gallium arsenide makes it the focus of research into the use of concentrated-sunlight conversion systems (see p. 117) at central power stations, which would be better equipped to maintain them than ordinary consumers.

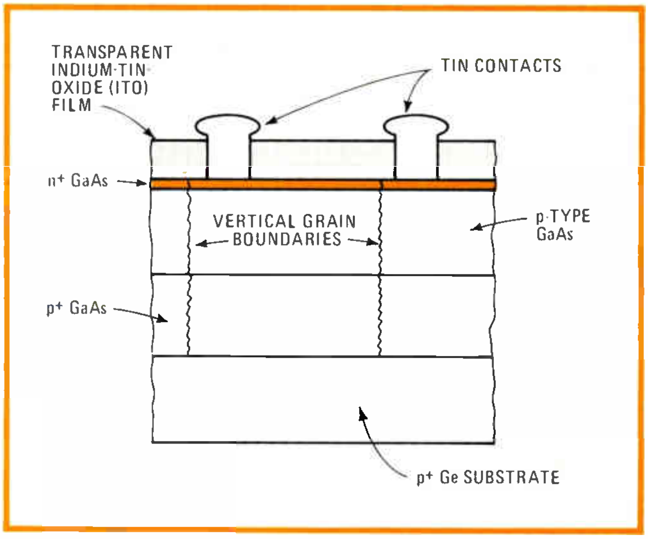
An alternative approach is to make GaAs cells cheap and efficient enough to use in direct sunlight. Virtually all research in this area is on thin-film polycrystalline GaAs cells that, although only 1 or 2 μm thick, have a theoretical conversion efficiency of 16%. Three types are currently being developed: GaAs metal-insulator-semiconductor (MIS), or Schottky-barrier, cells; GaAs homojunctions topped by a window of gallium aluminum arsenide; and GaAs shallow homojunctions. All have the same aim: to raise conversion efficiency by reducing the heavy losses of light-generated charge carriers that are caused by recombination at dangling covalent bonds in the thin molecular layer at the top of the cell where photons are absorbed.

Research into GaAs MIS cells is being conducted at JPL, at Southern Methodist University in Dallas, and at Rockwell International Corp.'s Science Research Center in Thousand Oaks, Calif. JPL, shooting for goals of 15% and 70¢/W, is growing p-type GaAs thin films epitaxially on substrates made by vapor-depositing germanium layers on coated steel and then recrystallizing those layers with a laser beam. At SMU, large-area (9-cm^2) thin films of GaAs deposited on cheap graphite substrates have demonstrated efficiencies of 6.7%. Rockwell is concentrating on developing liquid-phase molecular-beam epitaxy growth of thin GaAs films, also on low-cost substrates. Funding for Rockwell's efforts comes largely from a year-old DOE contract for $1 million that allows the firm to subcontract a portion of its laboratory work to four universities [*Electronics*, May 11, 1978, p. 50].

Rockwell is also looking into heterojunctions of GaAs topped by a thin layer of p-type gallium aluminum arsenide (GaAlAs). Transparent to virtually the entire solar spectrum, the GaAlAs layer has a lattice structure that closely matches that of GaAs and so reduces recombination losses. Although single-crystal cells of this type have shown efficiencies as high as 22%, the thinness of polycrystalline structures permits dopants to diffuse so rapidly through the cell that they soon short-circuit it. The search for slower-diffusing dopants, alternative cell structures, and new deposition techniques is continuing both at Rockwell's Science Center and at its headquarters in Anaheim, Calif.

Shallow GaAs homojunctions are the subject of development work at the Massachusetts Institute of Technology's Lincoln Laboratory in Lexington. There, researchers dope three layers of GaAs with different impurity levels (Fig. 9). This structure has demonstrated efficiencies as high as 20%. It has low losses because photons bypass the many recombination centers in the shallow (0.1-μm-thick) n^+ upper layer and instead are absorbed in the p-type layer beneath it.

MIT's shallow-homojunction structure has a transparent top layer of indium tin oxide (ITO) that reduces both resistance and reflectance losses. One organization bent on improving ITO growth techniques is the Engineering Center at Rensselaer Polytechnic Institute in Troy, N. Y. Researchers at RPI are now comparing two ways to grow ITO layers: chemical-vapor deposition and rf sputtering. Also rumored to be working on development of GaAs cells are researchers in the Soviet Union.



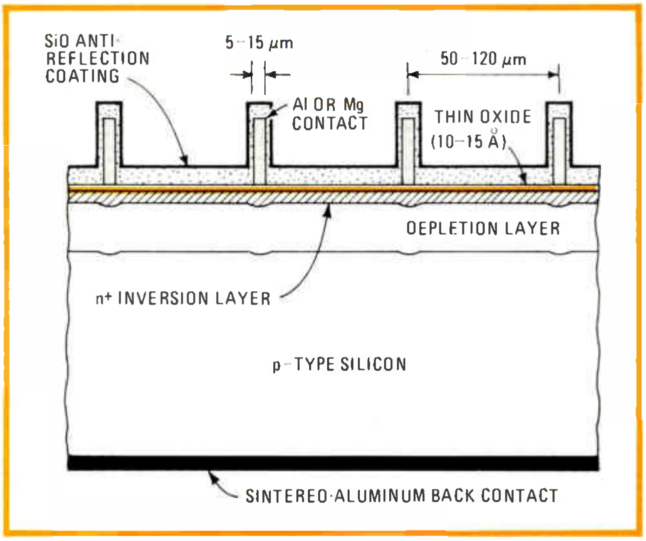
9. Fooling photons. This 20%-efficient shallow-homojunction cell comprises three layers of GaAs that are doped at different impurity levels. Photons pass through the thin top layer so quickly that few are lost; instead, they are absorbed in the thicker layer beneath it.

Advancing the frontiers of solar technology

One aspect of photovoltaic development on which all experts agree is the need for diversity. Although advanced cells based on single-crystal, polycrystalline, and amorphous silicon, cadmium sulfide, and gallium arsenide now can be considered the front runners in the race to meet short-term goals, long-term planners stress that simultaneous exploration of virgin technical territory is vital, to identify options that could be turned to should unforseen roadblocks halt progress in a thus-far promising technology.

Indicative of American commitment to this philosophy is the dramatic increase in the budget of SERI's advanced R&D program—from $6 million to $7 million in fiscal 1978, to $13.5 million in fiscal 1979, to a requested $47 million for fiscal 1980. In addition, in May 1978 President Carter infused another $22 million into advanced R&D during fiscal 1979. According to Donald Feucht, who heads DOE's advanced R&D lead center at SERI, the bulk of the $22 million is supporting additional projects on amorphous silicon and new solar cell materials that he labels high-risk—those that may or may not develop into cost-effective technology. Scientists overseas are also pursuing new cells aggressively, as the following roundup of advanced R&D activities in the U. S. and outside it shows:

■ Metal-insulator-semicondudtor (MIS) cells using silicon. MIS, or Schottky-barrier, solar cells have theoretically high conversion efficiencies because they lack a heavily doped surface layer where recombination losses can occur. Furthermore, they can be processed at temperatures below 500°C, which increases their long-term stability. Those characteristics give MIS cells based



10. Efficiency down under. To build this 17%-efficient MIS solar cell, Australian researchers first evaporate an aluminum contact onto the back of a p-type polysilicon wafer, then sinter the wafer in nitrogen. This produces the thin oxide layer on top of the wafer. The final steps are evaporations of the top contact and the antireflection coating. The latter step induces the n^+ inversion layer shown.

either on single-crystal or polycrystalline silicon the potential for low-cost manufacture.

Researchers at the School of Electrical Engineering at Australia's University of New South Wales in Kensington recently reported achieving 17.6% conversion efficiency from a 3-cm² polycrystalline-silicon cell with the structure shown in Fig. 10. Worth noting is the n^+ inversion layer, induced by the silicon-oxide coating, that improves carrier-collection efficiency. Also attractive is the cell's open-circuit voltage of 655 mV—the highest obtained from any silicon cell to date. The university's Martin A. Green expects to reach 20% efficiency by the end of the year.

Two other universities working on MIS silicon cells are Rutgers, in its electrical engineering department in Piscataway, N. J., and the University of Konstanz in West Germany. Rutgers reports having built both 12.5%-efficient single-crystal-silicon cells that are 2 centimeters square and 8.8%-efficient cells based on Wacker-Chemitronic's Silso semicrystalline silicon material. The University of Konstanz is now testing polycrystalline n- and p-type MIS silicon cells fabricated on several different metallic substrates.

■ Tin-oxide/silicon heterojunctions. At the Government Research Laboratories of Exxon Corp.'s Research and Engineering Co. in Linden, N. J., electron-beam and spray-deposition techniques are being used to make low-cost, high-efficiency heterostructures of tin oxide (SnO) and silicon and indium tin oxide (ITO) and silicon. Now reporting efficiencies of 12.24% for SnO_2/single-crystal silicon and 10% for ITO/single-crystal silicon and SnO_2/polycrystalline silicon, the Exxon group hopes to approach the theoretical efficiency of 20% and reduce production costs within DOE's timetable. Also investigating ITO/Si and oxide-semiconductor-on-silicon (OSOS) solar cells is a group at Colorado State University's electrical engineering department in Fort Collins.

■ Cadmium telluride. Among those studying deposition of CdTe solar cells are Monosolar Inc., Santa Monica, Calif., and Battelle Institut in Frankfurt, West Germany. Monosolar has produced 4%-efficient, 3-by-3-cm cells by electrochemically depositing CdTe films 0.1 to 0.2 μm thick on ITO-coated glass; its eventual goal is to produce 10%-efficient, foot-square cells for under 20¢/W. Battelle, aiming at concentrator applications, deposits layers of zinc telluride and cadmium-sulfide on slices of crystalline CdTe and is looking at alternate layers as well.

■ Cuprous oxide. Cu_2O solar cells could be very inexpensive to produce because they can be made by oxidizing copper, a cheap and abundant metal. They also have theoretical maximum efficiencies of 13%. Today, several groups are working to better their understanding of cuprous oxide's basic energy-conversion mechanism. For instance, at the University of Washington's Joint Center for Graduate Study in Seattle, Larry Olsen has extracted 1% efficiency from Cu/Cu_2O Schottky-barrier cells, while Kernforschungsanlage Jülich in West Germany reports similar performance from thin-film Cu_2O cells made by partially oxidizing copper foils. Also working with Cu_2O is a group at Wayne State University in Detroit, Mich.

■ Cadmium selenide. The Battelle Institut in Frankfurt hopes to double the 5% efficiency of its CdSe MIS cells to 10% and is also investigating alternatives to ZnSe as the insulating layer.

■ ITO/indium phosphide and ITO/GaAs. Researchers at Bell Laboratories in Murray Hill, N. J., have made 14.4%- and 12%-efficient solar cells by placing amorphous and polycrystalline ITO films on single-crystal InP and GaAs substrates, respectively. Deposition techniques that have been tried include ion-beam deposition, rf sputtering, and magnetron sputtering. Although such cells are still relatively inefficient, Bell Labs reports that they are easy to make and so potentially low-cost.

■ Zinc phosphide. The Institute of Energy Conversion at the University of Delaware in Newark has produced single-crystal and thin-film p-type Zn_3P_2 cells by vacuum evaporation techniques. IEC is now investigating ways to boost the efficiency of its magnesium-based Schottky-barrier Zn_3P_2 devices from their present 6%.

■ Electrochemical cells. A new program at SERI, electrochemical cell development, will soon begin at several of a dozen companies now negotiating contracts. Electrochemical cells with single-crystal-silicon electrodes immersed in an electrolyte have already demonstrated conversion efficiencies of 8% to 10%. Future work will investigate the use and stability of low-cost polycrystalline and amorphous-silicon electrodes.

One such system is now being developed by Texas Instruments Inc. Backed by DOE to the tune of $14 million over the next four years, the Dallas firm hopes to demonstrate the commercial feasibility of a photovoltaic fuel cell. The key to the system on which it is working is the immersion of inexpensive silicon droplets in the electrolyte. When sunlight hits the droplets, they generate a current that extracts hydrogen from the electrolyte; the hydrogen then is stored and used to charge a fuel cell that generates electricity when needed.

PART 4
CONCENTRATOR SYSTEMS

☐ One way to reduce the cost of power from a photovoltaic system is to use fewer expensive solar cells in the array, but equip them with a low-cost optical system to focus and intensify the sunlight reaching them. Over the last few years, this idea has been refined until today's concentrator systems stand an excellent chance of beating flat-panel (nonconcentrating) arrays to the Department of Energy's goal of $2.80/W by 1982. In fact, DOE last year asked eight industrial firms for their cost estimates for such systems. Their replies were unanimous: each said that using today's technology—12%-efficient cells in a concentrator system with 10% overall efficiency—it could attain the 1982 goal now, if its sales were on the order of 10 MW per year.

Although market expansion alone should enable the technology to reach the 1982 goal, considerable technical advances are still needed before it can attain DOE's 1986 goal of 70¢/W. Today, several firms are under contract to Sandia Laboratories, which coordinates DOE's concentrator efforts. All are working to lower the cost and raise the efficiency of concentrators' two basic components: solar cells that can work under intense illumination and optical systems that concentrate sunlight on them.

The types of solar cells being considered for use in concentrators are: silicon, gallium arsenide, and so-called multi-bandgap cells. In all three cases, high efficiency breeds cost-effectiveness because an increase in performance—a greater output current for the same light intensity—leads directly to a reduction in the area that must be covered by the magnifying optics. Gallium-arsenide cells require few design changes to be efficient at high concentration ratios, but special fabrication techniques are needed to maintain the efficiency of silicon cells when they are irradiated by the equivalent of more than 100 suns (Fig. 11).

Concentrating on silicon

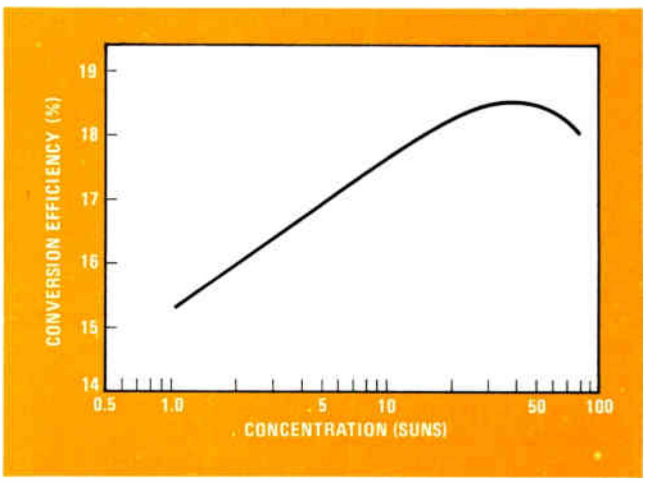
It was once thought that silicon cells would be ineffective at concentration ratios higher than 10 to 20 suns. Today, however, opinions have changed. Specially designed silicon cells have demonstrated conversion efficiencies as high as 14% at up to 1,000-sun intensities. Such silicon cells are quite different from those intended for flat-panel arrays. Their substrate resistivity is lower to minimize voltage drops at high temperatures, they have extra layers that are heavily doped to reduce ohmic losses, and their front-electrode grid patterns are finer, to enable them to handle the increased currents produced by concentrated sunlight.

Microwave Associates Inc., Burlington, Mass., now holds the record for conversion efficiency of a silicon cell operating under concentration: 20% at 600 suns. Several other firms also have designed silicon concentrator cells that have peak efficiencies ranging from 14% to 18% when illuminated at anywhere from 20 to 250 suns. Among the leaders in developing such cells are: Optical Coating Laboratory Inc.'s Photoelectronics division, City of Industry, Calif.; Motorola Inc.'s Solar Operations Group, Phoenix, Ariz.; Solarex Corp., Rockville, Md.; RCA Laboratories, Princeton, N. J.; Sandia Laboratories, Albuquerque, N. M.; General Electric Co.'s Space Systems Operations, Philadelphia, Pa.; and SGS-ATES Componenti Elettronici SpA, Milan, Italy. All produce large-area (typically 2-by-5-cm) cells that require cooling at high temperatures produced by concentration.

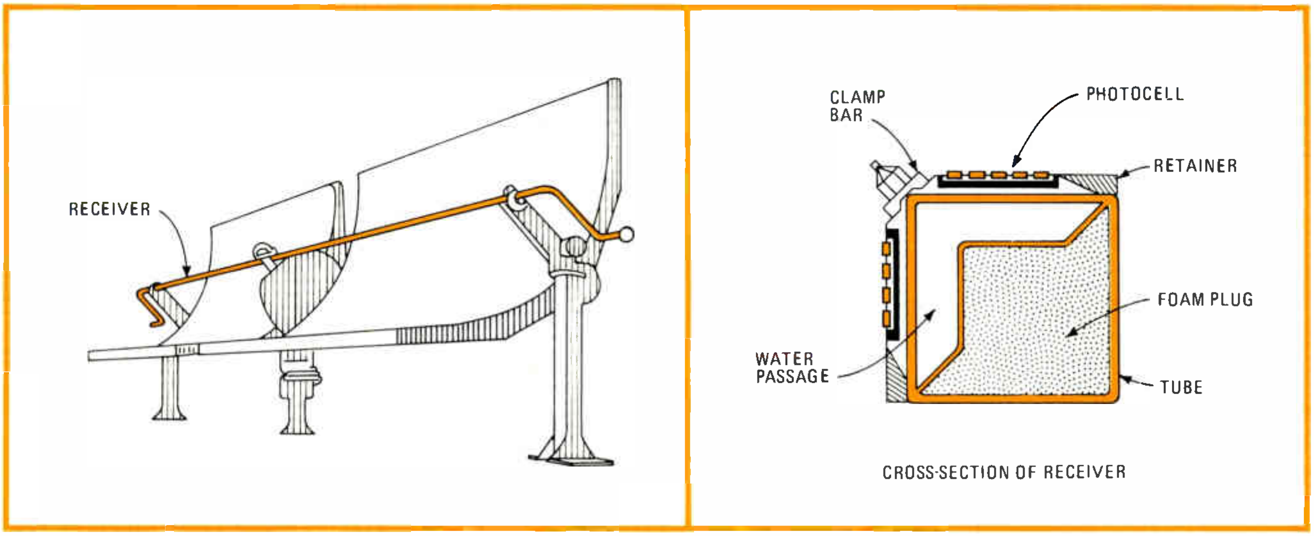
For gallium-arsenide cells, efficiency is not as much of a problem at high concentration ratios, since GaAs cells have a negative temperature coefficient of efficiency as small as 0.25% per °C increase in temperature. Especially promising for concentrator applications are heterojunctions of GaAs and GaAlAs. Those structures, which can be as small as 1 square centimeter, have demonstrated conversion efficiencies as high as 22% at concentration ratios of 1,000:1. Among the firms developing GaAs-based cells for concentrators are Hughes Aircraft Co.'s Research Laboratories in Malibu, Calif.; Varian Associates Inc. in Palo Alto, Calif.; Rockwell International Corp.'s Research Center in Thousand Oaks, Calif.; and Italy's SGS-ATES.

Splitting sunbeams

Rather than use its GaAs cells alone in a concentrator system, Varian instead teams them with silicon cells in what is called a multi-bandgap arrangement [*Electronics*, July 20, 1978, p. 42]. Since silicon and gallium-arsenide cells are most efficient when illuminated by light of different wavelengths, Varian uses a dichroic filter to



11. Some don't like it hot. Short-circuit current and conversion efficiency of silicon cells increase linearly at concentration ratios up to 40:1, but fall off at higher intensities. Reason: the currents induce internal voltage drops that lower cell output voltage.



12. Adaptable. Acurex Corp. has modified its parabolic-trough concentrator, normally used with solar heaters, to accommodate photovoltaics. The new receiver, which runs along the focus of the parabola, holds two adjacent rows of cells that are cooled by water.

split light of 165-sun intensity into high- and low-energy bands. The high-energy beam hits a 20%-efficient GaAlAs heterojunction and the low-energy beam strikes a 16%-efficient silicon cell, making total cell efficiency 31.4% and net system efficiency 28.5%, including optical losses. Varian hopes to boost the system's conversion efficiency to 35% and the concentration ratio to 500:1 by improving the cells and the optics.

Another firm with the same idea but a different approach is Research Triangle Institute, Research Triangle Park, N.C. RTI sandwiches two cells with different spectral sensitivities in a single package, eliminating the need for a filter. The top cell absorbs the high-energy photons in the concentrated light and transmits the photons with lower energies to the cell on the bottom. To date, RTI has exceeded 25% efficiency with this cell and sees 35% as an eventual goal.

It's all done with mirrors

Besides developing cheaper, more efficient concentrator cells, Sandia is funding several projects aimed at reducing the cost of the optical systems that concentrate sunlight on them. Their contractors are taking three approaches: adapting solar-heating concentrators, designing optical systems specifically for photovoltaics, and investigating any advanced concepts that seem to have low-cost potential.

Solar-thermal concentrator systems are now available commercially, and they are relatively simple to modify to accommodate photovoltaic cells, rather than thermal collectors. One such adaptation, by Acurex Corp., Mountain View, Calif., is shown in Fig. 12. Acurex changed the water-carrying receiver element of its parabolic-trough concentrator into a tube that is square in cross section and holds two rows of silicon cells. The 9%-efficient system uses 13%-efficient cells.

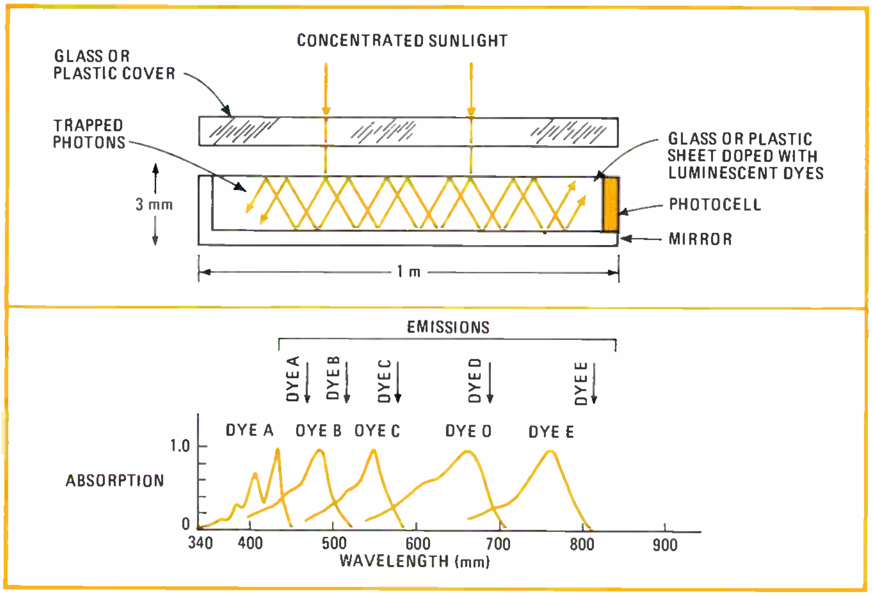
Of the optical-system designs that contractors have conceived from the ground up specifically for photovoltaic arrays, two look most promising: parabolic troughs and Fresnel lenses.

A parabolic trough focuses incident sunlight along a line parallel to its axis (Fig. 12). One 10-kW design, by Spectrolab Inc., Sylmar, Calif., comprises a number of troughs mounted in rows on a large turntable that permits azimuthal (horizontal) tracking of the sun. A single drive mechanism provides elevational tracking by pivoting all the troughs together about horizontal beams.

Martin-Marietta Corp., Denver, Colo., has built a 3.3-kW array that uses point-focusing, acrylic Fresnel lenses to concentrate 40-sun light on each of 272 silicon cells that are packaged as four-cell modules. Three of these arrays, which also track the sun about two axes, have been delivered to Sandia for evaluation. Other organizations working to reduce the cost of Fresnel-lens concentrators, and of the lenses themselves, are RCA's David Sarnoff Research Center, Princeton, N.J., and Swedlow Inc., Garden Grove, Calif.

Aware of the role that market expansion must play in reducing the cost of concentrators, Sandia and DOE's Albuquerque office have planned their deployment into the field to demonstrate their effectiveness and gain valuable operating experience. Phase 1 of the plan, which is called the Photovoltaic Concentrator Applications Experiments, ended this February. During Phase 1, 17 contractors were selected to submit detailed designs and budgets for proposed concentrator systems. Of these 17, five were chosen to continue into Phase 2, which is termed System Fabrication:

- General Electric Co.'s Space Systems Operation, Philadelphia, Pa., for a \$3.4 million, 110-kW, parabolic-trough system that will ultimately be installed at Sea World in Orlando, Fla.
- Arizona Public Service Co., a Phoenix-based public utility, for a \$6.5 million, 283-kW, Cassegrain-optics systems that will power that city's Sky Harbor International Airport.
- E-Systems Inc., Dallas, Texas, for a \$650,000, 27-kW, Fresnel-lens system that will provide electricity and heat to Dallas-Fort Worth's airport.
- BDM Corp., Albuquerque, N.M., for a \$1.1 million, 42-kW, reflective-trough system to power an office building in Albuquerque.



13. Glowing promise. This solar collector uses luminescent dyes that absorb sunlight in narrow frequency bands, then reradiate photons at different wavelengths. The system need not track the sun, as the dyes are sensitive to light incident at any angle.

■ Acurex Corp., Mountain View, Calif., for a $1.4 million reflective-glass dish system to be installed at a hospital in Kauai, Hawaii.

All of the above systems use silicon cells that are cooled by air or water. Installation should take about a year, so all five projects should be operational by mid-1980. Phase 3, Operation and Evaluation, will follow immediately and last up to two years. Significantly, Sandia hopes that all five systems will reduce purchases of electricity to the extent that they will pay for themselves by 1986.

Concentrators of the future

While Sandia expects market growth and applications experiments to help drive the costs of concentrator technology below $2.80/W by 1982, it recognizes that further reductions in cost will be difficult without the help of innovative technology. Therefore, it is also backing the development of four advanced concepts that hold promise for attaining DOE's 1986 goal of 70¢/W. They are a two-dimensional compound parabolic concentrator, a headlamp-type concentrator, an air-pressure-supported, a bubble-enclosed film concentrator, and a luminescent concentrator.

The two-dimensional concentrator under development at Sun Trac Corp., Wheeling, Ill., has two attractive features: a high concentration ratio (115:1), which allows the use of less efficient cells; and a high tolerance for tracking errors, which allows the use of a less expensive tracking system. The headlamp-type concentrator now being examined by Acurex Corp. could be inexpensive, as it could eventually roll off the high-volume assembly lines of automotive sealed-beam headlamps.

The air-pressure–supported, bubble-enclosed film concentrator now being developed by Boeing Co., Seattle, Wash., is both light and strong. Its concentrating reflector is a lightweight parabolic film formed in a vacuum and mounted on a lightweight tracking structure. The assembly is enclosed in an air-supported bubble that protects it from the environment.

Perhaps the most innovative of the four advanced concepts is the luminescent solar collector under joint development at Owens-Illinois Inc., Toledo, Ohio, and the California Institute of Technology, Pasadena, Calif. It comprises a glass or plastic sheet doped with luminescent dyes that are sensitive only to light in narrow frequency bands (Fig. 13). The dye molecules absorb sunlight and reradiate it at different wavelengths in many directions. Some of that light is reflected, becomes trapped within the sheet because the dyes cannot reabsorb it, and eventually bounces down the sheet to a photocell at its edge.

The most attractive feature of this system, aside from its 60% to 70% theoretical efficiency, is that it need not track the sun, since the dyes absorb light incident at any angle. At present, researchers are identifying dyes that have both long-term stability in sunlight and the correct absorption and reemission characteristics. Early results are promising, and projections are that this system may eventually cost as little as 63¢/W.

Thermophotovoltaics

Another advanced concept based on reradiation, but whose development is not supported by Sandia, is thermophotovoltaic conversion. This approach concentrates sunlight to heat a radiator to incandescence at about 2,000°C. The radiator then beams its own light, at longer wavelengths than those from the sun, onto a specially designed silicon cell that converts it into electricity at 40% efficiency. The cell also reflects unabsorbed light back to the radiator, maintaining its temperature.

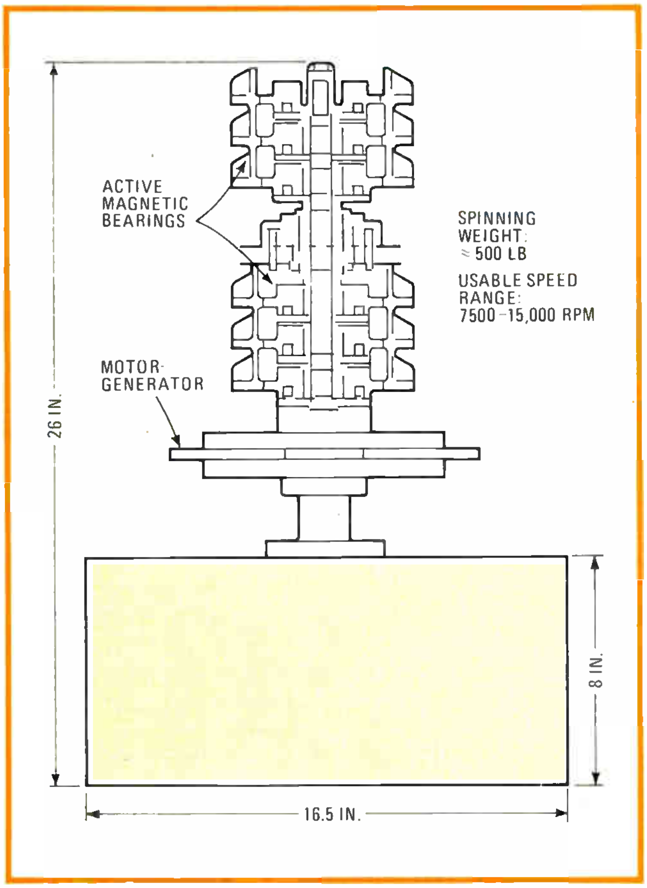
Assuming optical losses, such a system has a theoretical conversion efficiency of 35% to 40%. To date, Stanford University's Electronics Laboratories in Stanford, Calif., which is developing the concept with funding from the Electric Power Research Institute (EPRI) in Palo Alto, Calif., has achieved 26% efficiency, using an artificially heated radiator. By the end of the year, EPRI, which is totally funded by the U. S. utility industry, will have spent $650,000 over the last three years on cell development work at Stanford and $200,000 for optical and thermal R&D at various other contractors.

PART 5
SUBSYSTEMS AND APPLICATIONS

Despite the richness and diversity of Government-sponsored research and development on lower-cost of solar cells and concentrator systems, years will pass before those efforts begin to bear fruit. Only then will the market for photovoltaics expand beyond remote-power applications, in which they now serve, to larger markets like residences, commercial buildings, industrial plants, and utilities.

Before photovoltaic systems can begin to penetrate new markets, however, attention must be focused not only on reducing the cost of arrays but also on developing reliable, low-cost ancillary equipment to connect them to a wide variety of alternating-current loads. DOE recently recognized the eventual need for such equipment, which it calls balance-of-systems hardware, and now plans to devote a greater share of its 1980 budget to its development. Generally, balance-of-systems hardware comprises two categories of equipment: power-conditioning units and energy-storage devices.

All power-conditioning units contain an inverter, which converts the direct-current power from photovoltaic arrays into clean, alternating-current power required by ac loads. Although a wide range of inverters is available commercially today, most of them are inefficient when used with photovoltaic systems because the output voltage from solar-cell arrays varies significantly during normal operation.



14. Spinning reserve. MIT-Lincoln Lab's flywheel may someday make batteries and power conditioners obsolete in consumer applications. Now being built as a 1:10-scale model, the system, when scaled up, could store enough energy to power a home for a day.

Power-conditioning units also must control and distribute the output of the array. For stand-alone systems (those not backed up by a utility grid), control may involve connecting and disconnecting the array to and from the load at sunrise and sunset and during cloud cover. If the system includes a storage battery, the power-conditioning unit also must decide when to drive the load or charge the battery.

For grid-connected systems, the power-conditioning unit has additional duties. It must switch the load's input-power lines between the array and the incoming utility lines at the right times, matching impedances all the while, and it must also synchronize the array's output waveform with that of the utility when feeding power back into the grid.

Clearly, power conditioners are complex equipment. Recognizing this, Sandia Laboratories has funded the development of two such units: an industrial device designed by Westinghouse Electric Corp.'s Aerospace Electronics divison, Lima, Ohio; and one, destined for use in residences, that is now under development at Abacus Controls Inc., Somerville, N. J.

Westinghouse's power conditioner provides up to 62.5 kilowatt-amperes of three-phase power at 440 V ac. It includes a microprocessor that automatically synchronizes its output to utility lines and matches impedances precisely. During acceptance tests at Sandia, the unit succeeded in demonstrating an ac-dc conversion efficiency of 92% at full load.

Abacus Controls is at present developing a microprocessor-controlled, single-phase, split-110/220-V power conditioner that the firm says will have a conversion efficiency greater than 90%. It also says that the unit will be priced at $150 to $200/kW and that it will be sold commercially under the trade name Sunverter.

The storage story

In photovoltaic systems where no backup supply is available or desirable but where electricity is needed around the clock, some of the energy produced by the array during the day must be stored and then recovered to drive the load at night and on cloudy days. Today, conventional lead-acid and nickel-cadmium batteries are the only storage options. However, those batteries are expensive, inefficient, prone to rapid discharge, far from maintenance-free, and relatively short-lived. Therefore, DOE is now accelerating development of several advanced energy storage concepts that, in the long run,

Solar-power satellites to chase the clouds away?

If esoteric photovoltaic configurations like electrochemical fuel cells and dye-doped plastic sheets seem like technology borrowed from Buck Rogers, just wait. The Department of Energy and the National Aeronautics and Space Administration are together studying the feasibility of orbiting a series of massive, miles-long satellites bearing solar cells that would collect energy from the sun around the clock and beam it back to earth in microwave form.

With $20 million to spend over three years, the solar-power satellite (SPS) project office within DOE's Office of the Director of Energy Research is now identifying the technical, economic, environmental, and social implications of such a plan [*Electronics*, April 27, 1978, p. 96]. According to project head Frederick A. Koomanoff, the SPS concept as envisioned at present calls for 25 to 30 satellites to be launched and assembled in geosynchronous orbit by the end of the century.

Each satellite would measure about 18 by 5 kilometers and produce 5 gigawatts of electricity from silicon or gallium-arsenide cells, convert it into microwave energy, and beam it back to earth at 2.45 gigahertz. On earth, gigantic antennas 10 by 14 km in area would collect the microwave energy, convert it into 60-hertz power, and feed it into the nation's utility grid.

Koomanoff expects to have completed preliminary studies by June 1980. Then his group will publish their findings and recommend whether or not the concept warrants further detailed investigation. That next phase, he says, might be funded by legislation, now pending in Congress, that would appropriate $25 million for each year of subsequent research and development.

The SPS concept was first broached 10 years ago by Peter Glaser, a vice president of Arthur D. Little Inc., Cambridge, Mass., and since then has slowly gathered support not only in Congress, but in scientific circles as well. Undaunted by detractors who call SPS a boondoggle, Glaser maintains that the estimated $500 billion it would take to orbit the satellites "is not out of line with estimates of $1 trillion to develop alternative U. S. energy sources beyond oil and coal." As yet unanswered, however, are questions regarding defense of the satellites, the effects of concentrated microwave energy on the earth and its atmosphere, and what would happen if one of the satellites were to fall to earth.

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may prove both technically and economically feasible.

DOE's energy storage and photovoltaic programs are separate, but they work closely together. Albert Landgrebe, who heads DOE's division of energy storage, reports that, although the agency is only at the stage of defining the program, it already has a pretty good idea of what it will be looking for.

According to Landgrebe, batteries designed to store photovoltaic electricity should respond quickly when called upon, have a long operating life, and, of course, be low-cost. Among the batteries with those characteristics that DOE is now looking at are improved versions of lead-acid batteries, reduction-oxidation (redox) batteries, and zinc-bromine batteries. Landgrebe sees the latter type as especially promising because they are fire-retardant and therefore a good choice for residential applications since consumers can not only use but also maintain them safely.

In fiscal year 1979, DOE is spending about $2.1 million on battery development and plans to boost funding to $5 million next year. But, despite those outlays, many solar-energy experts are skeptical that electrochemical batteries can ever develop into a viable piece of balance-of-systems hardware. Instead, they say, what is needed is an all-solid-state, maintenance-free unit that stores energy efficiently and at low cost.

Alan R. Millner of MIT's Lincoln Laboratory thinks that he knows how to build such a system. His idea: store energy in inertial rather than chemical form, in a flywheel spinning at high speed in a vacuum. The key to the system's potentially low price is not the flywheel itself, but rather its compatibility with power conditioners that are cheaper than inverters.

The system that Millner envisions is huge. It would include: a 6-foot-high, 14-foot-wide, 2-ton flywheel made of fiberglass or a similar material; a 95%-efficient dc motor–ac generator to accelerate the flywheel to 7,500 to 15,000 revolutions per minute during the day and produce 60-Hz power during deceleration at night; and electronically controlled active magnetic bearings to support the motor-generator and flywheel in a vacuum. Such a system, if installed in a pit beneath a garage, could store enough energy to power a typical home for at least one day, and last 20 years with little maintenance.

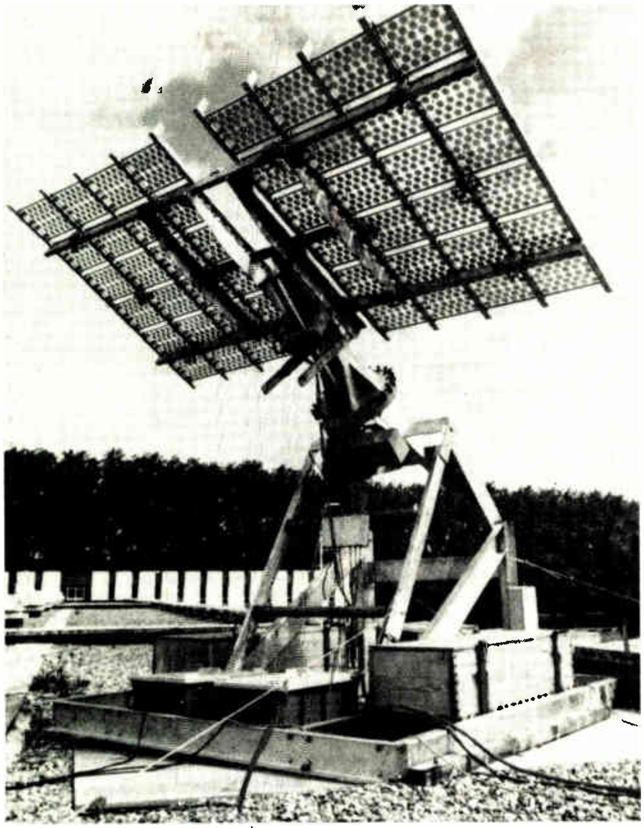
As to price, Millner claims that "on a life-cycle basis, flywheels will eventually cost less than today's batteries." He supports the prediction with preliminary cost analyses that show that, assuming reasonable reductions in the current high price of flywheel materials and the creation of mass-production facilities for all system components, the flywheel system could cost less than a combination battery-power conditioner as early as 1985.

Today, Millner is busy building an experimental model one tenth the size of his proposed system, which is shown schematically in Fig. 14. Assuming all goes well, he hopes to scale up to a full-size prototype that may even attract commercial interest.

Present and future applications

Clearly, there's an abundance of R&D into reducing the future costs of photovoltaic cells and related equipment. Even at today's prices of $10 to $15/W, however, solar cells are a growing business. More than a dozen companies now sell arrays of single-crystal-silicon cells for a wide variety of applications. Although those applications remain ones in which a conventional power source would be prohibitively expensive to install and run, there is growing evidence that the market for photovoltaics is beginning to expand.

To date, photovoltaics have served as reliable, maintenance-free, although small, power sources to remote equipment like satellites, mountaintop microwave repeaters, railroad signals, and navigational buoys. Some consumer products have been powered by solar cells, too,



15. Sun-powered pump. This experimental pumping station near Toulouse, France, moves 10 cubic meters of water each day. Built by Compagnie Industrielle des Piles Electriques, it is powered by a 500-watt array of solar cells from RTC-La Radiotechnique Compélec.

but they have chiefly been novelties like battery chargers for digital watches and calculators.

Now that array prices are falling below $10/W, however, photovoltaics are beginning to compete with diesel-electric generators for larger-sized (1-to-5kW), so-called intermediate-market applications—providing power to villages in less developed countries, as well as for outdoor lighting and rural pumps (Fig. 15). DOE, through the Federal Photovoltaics Utilization Program, is also helping to expand the intermediate market by encouraging Government agencies, including the armed forces, to buy photovoltaic arrays.

Three such Federally sponsored projects are notable for their size. One is a 60-kW installation that will power the U. S. Air Force's Mount Laguna radar station near San Diego, Calif. [*Electronics*, Jan. 19, 1978, p. 41]. This system was designed and built by Delta Electronics Corp., Irvine, Calif., a supplier of uninterruptible power supplies for computer, medical, and military applications. Today, the site is ready and the system is on its way from Irvine where it passed operational field tests with flying colors.

The remaining two sizable Federal photovoltaics installations are: a 360-kW concentrator system that will power and heat Mississippi County Community College in Blytheville, Ark., beginning this fall [*Electronics*, June 22, 1978, p. 44]; and a 100-kW setup that will power the visitors' center at Natural Bridges National Monument in southeastern Utah. This system, whose 260,000 silicon cells comprise the largest flat-plate array in the world, is scheduled to take over from the site's existing diesel engine late this year.

Eventually, when the cost of the photovoltaic systems falls below $1/W, solar power will become an attractive alternative to utility power purchased by consumers. Then, solar cells will begin to show up on small commercial buildings, industrial plants, and perhaps even on massive space satellites that would beam huge amounts of photovoltaic power back to earth in microwave form (see "Solar-power satellites to chase the clouds away?" p. 121). But the hopes for future cost reductions depend on continued international research and market expansion, and especially on timely achievement of the module-price goals that DOE is shooting for.

DOE's report card

Even assuming that some DOE contractors are reluctant to bite the hand that feeds them, a sampling of contractors' opinions of DOE's performance makes it clear that, in the words of Donald Feucht, manager of DOE's R&D lead center at SERI, the department is "charting a good course". Even Robert Willis, president of tiny Solenergy Corp., Wakefield, Mass., one of the few commercial solar-cell suppliers that receives no Federal money, agrees with DOE's philosophy of simultaneous R, D & D—research, development and demonstration.

Rather than fault DOE, many critics of the photovoltaics program instead blame the U. S. Congress, which holds the program's purse strings, for its one serious shortcoming—delays in funding. Those delays not only slow technical progress, they often force layoffs of hard-to-replace scientific and engineering specialists as well. Indicative of Congress' influence is the fact that many hold it responsible for stalling the growth of the entire solar-energy industry during the 18-month period between President Carter's unveiling of the National Energy Act and its enactment. During that period, 3 out of 10 solar-energy companies, many of them small, simply disappeared while potential customers waited for Congressional approval of promised tax credits against purchases of solar equipment.

Many also criticize the skimpiness of Federal support for photovoltaics development; in fact, America's annual budget for solar-cell R&D is roughly equal to what it now spends each day on imports of foreign oil. Recently, however, Washington has again begun to make louder noises about its commitment to photovoltaics and solar energy in general. Just last month, for example, President Carter announced the establishment of a financial development bank that would, among other things, provide low-interest loans for solar construction.

One remote possibility is a dramatic increase in funding for the photovoltaics program. Although far from a certainty at this point, such a crash program would envision solar cells supplying as much as 25% of U.S. electricity needs by the year 2000, a far cry from the present 5% goal. According to Paul Maycock, who heads the program, such a crash effort might accelerate DOE's timetable by two years. □

Paralleled slaves boost throughput of minicomputers

Programmable general-purpose unit uses same instruction set as intended host, allowing it to off-load software tasks

by Jerry Braun and George White, *Computer Automation Inc., Naked Mini Division, Irvine, Calif.*

☐ With the price of minicomputers dropping and their performance characteristics rising, parallel-processing techniques are an increasingly economical way to improve overall system performance. As noted in Part 1, peripheral processing is the most practical approach for applying parallel processing to existing minicomputers. Because peripheral processors are added to a minicomputer's bus in the same way as a direct-memory-access input/output (DMA I/O) controller, they fit naturally into existing minicomputer organizations.

Computer Automation's recently introduced 4/10S slave processor (Fig. 1) generalizes the peripheral-processing concept [*Electronics*, May 24, 1979, p. 202]. It can be programmed by the user, in contrast to specialized I/O peripheral processors.

The general-purpose slave processors available cover a broad performance range. Consequently, programming may involve using elementary and difficult-to-write microcode for a bit-slice machine, a standard microprocessor assembly language, or a more sophisticated and therefore easier-to-use minicomputer instruction set.

The 4/10S is called a "slave" because it is completely controlled by a single Naked Mini host computer. Under program control, the host may stop, interrupt, or reset any 4/10S. Slave processors cannot be used to create a true multiprocessing system, but they can effectively increase system throughput in many applications.

Whereas other slave computers have evolved from smart I/O controllers and have elementary instruction sets suitable for design engineers to program, the 4/10S is a version of the 4/10 minicomputer. Thus, it has the same architecture as the 4/10 and a superset of the standard 4/10 instruction set, which, because it is more comprehensive, eases programming.

The master

The 4/10 is the low-end machine of Computer Automation's Naked Mini 4 product line. A 16-bit machine with, for example, a register-to-register add instruction time of 3 microseconds, it has an address space of 64 kilowords, four general-purpose registers (two of which are also index registers), a stack pointer register, and a stack limit register. Four on-board Distributed I/O (DIO) ports allow connection of various I/O devices.

As seen in Fig. 2, the computer's architecture is partitioned between two custom large-scale integrated circuits. The control chip is a microprogrammed controller dedicated to interpreting the Naked Mini 4 instruction set and generating the necessary addresses to access the appropriate microcode from the external ROM. The data chip contains general-purpose 16-bit registers and an arithmetic and logic unit. To minimize the number of pins on the chips, the microinstructions coming from the

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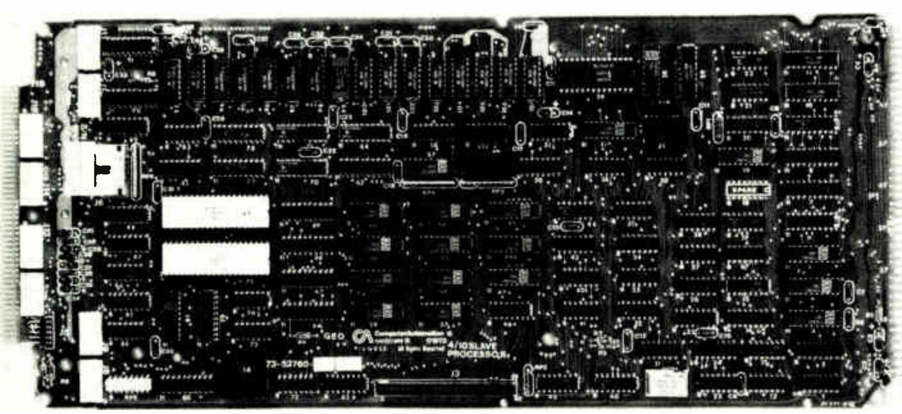
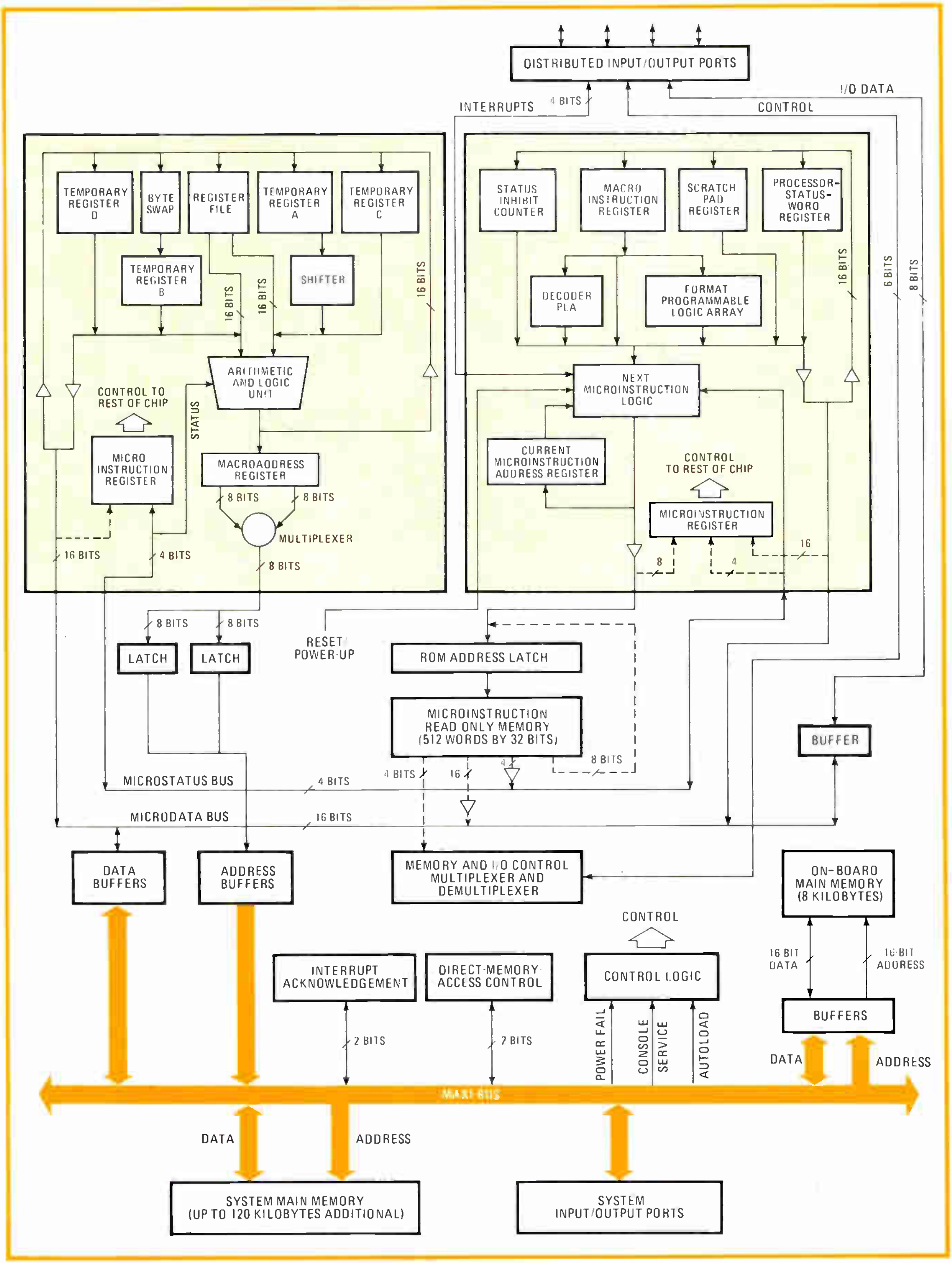
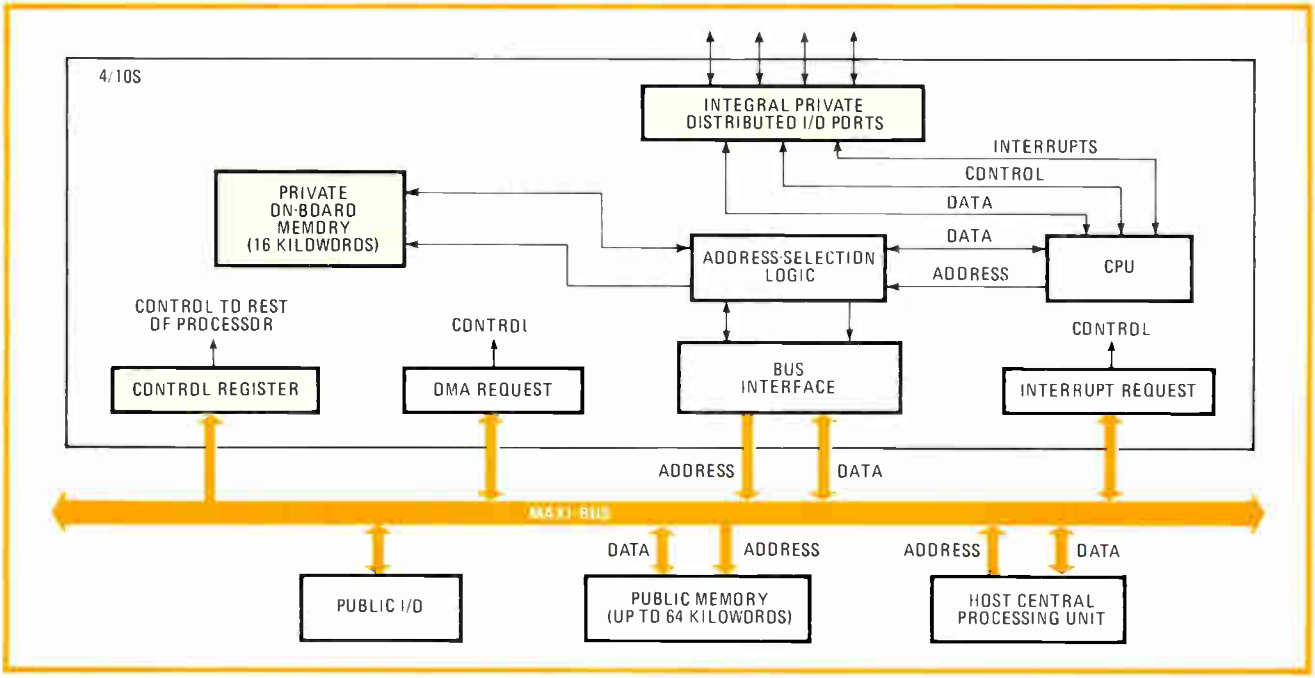
This is the second part of a two-part article on parallel processing with minicomputers. Part 1, which appeared in the July 5 issue, page 125, examined the various parallel-processing techniques and configurations currently in use.



1. Similar slave. Resembling the Naked Mini model 4/10 minicomputer, Computer Automation's new 4/10 slave processor uses the same two custom central-processing-unit chips (large white chips on left half of board) but has private input/output ports and 16 kilowords of memory.



2. Peripheral's parent. The Naked Mini 4/10, upon which the 4/10S is based, is built around two custom integrated circuits (tinted blocks). The data chip (left) contains the registers and arithmetic and logic unit; the control chip (right) interprets the instructions.



3. Attachable. The 4/10S attaches to the Maxi-Bus interface of a host Naked Mini computer. Address-selection logic on the 4/10S lets the CPU reference either the 16 kilowords of on-board private memory or the host system's public memory.

ROM are multiplexed with the interchip microstatus and microdata buses.

Because the 4/10 is microprogrammed, it can be modified to operate as either a host processor or a slave processor. For the same reason, the 4/10S can use the same custom chip set as the 4/10.

As seen in the block diagram (Fig. 3), the 4/10S attaches to the host Naked Mini's system Maxi-Bus interface and has direct access to the host's main system memory—what might be called public memory. The unit has 16 kilowords (32 kilobytes) of dynamic RAM on board as private memory that can be used for both data and program storage. References by the 4/10S to its private memory do not go out on the system bus or otherwise interfere with the rest of the system.

The 4/10S also has four private I/O ports. They emulate ports in Computer Automation's Distributed I/O scheme and allow a wide variety of slow and medium-speed devices to be operated by and dedicated to a 4/10S. Interfacing is accomplished with specialized Picoprocessors, small interface boxes that are available for use with various devices, including line printers, terminals, modems, and magnetic-tape and 5.25-inch mini-floppy disk drives, as well as Binary Synchronous protocol and IEEE-488 interfaces.

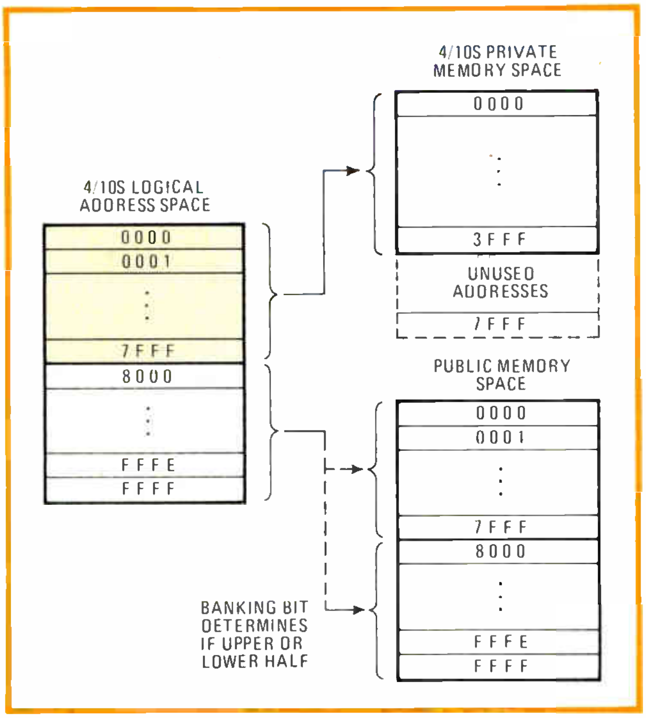
Characteristics

Some of the 4/10S's distinctive characteristics stem from its instruction set. Since, as mentioned earlier, it is a superset of the standard 4/10 instructions, the host and slave are programmed in the same language. Therefore, programs that run on a 4/10 can run on a 4/10S.

This approach yields several advantages over one in which a slave is based on a different set of instructions. To start with, documentation and the training of programmers are the same. Also, the potential exists for configuring a flexible software organization in which tasks can be shifted from the host to the slave. A final system might not have a 4/10S at all in its low-end configuration, whereas a higher-performance version might assign tasks to one or more 4/10Ss using much of the same code that originally ran on the host. This inherent flexibility, of course, requires the system designer to plan ahead.

Extra instructions were added to the slave unit that are important in its new role. Two of the most important are "block move" and "translate characters." The former provides a simple way of getting data from one place to another—even across the public-private memory boundary—in one instruction. The latter is a block-move instruction that uses a conversion table to translate the bytes it transfers. It might be used for conversion from American Standard Code for Information Interchange (ASCII) to Extended Binary Coded Decimal Interchange Code (EBCDIC) or for detecting or suppressing special characters in a block of data.

Since the Naked Mini machines have a 64-kiloword maximum logical address space, how can the 4/10S address its own 16 kilowords of memory as well as the public memory's 64 kilowords when it has a total addressability of only 64 kilowords (actually 2^{16} or 65,536)? Programs running on a 4/10S "see" a 64-kiloword address space, considered to be the 4/10S's logical address space. The lower half of this space (addresses 0 through 32,767) provides access to the 4/10S's on-board private memory; the upper half (32,768 through 65,535), access to public memory (Fig. 4). Therefore no special mapping method is required for a 4/10S program to be read out of, written into, or even executed out of public memory. A "banking" bit in a control register on the 4/10S determines whether the upper half of the address space maps into the upper or



4. Memory management. The lower half of the 4/10S's 64-kiloword logical address space (addresses 0 to 32,767—7FFF in hexidecimal) are used to reference the private memory; the higher addresses access either half of the host system's public memory.

lower half of the public address space.

Although the 4/10S can execute instructions out of public memory, this is only done in unusual cases, such as initialization, because it lowers performance.

The private DIO ports are treated in the same manner as the private memory in that they are controlled by the slave and are not directly accessible by the host central processing unit (CPU). These ports are used identically as the corresponding ports on a 4/10 minicomputer. They operate with programmed, interrupt, and automatic I/O (a pseudo-DMA input/output scheme for interrupt-per-character peripheral devices such as start/stop terminals).

In addition, the slave can perform programmed I/O on the host computer's bus. Computer Automation's Maxi-Bus interface is designed so that when the host CPU gives control of the bus to a DMA device, that device also gets control of the signals used by programmed-I/O instructions. This capability is supported by the 4/10S. It can automatically direct I/O instructions either to the private ports or onto the system bus, depending upon the device's address.

The control register

A key component of the interface between the host CPU and a 4/10S is the control register on the slave processor. This register is connected to the system bus and is therefore accessible by both the host and slave processors. The various bits in the register control initialization of the slave, interrupts posted to and from the slave, console functions, and memory-space mapping.

Setting the slave-interrupt bit in the control register interrupts the 4/10S program. After responding to the interrupt, the 4/10S resets that bit, indicating acknowledgment. The slave-control bit, when set, causes the 4/10S to perform console, or so-called front-panel, functions. It reads a console command word from a fixed location in public memory that directs it to carry out a traditional console function such as read memory location, write memory location, read register, load register, stop, start, and even single-step.

Since bits in the control register are set, reset, and tested by both host CPU and slave programs, some synchronization and arbitration are required. They are accomplished by having the control register accessed only over the Maxi-Bus interface. A 4/10S must actually acquire control of that shared bus to alter or test its own control register, solving the synchronization problem by using the existing bus-arbitration mechanisms.

An apparent drawback to this approach would be that the program running on a slave would have to know its device address in order to talk to itself. This is avoided by reserving one "dummy" device address to which no bus unit may be assigned and having slaves use that address when talking to themselves. A special path into the 4/10S's own device-address–selection logic causes it to respond to itself.

Considerations of slave computing

Despite their advantages, slave processors are not without problems, the major ones being synchronization, I/O operations, data movement, and debugging.

The flexibility obtained by using RAM for the 4/10S's program storage, for instance, introduces the problem of initial program loading. Although the loading could be done using the console-type functions, such a solution would require much of the host CPU's time to load each word individually into the private memory. Initialization is best performed using the slave to execute instructions from public memory. After placing a bootstrap program in that memory, the console function is used to load the slave's program counter, and then the start function is employed. The bootstrap program is executed out of public memory and can then load the application program into private memory and transfer control to it.

A frequent question with parallel-processing systems is how to allow general synchronization. It is sometimes assumed that a special instruction—an interlock primitive—is required to synchronize parallel processors, but it is in fact needed only in true multiprocessing systems. Since a host-slave arrangement is not such a system, synchronization is performed in much the same way that a host synchronizes with a disk controller—it commands the start of an operation and is interrupted upon its completion. If a more general synchronization is required in a multislave system, the interlocked operations must be performed by the host on behalf of the slaves.

Another typical problem with slave processors is that the only I/O devices they have access to are private on-board I/O ports. This restricts the slave's generality and might force different models of slaves to be used, depending on what device port is desired.

The 4/10S eliminates this problem in two ways. First, as mentioned earlier, the four private DIO ports allow connection of a wide variety of slow and medium-speed devices. Second, the 4/10S can perform programmed I/O directly to Maxi-Bus devices. For example, a slave could create a control block for a disk controller and send it a start command. The disk controller would access public memory directly and the slave could poll it to determine if the operations were finished. In this way, slaves can control devices not on its private DIO ports.

Debugging

Parallel processing also presents some difficulties for software debugging. Extra complexity is the root of the problem, but other factors contribute to the difficulties. Slave processors usually do not have front-panel consoles, and their references to on-board memory are not visible to instrumentation attached to the main bus.

By setting the slave-control bit in the 4/10S's control register, consolelike functions may be performed on the 4/10S through the host. These functions allow memory and registers to be changed and examined and the program to be single-stepped by a program on the host CPU. Another debugging technique is to attach a terminal to one of the DIO ports and load Computer Automation's debugging utility into the 4/10S. Since it executes the same instruction set as a 4/10 minicomputer, the utility will run on it and be controlled by a private terminal. This utility supports breakpoints, memory searches, and other tools for isolating problems.

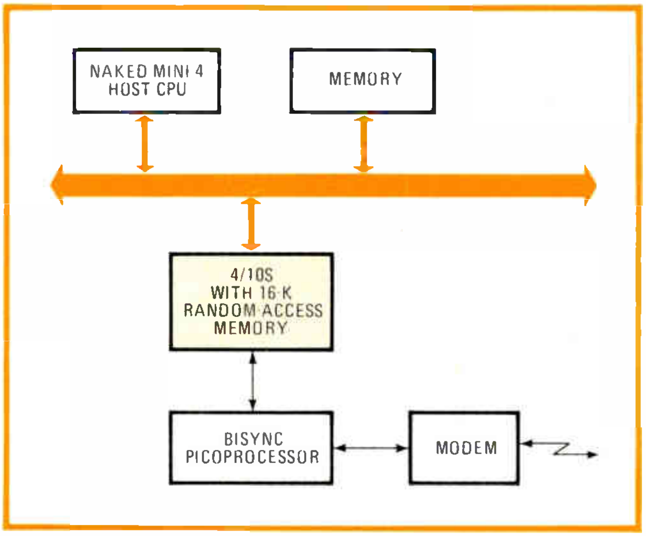
An important class of debugging techniques involves actually monitoring bus transfers with hardware analyzers. This may be done with general-purpose logic-state analyzers or with special units like Computer Automation's bus monitor. The latter works much like a logic analyzer—it triggers on specific data patterns and stores large amounts of pre- or post-trigger information—but is set up and read out by program control.

A version of the debugging utility provides support for this hardware, but it is useful only if the memory references actually occur on the main bus; private memory references cannot be monitored. The 4/10S overcomes this constraint by having a special debugging mode in which references that would normally be to private memory are instead diverted to a specific region in public memory. This mode allows the bus monitor to be used and also can help confirm or rule out private memory as a faulty element when making repairs.

Applications

In general, the most appropriate applications for slave processors involve situations in which part of a program is clearly separable from the mainline program and may run in parallel with it. Also the subtask must require extensive high-speed communication with the main program; otherwise, a loosely coupled system might be more appropriate. Another factor is the host CPU itself. Is a more powerful host available that is compatible and provides the extra computing power required, or is it more economical to expand the existing system?

Communications-protocol handling is a natural application for a slave processor. This function is often added onto an existing system when minimum impact to that system is a prime concern. Protocol handling can put a strain on a computer in terms of both computation time and memory usage. By adding this function with a 4/10S, the existing system retains its resources to handle the original applications. A general-purpose RS-232-C asynchronous Picoprocessor or the new Binary Synchronous Picoprocessor may be connected to the private ports of a 4/10S to implement such a system. By having the 4/10S execute the protocol-emulation software (Fig. 5), such a configuration allows emulation of IBM's 2780 or 3270 protocols to be accomplished with minimum impact on the system.



5. Appropriate application. Used as a communications-protocol controller, the 4/10S, together with a Bisynch Picoprocessor can free the host processor from executing the protocol-control software needed to emulate terminals like IBM's 2780 or 3270.

Sort, schedule, 'smarten'

Distributed computation is a general application suitable for the 4/10S. Examples might include the use of a quick-sorting algorithm that breaks data up into sections that are individually sorted and then merged. Individual 4/10Ss could be used to work on those sections in parallel. The 4/10S also might be used to perform an operating-system function like time-sliced scheduling: while one job is running on the host CPU, a 4/10S could be scanning the task list to determine which job to run next on the host and how much time to give it.

Perhaps the most typical use for the 4/10S is as a peripheral-device controller. One example might be to control up to four "dumb" terminals connected to the 4/10S's ports so that they look like smart terminals. Others range from line-printer spoolers (buffer managers) to file-system managers.

Depending on the requirement of the tasks to be performed, the slave can often be doing more than one at a time. RTX, a real-time multitasking operating system, can be run on the 4/10S to make that possible.

As has been discussed, parallel processing can take many forms. But, as the 4/10S shows, a computer user need not purchase a true-multiprocessing system in order to see tangible benefits. The more mundane host-slave organization, in fact, is well suited to many dedicated applications and fits much more comfortably into traditional minicomputer architectures. ☐

Logic-function generator needs no power supply

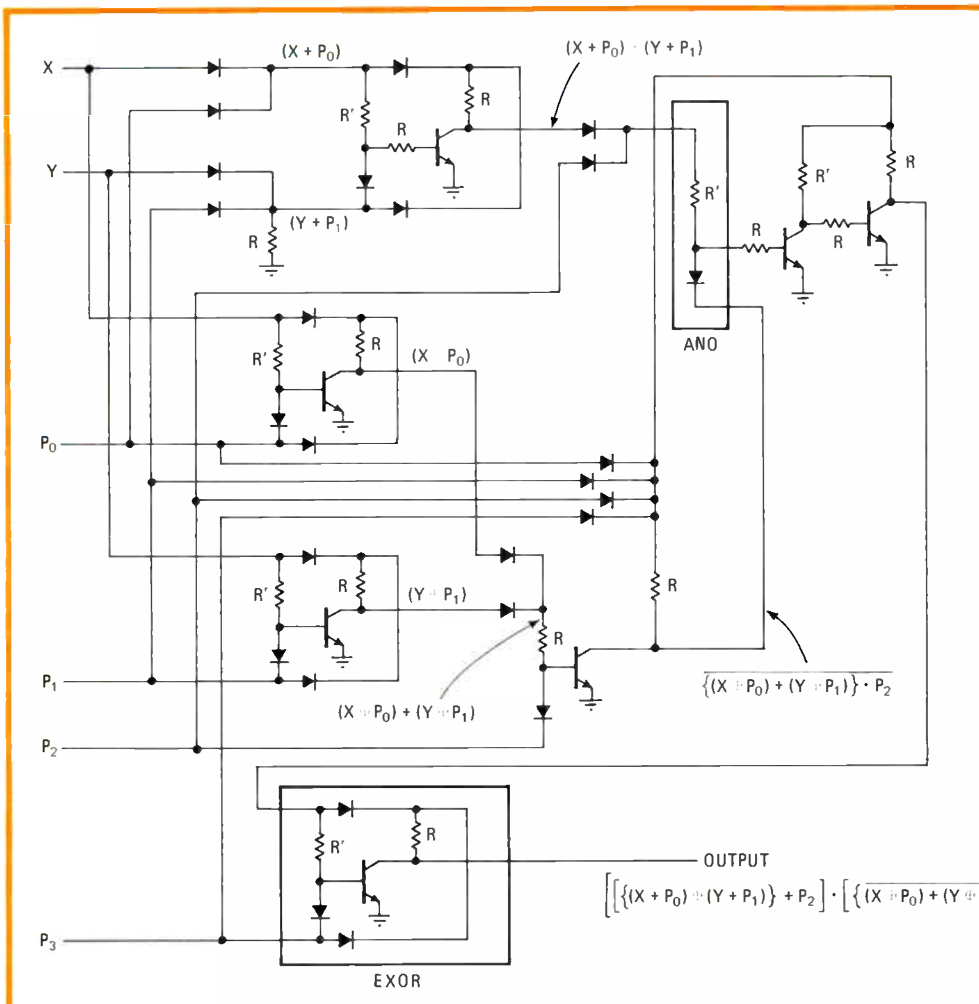
by P. R. K. Chetty, *Department of Electrical Engineering, California Institute of Technology, Pasadena*

When the same logic and control signals that drive this generator are also used to power it, 14 functions of two input variables are generated without the benefit of a bona fide supply. Consequently, dc power is conserved, and the physical size of the generator is also reduced. It is only necessary that each input signal be able to provide a minimum average current of 15 milliamperes at 5 volts to energize the generator.

Given input variables X and Y, the generator (see figure) will derive most of the popular logic functions of both when ordered by control inputs P_0–P_3. A logic 0 and logic 1 output can also be generated.

The X and Y signals are applied to one or more of three exclusive-OR gates and directly combined with three of the P lines, as shown. Each of the exclusive-OR gate outputs is combined in various ways with the aid of one AND and one OR gate so that the general logic function appearing at the output of the fourth exclusive-OR gate is denoted by the Boolean expression shown. By suitable choice of the logic value of the P_i terms (see table), the desired logic function will be generated.

Although discrete transistors, resistors, and diodes are used, the circuit can easily be condensed into a four-chip device using a transistor array, such as the CA3081, resistor arrays (Beckman 898-3) and a diode package (LM3039). In either case, the circuit will be compatible with TTL, although the unit will accept and generate a wide range of voltages, corresponding to the magnitude of the driving signals. □



P_3	P_2	P_1	P_0	OUTPUT
0	0	0	0	$X \oplus Y$
0	0	0	1	$\overline{Y}$
0	0	1	0	$\overline{X}$
0	0	1	1	0
0	1	0	0	$\overline{X} \cdot \overline{Y}$
0	1	0	1	$X \cdot \overline{Y}$
0	1	1	0	$\overline{X} \cdot Y$
0	1	1	1	$X \cdot Y$
1	0	0	0	$\overline{X \oplus Y}$
1	0	0	1	Y
1	0	1	0	X
1	0	1	1	1
1	1	0	0	$X + Y$
1	1	0	1	$\overline{X} + Y$
1	1	1	0	$X + \overline{Y}$
1	1	1	1	$\overline{X} + \overline{Y}$

ALL DIODES 1N914
ALL TRANSISTORS 2N3019
R = 1 kΩ
R′ = 22 kΩ

Signal power. X-Y driving logic, and control signals that select 1 of 16 possible outputs (see table) simultaneously provide power for function generator. All inputs should be capable of providing at least 15 mA to circuit, which uses wired-AND, OR, and EXOR gates throughout.

Single a-d converter cuts cost of droopless sample-and-hold

by Carl Andren
Harris Corp., Electronics Systems Division, Melbourne, Fla.

Because leakage currents cause droop, sample-and-hold circuits with capacitors as storage elements cannot retain a sampled voltage indefinitely. This is the major reason designers, to improve sample-and-hold performance, have resorted to converters combining analog-to-digital and digital-to-analog converter functions. But a single a-d device can be made to perform both functions alternately, thus cutting the cost and complexity of the two-converter scheme. Only one operational amplifier and a solid-state switch are needed in addition.

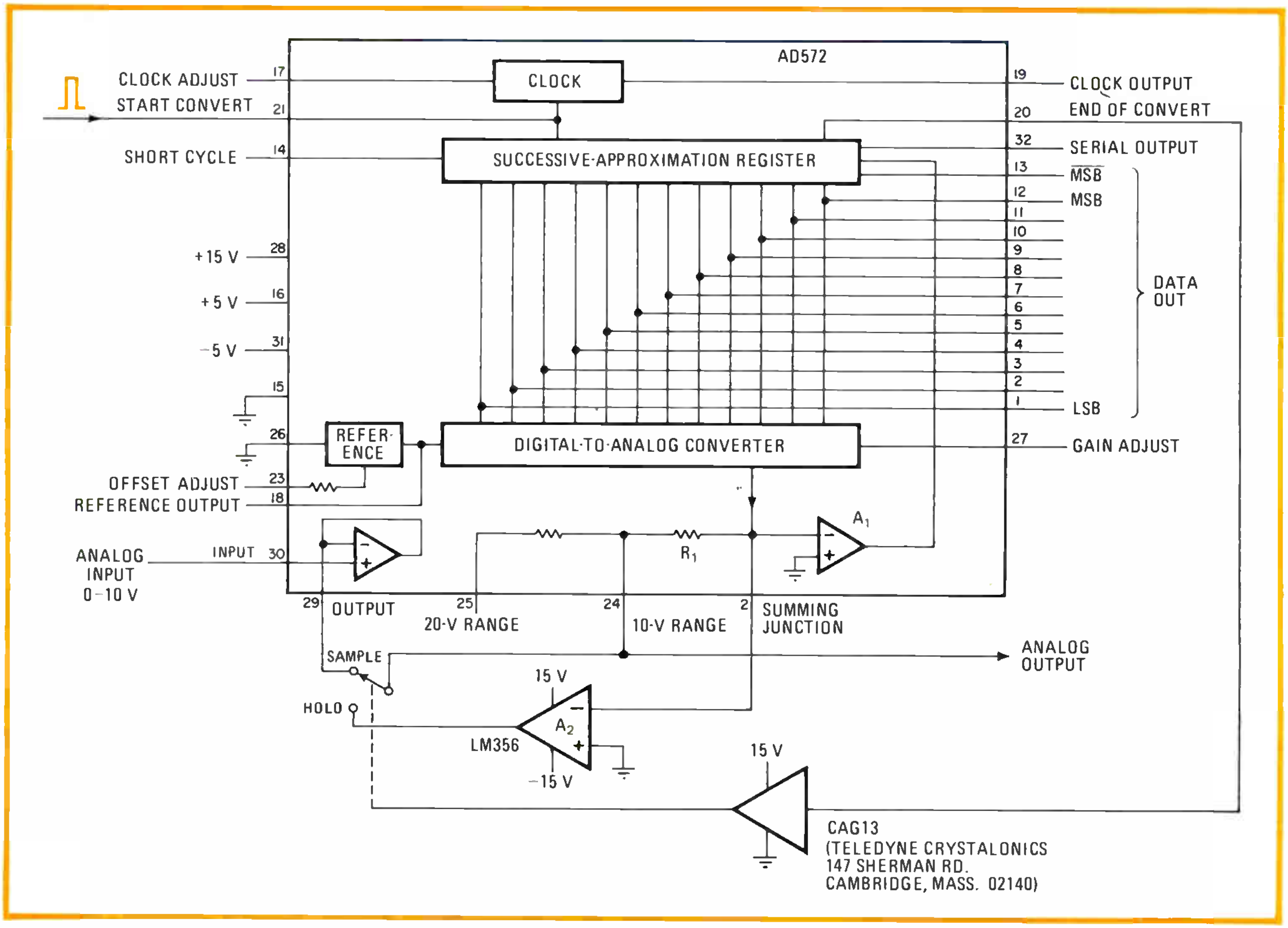
The more popular forms of a-d converter use a successive-approximation register that—with the aid of a self-contained comparator and a d-a converter—generates a digital estimate of the sampled analog voltage. When the comparison has been approximated to the least significant bit, the measurement is ended and an end-of-conversion signal is generated. If the unit is then configured as a latched d-a converter, the sampled analog voltage may be recovered and held indefinitely (assuming that one input of the comparator is accessible).

As shown, in the normal a-d conversion mode of a representative device like the AD582, a start-convert pulse initiates the measurement. An analog voltage, applied across resistor R_1 in the summing junction of comparator A_1, can then be sampled.

The successive-approximation register generates a 12-bit equivalent of the analog voltage and also drives the d-a converter that is connected to A_1's summing junction. The d-a converter then attempts to null A_1's output, whereupon the end-of-conversion signal (EOC) is generated. The sampling period takes a nominal time of 2.5 microseconds.

In this circuit, the EOC signal energizes a solid-state relay (CAG13) so that the converter can be switched to the holding mode. R_1 is then placed at the output of an op amp, A_2.

A_2's output maintains A_1's summing junction at a voltage null so that the output voltage becomes the potential across R_1—that is, the sampled voltage. Note that the switch resistance and A_2's input-bias current are taken into consideration for both modes and therefore they are not, for all practical purposes, sources of error in the measurement. □



Inverting the converting. This analog-to-digital converter, when it is combined with an op amp and switch, can provide d-a function on the hold portion of sample-and-hold cycle, thereby reducing cost and complexity of the usual two-converter (a-d–d-a) scheme. No sampling-peak capacitor is required in the converter sampling technique, so that the sample-voltage droop is eliminated.

Gray-code counter steps torque motor

by Thomas L. Clarke
Miami, Fla.

The positional accuracy of a simple stepping-motor system is limited by the response of its mechanical drive. This drawback can be eliminated electronically by using a position sensor and a counter working in Gray code to control the motor. The mechanical-drive circuit can be simplified with digital logic to reduce system errors and nonlinearities. A four-state Gray-code counter enables the system to move smoothly from its starting point to the desired position.

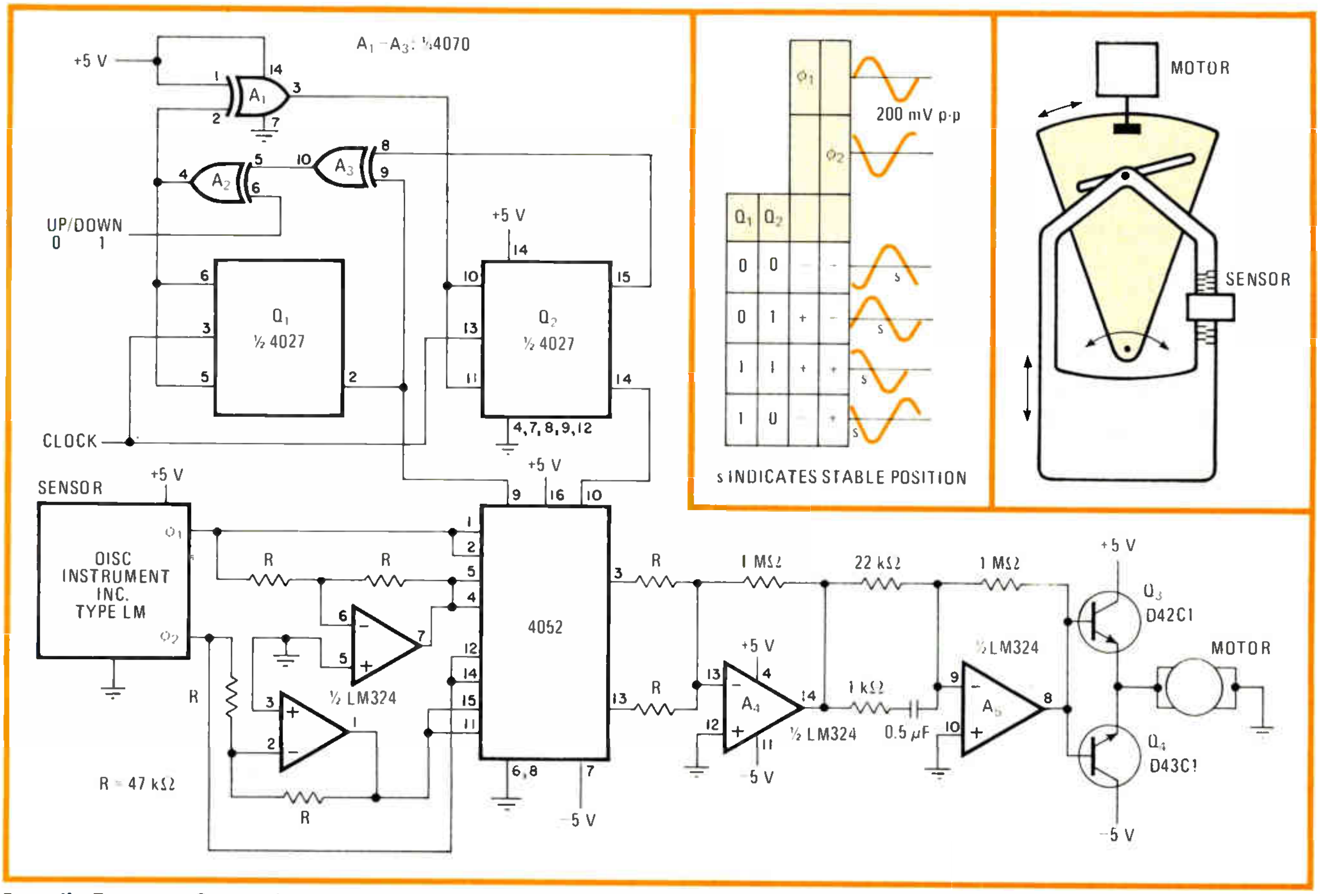
In this circuit, the summed quadrature outputs of a photoelectric sensor and the counter (see inset) set the position of the system. With suitable clock signals, the counter is advanced one location, causing the motor's position to change and the output from the sensor to vary accordingly. Thus the system is rotated 90° for each clock signal.

This circuit is intended for visual setting of a desired position through manual control of the clock and up/down inputs. For automatic tracking, the sensor's output must be compared to the desired position with additional circuitry in order to generate those signals.

Flip-flops Q_1 and Q_2 and exclusive-OR gates A_1–A_3 comprise the up-down Gray-code counter. The direction of the counting is determined by the logic state at the up/down input.

The output of the counter changes on the positive transition of each clock pulse. Depending upon the state of the counter, either the normal or inverted sinc-wave outputs of the sensor are summed at the output of the 4052 four-input multiplexer. As a consequence, the output from A_4 forces the system to a new position, which is reflected at the sensor as its output steps a quarter cycle. The motor is driven through Q_3 and Q_4 by a positional signal that progressively advances or recedes (depending upon the state of the up/down counter) by a quarter cycle.

A minimum settling time of a few milliseconds is set for the system by the lead-compensation components between stages A_4 and A_5. Lead compensation is required in this situation because the system response is that of a double integration network that acts to saturate Q_3 and Q_4. The open loop would tend to be sluggish without the lead compensation, which reduces the effective system gain at low frequencies. □



Smooth. Four-state Gray-code counter Q_1–Q_2 provides signal that, when summed with output of optical sensor by 4052 multiplexer and op amp A_4, generates quadrature output for smooth stepping of motor in quarter-cycle increments. Compensation network between A_4 and A_5 prevents saturation of Q_3 and Q_4, eliminating sluggish system response by reducing effective gain at low frequencies.

Field-programmable logic, Part 2

Sequencers and arrays transform truth tables into working systems

by Napoleone Cavlan and Stephen J. Durham
Signetics Corp., Sunnyvale, Calif.

☐ Because of its power and flexibility, the Signetics field-programmable logic family is ideal for replacing the discrete logic normally used to interface large-scale integrated devices, as shown in Part 1 [July 5, 1979, p. 109]. The examples of applications that follow show how to exploit its special features.

In designing with these gate and logic arrays and logic sequencers, the user need concern himself only with generating truth tables associated with the state diagrams or sets of Boolean logic equations that define his function. The one restriction is that he must use logic symbols corresponding to the status of fuse links.

As indicated in Fig. 1, an extra set of symbols is needed to describe all the states of FPLF gates corresponding to all combinations of blown and unblown fuse links. Once ordered into truth tables, the user-defined functions are then directly mapped onto standard program tables furnished with FPLF elements, whose fuses are then blown by a logic-type programmer. As the user gains experience, he can manipulate logic variables intuitively and can eventually implement algorithms directly on the program tables with only the device schematics for reference. (The formal step of deriving state diagrams and logic equations will not be considered here.)

Because of their simple and uncommitted structure, FPLF elements are suited to a wide variety of applications, several of them already well documented. The following examples illustrate the typical use of each logic element and match devices with applications.

Bus translator

Signetics' Instructor 50 microcomputer system is built around the 2650 microprocessor; but for compatibility with other systems and peripheral devices in the hobbyist market, it interfaces to the S100 bus, which is based mainly on 8080 microprocessor signals. Yet to carry out the seemingly unwieldy task of bus translation, only a single FPGA is needed. The gate array translates the logical combinations of timing, enable, and control signals supplied by the 2650 and its I/O hardware into control signals entirely compatible with the S100 bus definitions, as shown in Fig. 2.

The programmable feature of the FPGA is strategically invaluable in this case since the S100 bus is not yet totally standardized. The FPGA permits easy adaptation of the interface to changes in specifications, which are subject to arbitrary manipulation by manufacturers in the hobby arena.

Two-level logic

The logic arrays add a second level of combinational logic to the gate arrays, and thus another level of versatility. AND/OR combinations of the FPLAs are well suited to carrying out polynomial equations and the like, as shown in the next example.

In systems that transfer large blocks of data, a cyclic redundancy check (CRC) scheme can significantly improve data integrity. The technique appends a check word to a transmitted sequence of data, and the receiving end uses that word to check for errors. A cyclical division of the transmitted data by an industry-standard polynomial generates the CRC word; the remainder from the division forms the check word.

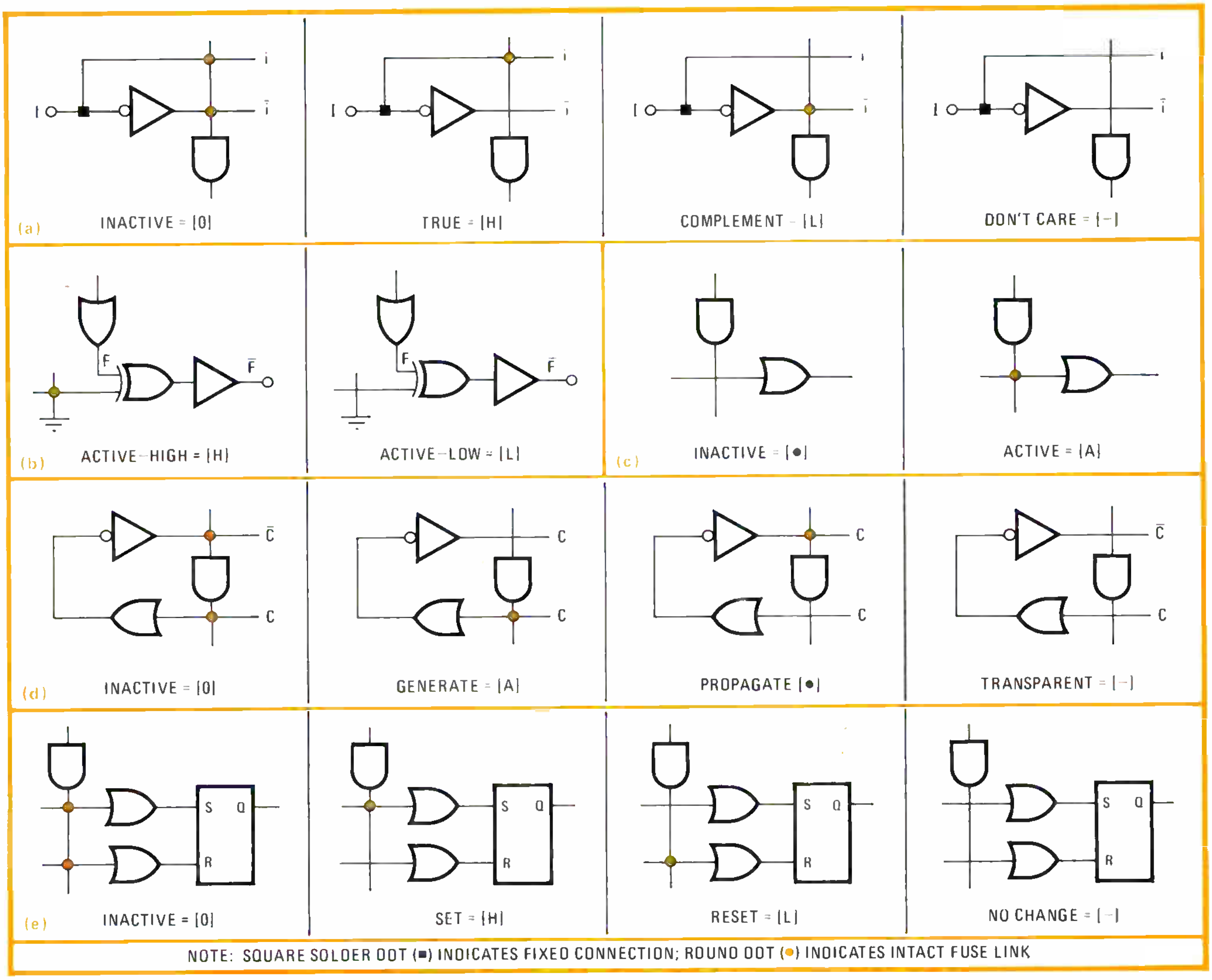
Polynomials lend themselves to serial manipulation, and serial CRC generation and checking are easy to implement. But in a multiple-line data system with parallel organization, a considerable amount of hardware may be needed for parallel-to-serial conversion. Moreover, the multiple-bit clocking for each word carries an inherent speed loss—a factor of 8 for a byte-oriented system. A parallel CRC generator-checker circuit is the answer, developed from the set of logic equations describing the function of the circuit in the form of a state machine.

The general design of the CRC circuit is shown in Fig. 3a, along with the logic equation set for the popular CRC polynomial $P(x) = x^{16}+x^{15}+x+1$. Figure 3b shows that the entire byte-wide parallel CRC generator-checker circuit can be implemented with only five chips: two 8-bit latches, two FPLAS, and an FPGA. The FPLAS contain the set of logic equations controlling the flip-flop inputs, which are expanded from EXOR form to sum-of-products form. In Fig. 3a, variables N_0–N_{15} represent the next CRC word after clocking, based on the current word B_0–B_{15} and the present input byte D_0–D_7.

CRC generation begins by driving the $\overline{\text{RESET}}$ line low to initialize the latches to zero. Pulsing the clock line then transfers the first byte of the data block in at D_0–D_7. Subsequent bytes are clocked in the same way. The cyclic nature of this design places no limit on the size of the data block that can be processed. During data transmission, the 16-bit CRC word is available at outputs B_0–B_{15} after the last data byte has been clocked in; it is appended as two check bytes to the data in the block.

Checking

The circuit is used in the check mode when receiving data containing CRC characters. The last 2 bytes in the data block received are CRC send characters. They too are clocked in and contribute to form a final receive pair of CRC characters, which, for error-free transmission, must both be zero. If an error has occurred, B_0–B_{15} will be nonzero. The FPGA will detect the nonzero condition and generate an error signal. This parallel CRC format can operate on data blocks at speeds in excess of 5.7



1. New notation. The many combinations of blown and unblown fuse links in the field-programmable logic family require new notation. The four possibilities for AND gates are shown in (a), while those for exclusive-OR outputs are in (b). The combinations for OR gates are in (c). The complement array in the logic sequencers is detailed in (d). Finally, OR gates controlling the flip-flops in sequencers are in (e).

megabytes per second.

An interesting use for the FPLA is in changing data at a few locations of a read-only memory (see "How to patch a read-only memory," p. 137).

The abilities of the field-programmable logic sequencer are well demonstrated by its use as a controller for a cartridge-tape transport. In this example, one chip replaces many—a distinct advantage if the controller is to be packed on a single-board microcomputer. Although the chip's function is complex, it can be programmed methodically and worked directly from a flow chart.

Controller routines

The controller executes fixed routines in response to status and input commands that may originate from an input/output bus or a monitoring station. Its outputs operate the velocity servo that drives the cartridge, form I/O status signals, and enable writing of data. The input and output signals of the one-chip controller are shown in detail in Fig. 4.

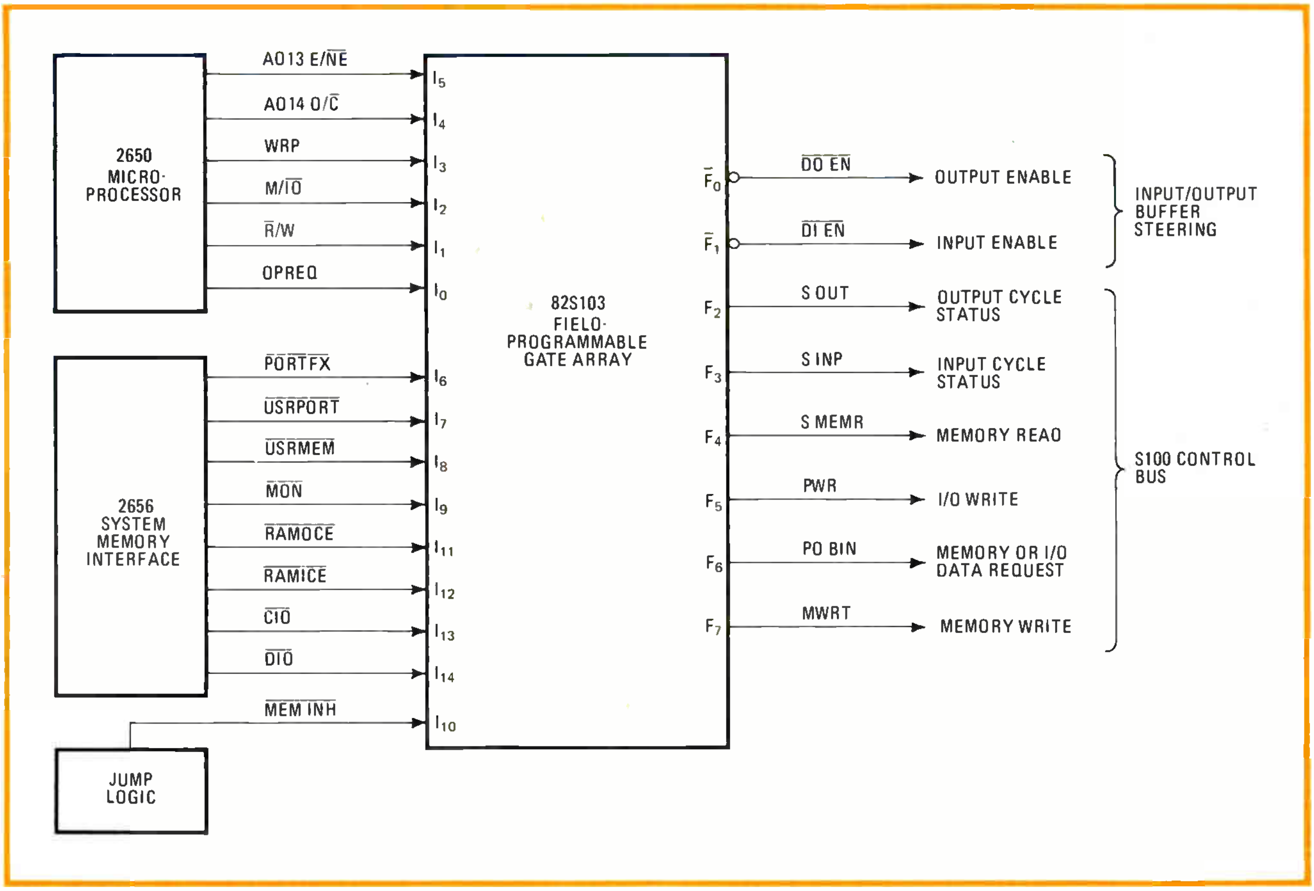
The controller carries out these eight routines:

- Move tape fast-forward.
- Move tape slow-forward.
- Move tape fast-reverse.
- Move tape slow-reverse.
- Bring tape to load point when cartridge is inserted.
- Rewind tape to load point.
- Rewind tape to beginning and eject cartridge in response to unload command.
- Rewind tape to beginning and eject cartridge in response to auto-unload true condition.

The routines could be represented concisely in a conventional Mealy state diagram, but that often obscures the actual machine function. Flow charts are more easily understood, where input variables, machine states, and output functions are given variable names. Such a chart is shown in Fig. 5.

Diagramming the flow

What would be transition terms in a Mealy state machine become true/false statements regarding the system inputs (taken one at a time) in the chart. The correlation is most obvious in the simple example in Fig. 6. The flow chart in (a) shows a conditional change from



2. Translator. Getting S100 bus signals, which are mostly 8080 microprocessor signals, out of a 2650 microprocessor calls for a field-programmable gate array. One 82S103 translates signals from the 2650 and its companion 2656 interfacing chip to the hobby bus.

state A to state B. The conditions in the flow chart's diamonds must be simultaneously satisfied for the state change to occur. The conditions take on variable names, and for this example, which arbitrarily assumes a 4-bit state register, three inputs, and two outputs, the corresponding state diagram is shown in Fig. 6b.

The transition from A to B denotes a jump from 10 (1010_2) to 13 (1101_2) and an output transition to 2 (10_2) at the next clock pulse if the combination $X_n = 4$ (100_2) is true. The transition is synthesized by forming a transition term $T = P_3\bar{P}_2P_1\bar{P}_0I_2\bar{I}_1\bar{I}_0$ and using term T at the next clock pulse to generate next-state and next-output commands for the state and output registers, respectively. For the state register, flip-flops N_0 and N_2 are set by connecting T to set lines S_0 and S_2, and flip-flop N_1 is reset by coupling T to the R_1 reset line. Similarly, for the output register bit F_0 is reset and bit F_1 is set by connecting T to corresponding flip-flop reset (R_0) and set (S_1) lines.

Controller conditions

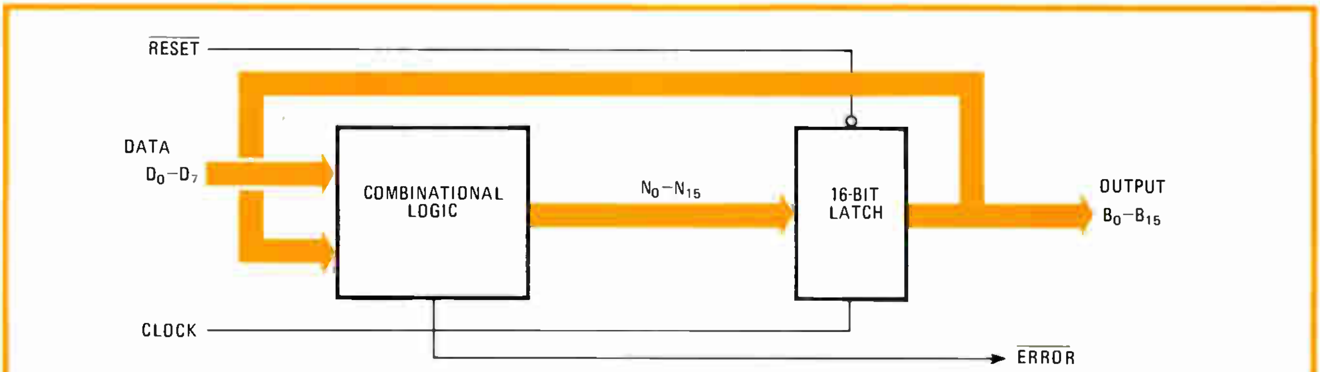
Referring again to the controller flow chart, it can be seen that whenever the tape-drive power is turned on, or when an interlock is opened, the transport must be stopped. That is achieved by an input signal to the controller called $\overline{\text{INTRDY}}$ that resets the state register with an unconditional jump to state 1 or STOP. When that occurs, all outputs on the FPLS chip become inactive, WRITE is inhibited, and speed and direction are arbitrarily set to SLOW and REVERSE. From the STOP state, operation into any mode ocurs by state and output jumps when all of the intervening conditions are simultaneously satisfied.

As an example, writing at normal speed will occur with a jump from state 1 to state 3, which requires that the following criteria be satisfied:

- The data cartridge is in place; therefore CIP is true.
- The drive has been addressed; SEL is true.
- The tape has been commanded to run; TR is true.
- The controller is not in state 6; state 6 is false.
- The tape should move slowly; therefore $\overline{\text{FAST}}$ is true (an active-low signal).
- The tape should move forward; $\overline{\text{FWD}}$ is true.

In tracing the jump between these states two things must be noted. First, the commands RWD, UNL, and TR are mutually exclusive, so that when either is true the others can be considered false or "don't care." Second, after TR = true, the condition (State = 6?) is inserted to indicate invalid jumps to states 2 and 3, which could originate from state 6 with an AUTO UNL false. Clearly, these should be avoided to inhibit honoring requests for read slow (or fast) forward while stopped at the end of the tape. So, the (State = 6?) condition is a reminder to avoid programming 6 → 2 and 6 → 3 state jumps in the FPLS. A similar argument holds for (State = 7?) and (State = 11?) conditions.

After data has been either written or read, the tape drive is commanded to stop by TR false, which causes a



$$N_0 = D_0 \oplus D_1 \oplus D_2 \oplus D_3 \oplus D_4 \oplus D_5 \oplus D_6 \oplus D_7 \oplus B_8 \oplus B_9 \oplus B_{10} \oplus B_{11} \oplus B_{12} \oplus B_{13} \oplus B_{14} \oplus B_{15}$$

$$N_1 = D_0 \oplus D_1 \oplus D_2 \oplus D_3 \oplus D_4 \oplus D_5 \oplus D_6 \oplus B_9 \oplus B_{10} \oplus B_{11} \oplus B_{12} \oplus B_{13} \oplus B_{14} \oplus B_{15}$$

$$N_2 = D_6 \oplus D_7 \oplus B_8 \oplus B_9$$

$$N_3 = D_5 \oplus D_6 \oplus B_9 \oplus B_{10}$$

$$N_4 = D_4 \oplus D_5 \oplus B_{10} \oplus B_{11}$$

$$N_5 = D_3 \oplus D_4 \oplus B_{11} \oplus B_{12}$$

$$N_6 = D_2 \oplus D_3 \oplus B_{12} \oplus B_{13}$$

$$N_7 = D_1 \oplus D_2 \oplus B_{13} \oplus B_{14}$$

$$N_8 = D_0 \oplus D_1 \oplus B_0 \oplus B_{14} \oplus B_{15}$$

$$N_9 = D_0 \oplus B_1 \oplus B_{15}$$

$$N_{10} = B_2$$

$$N_{11} = B_3$$

$$N_{12} = B_4$$

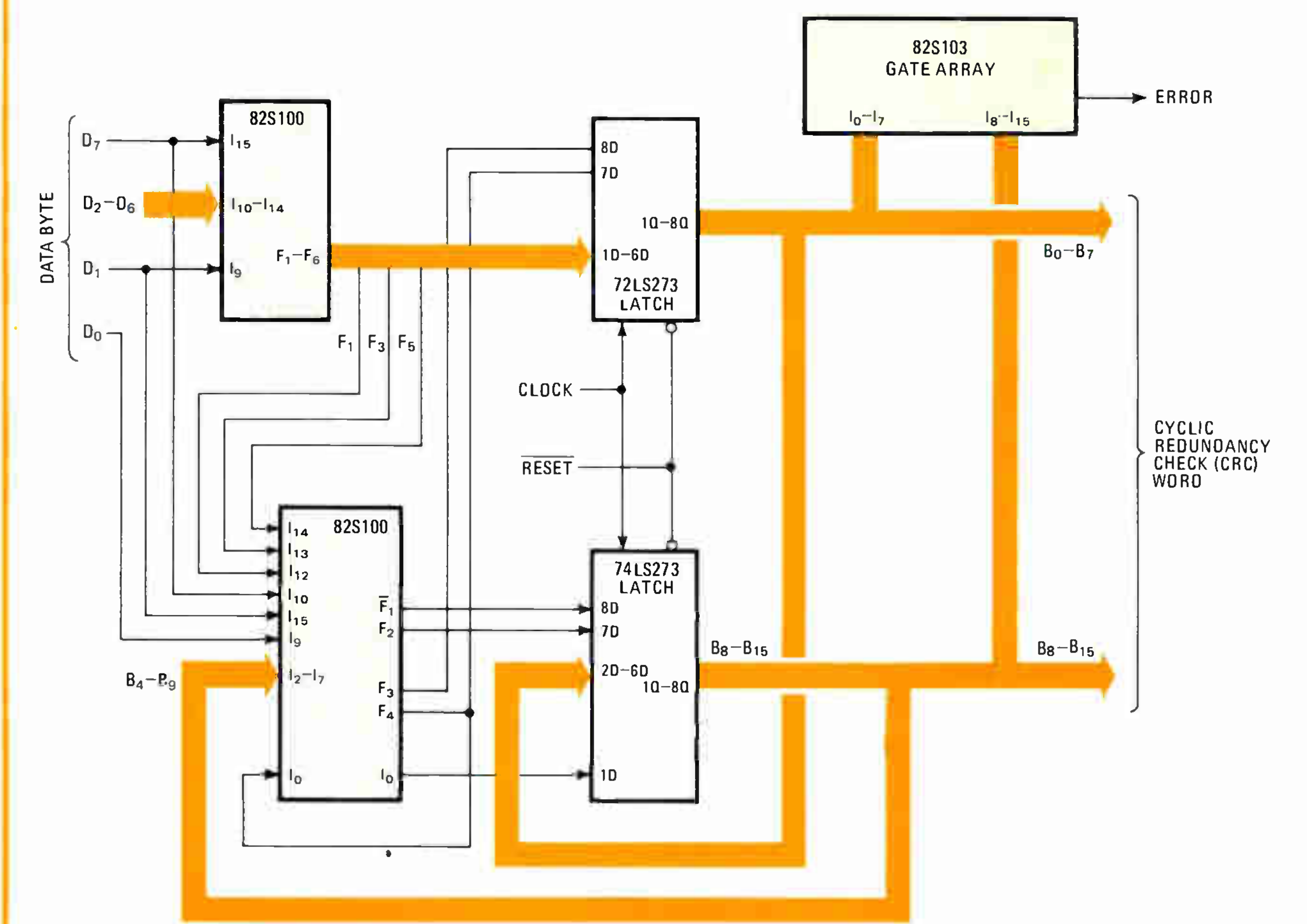
$$N_{13} = B_5$$

$$N_{14} = B_6$$

$$N_{15} = D_0 \oplus D_1 \oplus D_2 \oplus D_3 \oplus D_4 \oplus D_5 \oplus D_6 \oplus D_7 \oplus B_7 \oplus B_8 \oplus B_9 \oplus B_{10} \oplus B_{11} \oplus B_{12} \oplus B_{13} \oplus B_{14} \oplus B_{15}$$

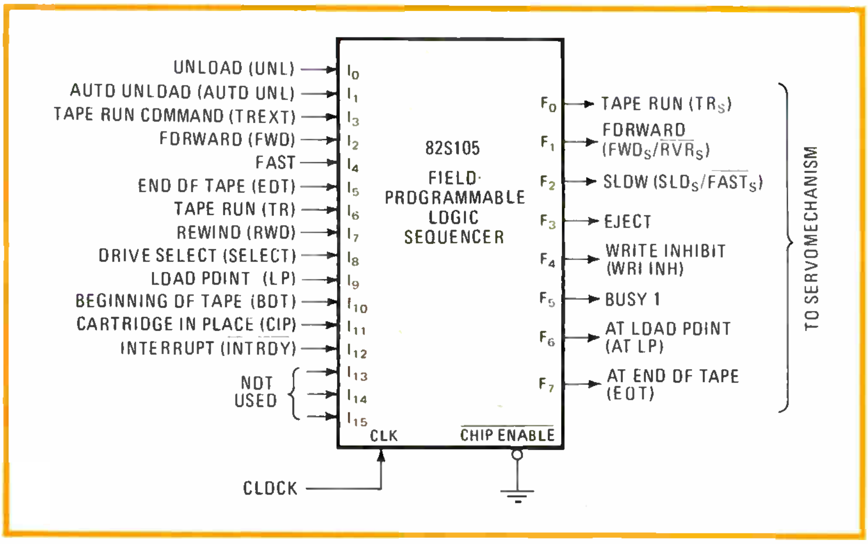
$$\overline{ERROR} = \bar{B}_0 \cdot \bar{B}_1 \cdot \bar{B}_2 \cdot \bar{B}_3 \cdots\cdots \cdot \bar{B}_{15}$$

(a)

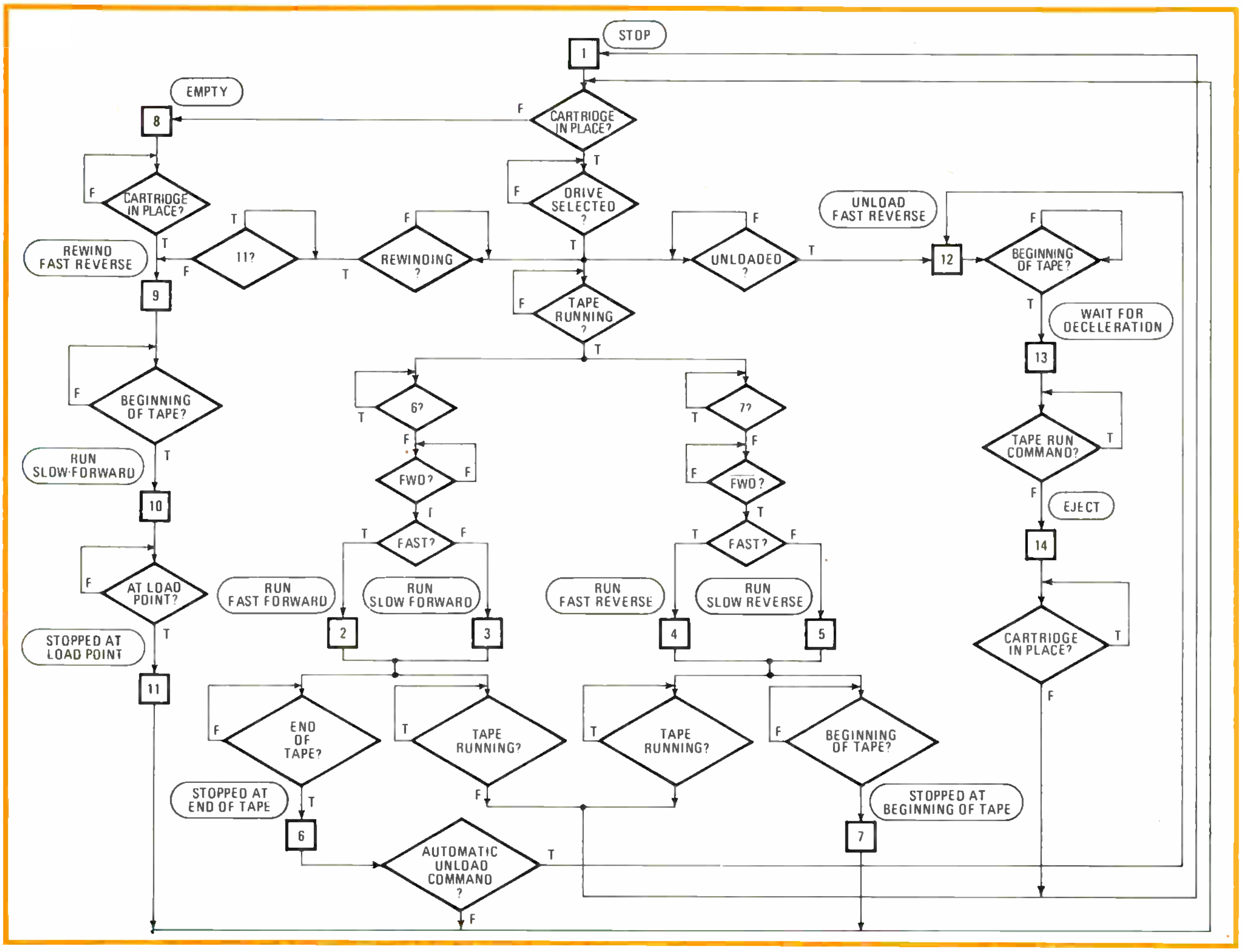


(b)

3. Error-free. The technique of using a cyclic redundancy check (CRC) word for error-free data transmission requires complex logic to generate the word (a). A pair of logic arrays, two latches, and a gate array (b) do the job, which usually requires a boardful of chips.



4. Tape controller. A field-programmable logic sequencer like this tape controller can perform extremely complex tasks. The 82S105 receives commands from an input/output bus or monitor, and provides all the necessary signals for driving the tape-transport servo-motor mechanism.



5. Goes with the flow. The first step in designing the controller is preparing a flow chart of the operation. The chart is much easier to understand than a state diagram or Mealy machine, yet provides all the information needed for programming the logic-sequencer chip.

jump from state 3 (RUN SLOW FORWARD) to state 1. By similar arguments, the tape drive can be run either fast or slow in either forward or reverse directions by jumping to states 2, 4, and 5.

When the end of tape is reached (EOT true), the tape drive is stopped. That is implemented by jumps 2 → 6 or 3 → 6. Once in state 6, the tape drive can no longer move in the forward direction because of the State 6 false condition preceding states 2 and 3. If AUTO UNL is true, the drive will automatically rewind (state 12), wait for tape to decelerate (state 13), eject the tape cartridge (state 14) and stop. If AUTO UNL is false, the drive must

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How to patch a read-only memory

It is a shame to throw away read-only memories. But often firmware-based systems must commit control programs to large mask-programmed ROMs, only to have a design revision requiring a new program—and a new ROM. If no pin-compatible, user-programmable ROM is available, the customer could end up waiting out the 5-to-10-week turn-around time for the new mask parts—and throwing away his inventory of old ROMs.

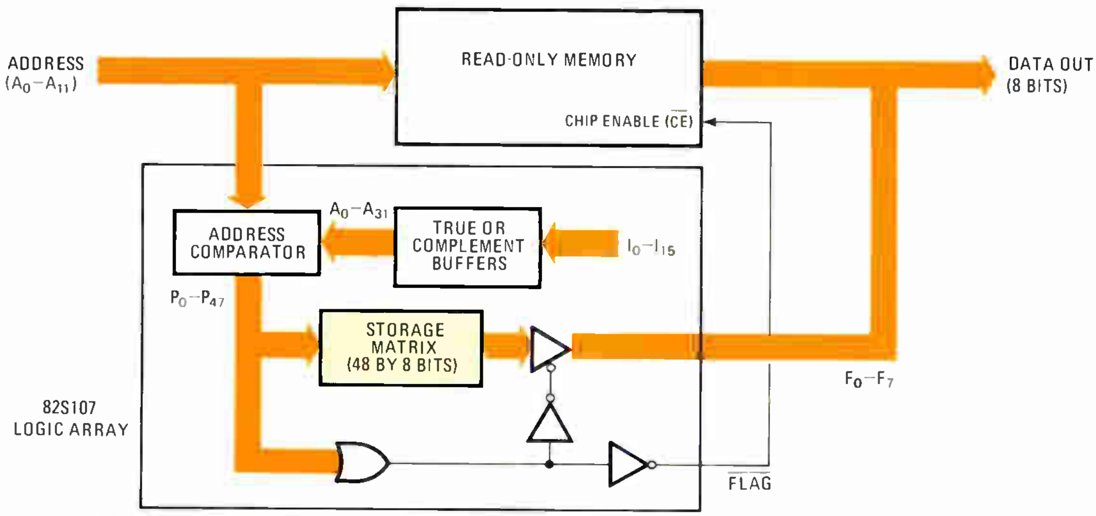
One way to save an obsolete ROM (or even PROMs—it hurts to throw them away, too) is by patching, which redirects certain addresses to an adjunct smaller memory. This can be done most efficiently with an 82S107 field-programmable logic array.

As a ROM patch (FPRP), the FPLA becomes a programmable, content-addressable PROM that continually monitors the address bus. As shown in the figure, when the FPRP encounters a match that signals a correction of data, its flag output ($\overline{FL}$) disables the ROM, and new data from the FPRP is put on the output bus. If, for example, address 750 were to be given new data A9, address 5FE were to be given 7F, and addresses OA4–OA7 were all to be reassigned B4, the FPRP would be programmed as in the table. For a 12-bit address, only inputs I_0–I_{11} are used, and the remaining four, I_{12}–I_{15} then become "don't care." (Incidentally, inputs I_0 and I_1 in the second product term are also "don't care" because they define an address block of four locations.)

The address comparator can patch up to 48 non-overlapping addresses anywhere within a memory field of 64 kilobytes. Block addressing is possible, too, using the FPRP's true or complement input buffers. Moreover, the number of addresses can be expanded by hooking several devices in parallel and wire-ANDing their flag outputs.

Since the outputs of the ROM patch primarily define a byte of memory data rather than a set of logic functions, output polarity is not controlled. Also, to maintain compatibility with the gate array, the FPRP generates its self-enable signal with a fixed multiple-input OR gate; the only disadvantage of that method is addresses (AND terms), once programmed, may no longer be deleted.

The ROM patch affords a recovery strategy effective in several design situations, including modifications of dedicated application programs, operating systems, assemblers, and monitor routines. It also permits on-site optimization of system parameters, in accordance with, say, environmental variables, and allows custom function options and product-line diversification. The customer need only allot board space next to the mask ROM for an FPRP; no parts are actually used until program changes are required after the product is in the field.



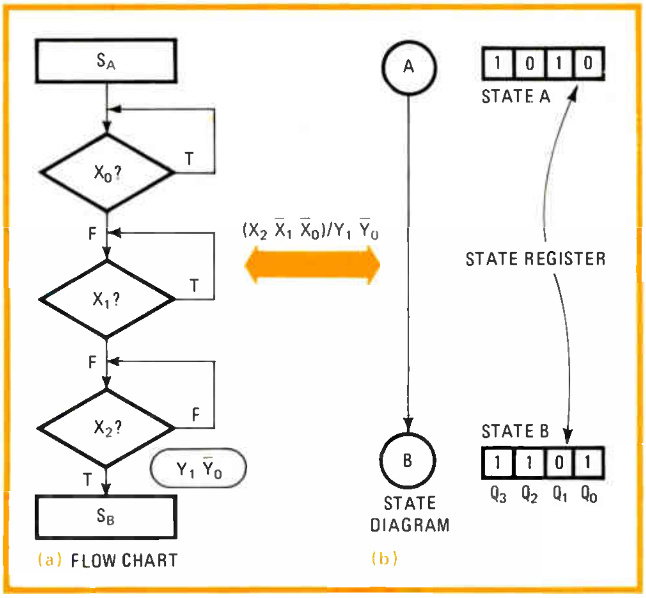
PROGRAM TABLE FOR ROM PATCH

Input address	Product term No.	Comparator input																Active level								Output data
																		H	H	H	H	H	H	H	H	
																		Output function								
		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	
750	0	–	–	–	–	L	H	H	H	L	H	L	H	L	L	L	L	A	•	A	•	A	•	•	A	A9
5FE	1	–	–	–	–	L	H	L	H	H	H	H	H	H	H	H	L	•	A	A	A	A	A	A	A	7F
OA4 OA7	2	–	–	–	–	L	L	L	L	H	L	H	L	L	H	–	–	A	•	A	A	•	A	•	•	B4
						A_{11}											A_0	D_7							D_0	

wait for either a rewind command (RWD), an unload command (UNL), or reverse command (FWD).

If the tape is moved in the reverse direction until the beginning (BOT), the drive is stopped. This is implemented by a jump from states 4 or 5 to state 7. Once in state 7, the tape drive can no longer move in the reverse direction because of the state 7 false condition preceding states 4 and 5. The tape will remain stopped at the beginning until TWD, UNL, or FWD commands are given.

If no cartridge is in place (CIP false) when the tape drive is turned on, the controller will jump from state 1 to 8, and signal EMPTY. When a cartridge is installed,



6. Flow chart to state diagram. Simple transition from state A to state B is shown in flow chart (a). Three inputs (X_0,X_1,X_2) and two outputs (Y_0,Y_1) are assumed. The contents of a four-bit state register show the transition from state A (1010_2) to state B (1101_2).

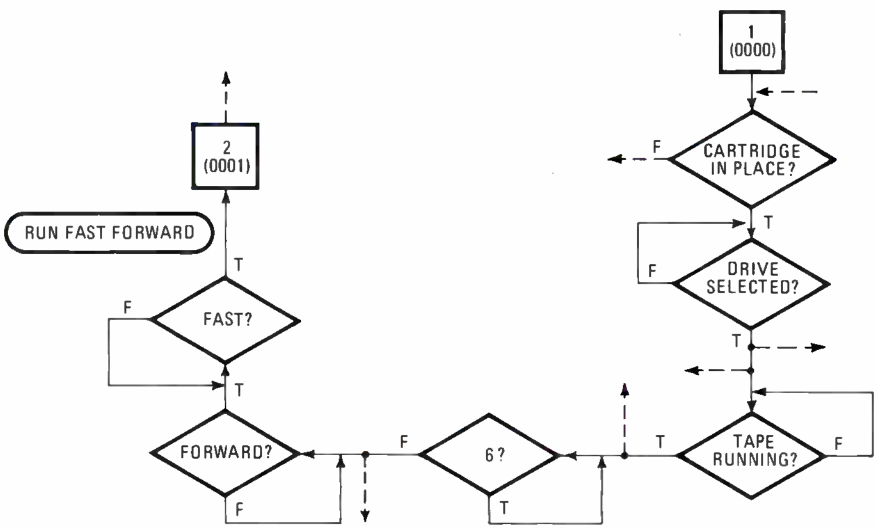
CIP = true implements a jump from state 8 to 9. In state 9 the tape will rewind in fast reverse until a BOT mark is reached. BOT true implements a jump from state 9 to 10. The tape now runs at slow speed in the forward direction until the load point (LP) is reached. LP true implements a jump from state 10 to 11 indicating STOPPED AT LP. From state 11, forward, reverse, or unload commands can be executed, but not rewind, because of the state 11 condition preceding state 9. That keeps RWD from being needlessly repeated.

State jump

A single state jump is shown in detail in Fig. 7. The transition is from state 1 to 2. In the latter, the controller is required to enter the READ FAST FORWARD routine from STOP when:

- CIP is true.
- SEL is true.
- TR is true.
- State 6 is false.
- FWD is true.
- FAST is true.

In response to this jump, the controller outputs that must change to issue the appropriate commands are run (TR),



PARTIAL PROGRAM TABLE

State jump	Transition term																								Output term													
	NO.	C	Input variable (I_m)																Present state (P_s)						Next state (N_s)						Output function (F_n)							
			15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	5	4	3	2	1	0	5	4	3	2	1	0	7	6	5	4	3	2	1	0
1-2	0	—	—	—	—	H	H	—	—	H	—	H	—	H	H	—	—	—	—	—	L	L	L	L	—	—	L	L	L	H	L	L	L	H	L	L	H	H
I/O assignment						INTERRUPT (INTRDY)	CARTRIDGE IN PLACE (CIP)	BEGINNING OF TAPE (BOT)	LOAD POINT (LP)	DRIVE SELECTED (SEL)	REWIND (RWD)	RUN (TR)	END OF TAPE (EOT)	FAST	RUN COMMAND (TR EXT)	FORWARD (FWD)	AUTOMATIC UNLOAD (AUTO UNL)	UNLOAD (UNL)													AT END OF TAPE (EOT)	AT LOAD POINT (LP)	BUSY 1	WRITE INHIBIT (WRI INH)	EJECT	SLOW (OR $\overline{\text{FAST}}$)	FORWARD (OR $\overline{\text{RVR}}$)	TAPE RUN (TR)

7. Detailed state jump. The transition from state 1 (STOP) in the tape cartridge controller to state 2 (READ FAST FORWARD) is shown in flow-chart form. That part of the logic sequencer coding of the state jump is shown below, including transition and output terms.

TABLE 1: COMPARISON OF DESIGN ALTERNATIVES FOR TAPE CONTROLLER			
Parameter	Field-programmable logic sequencer	Discrete logic	Monolithic Memories Inc.'s Programmable Array Logic
Chip count	1 chip	6 chips	14 chips
Circuit-board area	0.84 in.^{2}	2.13 in.^{2}	3.78 in.^{2}
Power (typical)	0.60 W	1.36 W	4.8 W
Speed	90 ns/state	132 ns/state	105 ns/state
Voltage	+5 V	+5 V	+5 V
Cost (high-volume production)	$12	$14	$48

TABLE 2: PROGRAMMING EQUIPMENT FOR THE FIELD-PROGRAMMABLE LOGIC FAMILY							
Type	Manufacturer	Model	Field-programmable device				Availability
			Gate array	Logic array	ROM patch	Logic sequencer	
Logic	Signetics	FP-103	•				now
		FP-104		•	•	•	
	Curtis	PR-100		•			
		PR-100A		•	•		
	Data I/O	10		•	•		
Memory	Data I/O	17,19	•	•	•	•	3Q79
	Sunrise Electronics	SM100		•	•		now
			•			•	in development
Hybrid	Stag	PPX-Plus		•	•		now
			•			•	in development

forward (FWD), and fast (FAST).

The flow chart of the controller routines is complete with 14 states and 36 state jumps (including synchronous reset). As such, four state-register flip-flops sufficiently represent all states. All state jumps can be directly programmed into the chip from the flow chart. All state jumps occur on the leading edge of the clock.

The advantage of a controller built with the FPLS is best shown by a comparison to discrete logic, which would comprise PROMs, latches, and gates, using the same state diagram as for the FPLS. Table 1 compares the FPLS controller with a discrete implementation as well as with Monolithic Memories Inc.'s Programmable Array Logic chips, in several aspects.

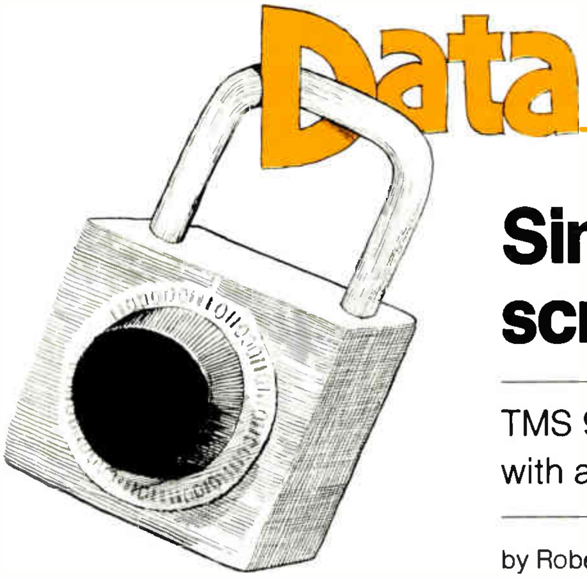
Programming

The key to design flexibility with programmable logic is the availability of programming equipment. The need for PROMs in this equipment has led to a large number of memory programmers being offered by several manufacturers. Generally, they operate with personality card sets that meet the requirements of various PROM technologies. Suppliers have already begun developing sets compatible with memory programmers for logic devices. Hardware is expected to be available by the end of the third quarter of this year.

For the concept to work, the logic devices must be manipulated as memory chips are—by defining the desired fusing pattern in terms of an address-data relationship. Although this tends to obscure the logic function of the device, which is not visible on the program table, it is sure to provide low-cost programming equipment that can be manned by low-skilled labor.

Logic programming is another possibility, and low-cost equipment is already available from Signetics. Logic programmers allow direct entry of the logic function from the program table; no reference to the device logic diagram is necessary, and the user need not specify the status of each individual link in a device. Such programmers are more convenient for engineering use during the initial design phase, but with their high programming speed—about 10 seconds per device—can also be effective in production. Their only drawback is that they are dedicated machines and cannot program PROMs.

Some manufacturers offer a hybrid type of PROM programmer that can also be configured to do logic programming. Table 2 shows the various options available to prospective users now, or in the near future. □



Single-chip computer scrambles for security

TMS 9940 implements data encryption standard with a 4,800-bit-per-second throughput

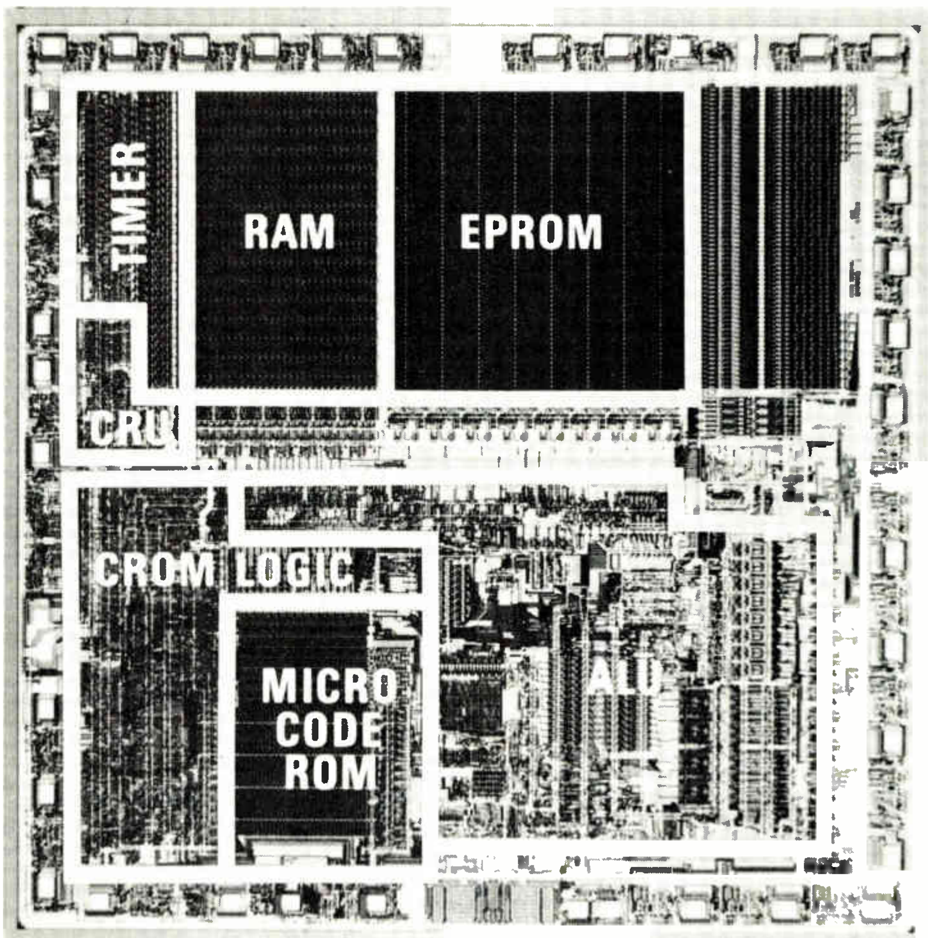
by Robert Budzinski, *Texas Instruments Inc., Dallas, Texas*

□ Unauthorized manipulation and outright theft of sensitive data are major problems for the communications, computer, and banking industries, among others. The situation has become increasingly grim with the rapid growth of data traffic.

This is the first article in a series on data encryption implementations to follow the special report on the National Bureau of Standards' data encryption standard that appeared in the June 21 issue, page 107.

Thanks to the efforts of the National Bureau of Standards, there now exists a Federal Data Encryption Standard (DES) for safeguarding critical (but not classified) information [*Electronics*, June 21, 1979, p. 107]. This document prescribes specific security procedures and defines a standard algorithm for the encryption of data.

The DES applies by statute only to certain Government agencies not involved in national security. Yet there is every indication that the DES will become widely used in the commercial sector as well. The Federal government



1. Fully packed. The TMS 9940 microcomputer contains all the circuitry needed to implement the data encryption standard algorithm. Alone, it can encrypt or decrypt 4,800 bits per second; if more speed is needed, paralleling n 9940s increases throughput by a factor of n.

may require certain nongovernment data-communication users to protect their message transmissions for such things as funds transfers and securities and commodities exchanges. The banking industry, however, is adopting the DES without governmental prodding.

IBM Corp. has announced both software and hardware DES products for System/370 computers. DES devices are now available for satellite data transmission and secure telephone conversations. And a dozen or more manufacturers are introducing chips, circuit boards and stand-alone encryption devices for the potential DES user to evaluate.

Dedicated microcomputer

While the DES algorithm is complex, it was designed expressly for efficient hardware implementation and can be handled by a single chip. Texas Instruments Inc.'s TMS 9940 single-chip microcomputer is one that can be set up to implement the DES. It can encrypt or decrypt 4,800 bits per second when driven by a 5-MHz clock. Of course, the effective rate of any encryption device can be increased by a factor of n if n chips are used in a parallel-processing arrangement. The TMS 9940 data encryption units, like the Intel 8294 DES implementation, can be easily interfaced to microprocessor buses using TTL, so they are convenient to use in parallel.

It is possible to use a single 9940 instead of a DES printed-circuit board or stand-alone box for applications that do not require high-speed encryption. Its input/output capability is flexible enough to satisfy a wide range of these applications. Among its hardware-supported functions are input/output expansion, multiprocessor communication, power-down mode, and a clock output for synchronization. It is compatible with the 9900 instruction set and circuit-design support tools such as TI's AMPL package. In fact there is no compatibility problem with any member of the 9900 family of peripheral support chips.

What's on board

The TMS 9940 is the first microcomputer in TI's 9900 family (Fig. 1). Its single substrate contains a microprocessor, 2,048 8-bit bytes of read-only memory (programmable electrically or by mask with the DES algorithm), 128 bytes of random-access memory, 388 single-bit locations in the communications register unit I/O memory space, a 14-bit timer/counter, and an interprocessor-communication interface.

Since the 9940 is designed for single-chip applications, no provision has been made for off-chip RAM or ROM. However, the I/O space is very flexible and up to 32 bidirectional pins can be dedicated to a specific application (Fig. 2).

The 9900 instruction set is essentially the same as the one used in TI's 990 family of minicomputers. But the 9940 instruction set is particularly easy to use. The fact that there are very few special cases built into it makes it simple to learn. Nearly all the op codes can use the full range of operand addressing modes. And the architecture supports 16-bit memory addresses, thus avoiding the complexity and added potential for error of smaller address spaces.

There are five operand addressing modes that can be specified with a 9940 instruction. The register address mode designates a memory location to be accessed, in contrast to an actual hardware register. The current register space is designated by a workspace pointer. This pointer designates the first word of 16 16-bit workspace words. The 9940 has up to four sets of workspaces available.

The advantage of the workspace is the ability to switch contexts rapidly. Three words are stored in the interrupt workspace for a context switch. These are the current workspace pointer, the program counter, and the status register. Implementation requires less than 8 microseconds with a 5-MHz clock.

The other addressing modes include workspace register indirect, workspace register indirect autoincrement, indexed, and symbolic (immediate address). In addition, some instructions allow immediate operand addressing.

In and out

The instruction set supports I/O with the communication register unit (CRU). Its address space is a bit-oriented I/O interface: the data elements in this memory space are 1 bit wide. The address for a CRU bit is formed by adding the 8-bit displacement contained in a 16-bit CRU instruction to 9 bits from workspace register 12.

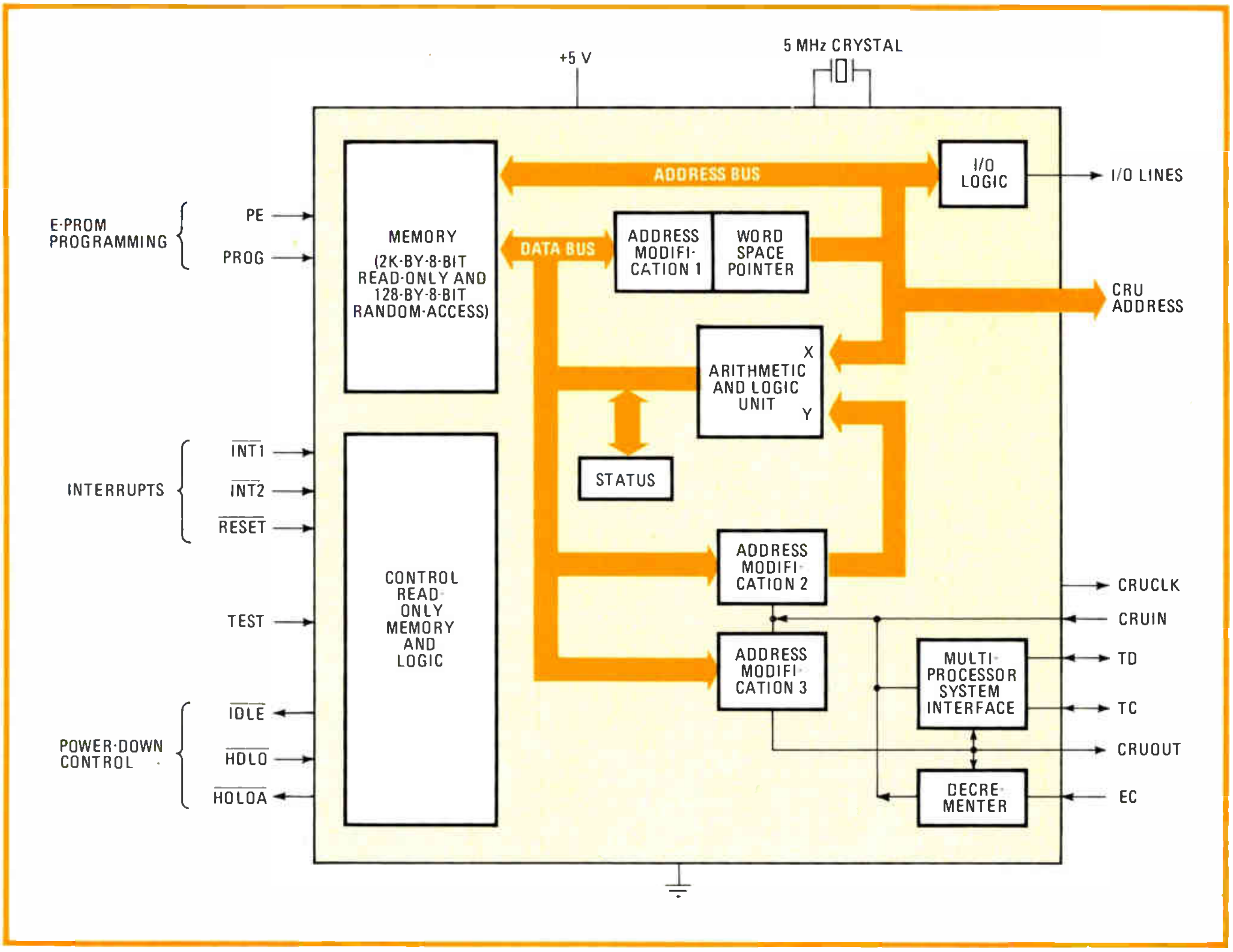
There are five different CRU instructions. Three of them are single-bit–oriented. One of these sets the addressed bit to a logical 1 (SBO) and another sets the bit to a logical 0 (SBZ). The third tests the bit's value (TB).

The multiple-bit CRU instructions transfer information between the CRU space and the random-access memory space. The CRU address for the transfer is contained in register 12. The number of bits transferred can vary from 1 to 16 and is contained within the instruction.

The location in the memory space is specified by one of the five general operand addressing modes discussed earlier. The load CRU (LDCR) instruction transfers the number of bits specified in the instruction from the specified memory location to the CRU space. This begins at the CRU address in register 12. The store from CRU (STCR) instruction performs the same operation except that data is transferred from the CRU to the memory space. The maximum instantaneous CRU data-transfer rate is 1.25 megabits per second.

There are two possible implementations of any particular location in the CRU space. One is to use a register to implement locations. In this case the CRU location(s) act as a read/write memory space. Another way is to have separate input and output lines. This way, reading from the CRU space using a STCR instruction senses the values of externally driven signals. Conversely, writing into the CRU space using LDCR drives signals to external inputs.

All I/O on the 9940 is done through the use of CRU instructions. There are 4 interrupts and 32 general-



2. Flexible. The 32 bidirectional input/output pins of the TMS 9940 can be dedicated to specific hardware-supported functions; TTL can be used. Up to 4 16-word workspaces are available. All operations are compatible with the 9900-series instruction set and support chips.

purpose I/O pins to do this. When the reset interrupt ($\overline{\text{RST}}$) is enabled, the 32 pins are set to the input mode. The direction of the 32 pins (input or output) is controlled with a CRU accessible-direction register.

The I/O pins can be read (STCR, TB) regardless of direction. However, it is not possible to write (LDCR, SBO, SBZ) to a pin that is in the input mode.

Special functions

Some of the 32 general-purpose I/O pins can also be configured for special functions. There are four of these: CRU expansion, multiprocessor system interface, external synchronization (clock output), and power-down-and-hold logic. Any combination of these is possible.

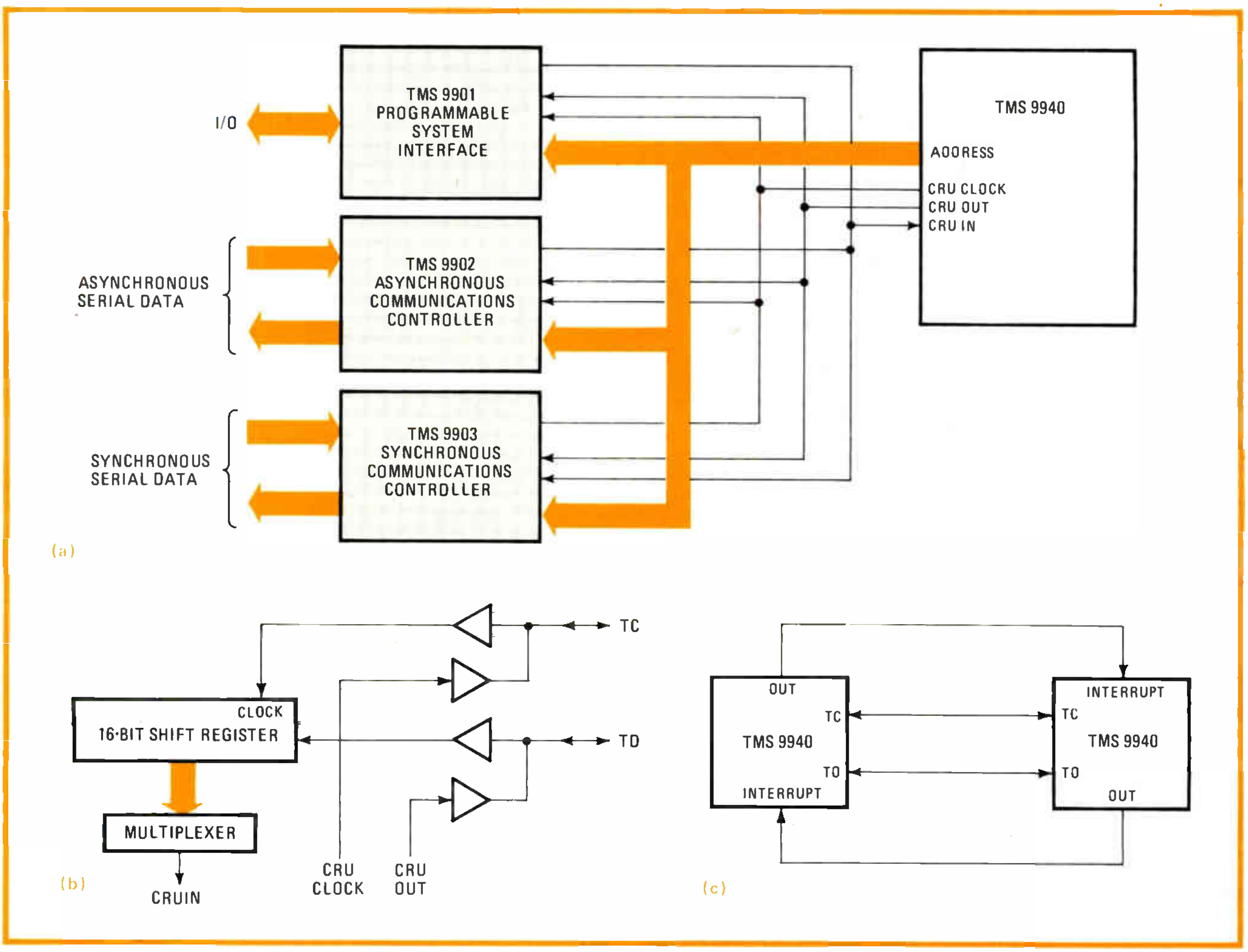
Actually, the use of each function is determined by the value of its associated configuration bit. There are 4 configuration bits—one for each function—that are accessible in the CRU space. The configuration bits are set to the general-purpose mode (all special functions disabled) after a reset. In addition, the special functions can readily be utilized under program control. The special function for CRU expansion allows 256 CRU bits to be implemented externally by using 11 of the general-purpose pins. Nine of these (A_0–A_8) are used for output, and one is for input (CRUIN). The remaining pin (CRUCLK) is used as a strobe when data is sent out on the CRUOUT pin.

The 9940 offers three interfacing possibilities. They involve using the TMS 9901, a programmable system-interface circuit; the TMS 9902, an asynchronous communication controller; or the TMS 9903, a synchronous communication controller (Fig. 3a).

The Multi-Processor System Interface (MPSI) is a two-wire facility for communication among processors. It is a serial interface that allows transfer of 1 to 16 bits (Fig. 3b). When enabled, the MPSI is normally in the receiving mode. Data on the TD line is strobed into the 16-bit register by the TC line. Data can also be stored internally by executing a STCR instruction to the dedicated MPSI addresses. And finally, data can be sent from the MPSI register by executing a LDCR from the MPSI addresses.

Multiple-chip encryption

It is possible to hook up a dual-9940 network using cross-coupled interrupts to coordinate communications (Fig. 3c). Other 9940s can be added by wire-ORing the TD and TC lines. Communication coordination is accomplished through specific protocols. Which one is used depends on performance requirements and cost consider-



3. Interfaces. Chip communication options include using programmable, synchronous, and asynchronous communication chips (a), two-wire serial hook-up (b), and cross-coupled interrupts (c). More than two chips may be wire-ORed together using the latter method.

ations and the balance struck between the two.

The timer/event counter capability is another special function that can be enabled with a configuration bit. The counter can be used as a timer when it is selected to be driven by the system clock. In this mode, the system clock is scaled to 1/15 of its frequency before driving the counter. The counter can also be driven as an event counter by the positive edge of external signal. The mode in which it is used is determined by a CRU-accessible bit.

Timer/counter function

Initially, the timer/counter is disabled (by a reset instruction). If the counter function is selected, the counter is enabled by selecting its mode and loading the clock register with a nonzero start value via a LDCR instruction. The counter is decremented by the selected source until it reaches zero. Then a latched interrupt is issued to the CRU and the counter is reinitialized to the previous start value. The current value in the counter can be read with a STCR instruction.

The 9940 has a power-down mode in which only the 128 bytes of RAM and the interrupt logic are powered. The power-down mode is enabled by a configuration bit. The timer/counter interrupt $\overline{\text{INT2}}$ is disabled, but both the $\overline{\text{RST}}$ and the $\overline{\text{INT1}}$ interrupts remain enabled.

The central processing unit (CPU) can be repowered—with the integrity of data in RAM maintained—by enabling $\overline{\text{INT1}}$. If $\overline{\text{RST}}$ is used instead, the CPU is repowered, but the data in RAM is lost. External circuity is needed to implement a self-induced power-down.

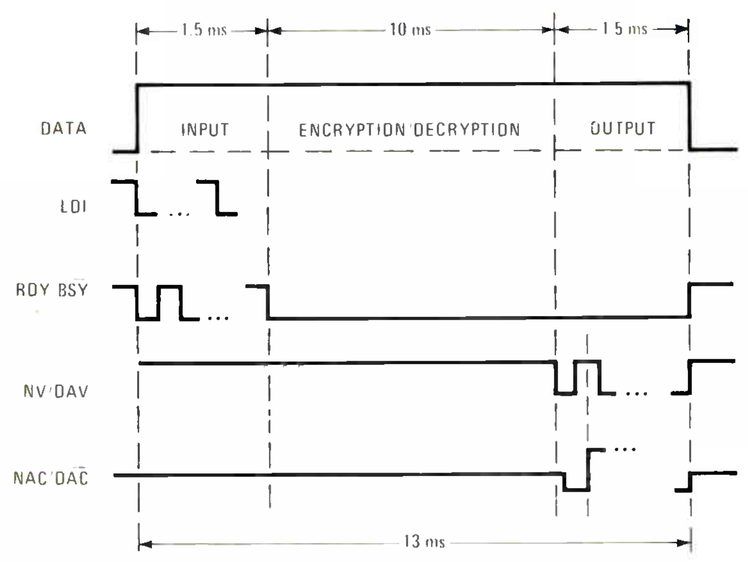
A 9940 can also be powered through external control. Assuming the power-down mode is enabled, the processor can be placed in the power-down mode by setting $\overline{\text{HLD}}$ to zero. This causes the hold acknowledge signal $\overline{\text{HLDA}}$ to become zero. This approach is useful for synchronizing the sharing of resources among processors.

Another configuration option is to provide a clock output for synchronization. If enabled by a configuration bit, the system clock is an output from the 9940. The frequency of the clock is half the oscillator frequency that is the actual internal system frequency.

The 9940 also has a 16-bit flag register accessible through CRU instructions. It can be used for storage or bit manipulation.

Encryption operations

The TMS 9940 data encryption unit has been implemented with the goal of maximum throughput with a flexible, easy-to-use interface. Throughput is maximized by careful control of the amount of ROM used to execute



4. Timing. Key entry, data input, and data output are controlled by externally applied handshaking signals. Complete processing of a 64-bit data block, including input, output, and all encryption operations, requires 13 milliseconds.

the Data Encryption Standard algorithm.

The 16 48-bit auxiliary keys used in the 16 main data manipulations are calculated and stored shortly after entry of the 64-bit main key. (The 64-bit key includes 8 bits used for parity checking; the remaining 56 bits make up the active key.) Consequently, time is not wasted during an encryption or decryption operation for auxiliary-key calculation.

Key entry

A key may be entered after reset on the completion of an encryption or decryption operation. The key entry flag pin, NK/$\overline{\text{KE}}$, is polled after reset or completion of an operation. If a key entry is sensed, the next 64 input bits are assumed to be the key.

A parity check is then performed. If an error is found, the active low parity error signal $\overline{\text{PE}}$ is activated and operation is halted. In order to recover from a parity error, the $\overline{\text{RST}}$ input must be enabled and the key-entry operation repeated. After receiving a key without parity errors, the 16 auxiliary keys are calculated and stored in onboard RAM.

The 9940 data encryption unit is designed to be a peripheral circuit supported by an external microprocessor or other circuitry. With this in mind, the basic sequence of operations after a key has been entered and after the key calculations are performed is easily understood. The first step is either plain or encrypted text input to the chip.

Shuffle and substitute

After the 64-bit block of plain or encrypted text is received, it is stored in the current workspace registers with STCR instructions. The initial permutation, which is a simple reordering or transposition of the input bits, is performed using on-board RAM.

The 16 main data manipulations that use the 48-bit auxiliary keys as specified in the DES are done with exclusive-OR functions and look-up-table logic. The 9940 provides automatic control of the workspaces and storage registers during these manipulations.

The final permutation (the inverse of the initial permutation) is executed using additional storage space. The 64-bit block is then read from the chip using LDCR instructions, making the chip ready to receive the next data block.

While the input and output ports are common, the system designer has the flexibility of setting them 8 or 16 bits wide. The width of the input word can be chosen separately from the size of the output word, allowing four combinations of input/output word size: 8/16, 8/8, 16/16, or 16/8. This flexibility allows easy interfacing of 8-bit systems to 16-bit systems.

I/O handshaking

Input and output are controlled by a set of handshake signals (Fig. 4). Input is initiated by the load data input ($\overline{\text{LDI}}$) signal; the $\overline{\text{LDI}}$ is attached to $\overline{\text{INT1}}$ of the 9940. Thus a low signal on $\overline{\text{LDI}}$ will interrupt the CPU.

Upon receiving the interrupt, the chip determines if there is space to store an input word. If the input can be accepted, the port is set to the input direction and data is read. When the input is completed, the RDY/$\overline{\text{BSY}}$ signal is set high. If the 9940 cannot accept the data, an internal flag is set and the interrupt is disabled. Upon completion of the current operation, the flags are scanned. If input is pending, the data input begins as if it were initiated by an interrupt.

Output is also controlled by a pair of handshake signals. When output is ready to go, the data is put in the output port and the data available signal, $\overline{\text{DAV}}$, is activated. The CPU then polls the data accepted ($\overline{\text{DAC}}$) input signal.

When the receiving device has taken in the output data from the chip, the next output word can be sent. Once the entire 64-bit block has been read out, the chip is placed in the receiving mode so that the next block of encrypted or plain text can be read in. □

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Measuring pulse bandwidth in the time domain

by Jim Dettmer
King Radio Corp., Olathe, Kansas

Using a spectrum analyzer to measure the energy bandwidth (the bandwidth over which 90% of a pulse transmitter's energy is contained) doesn't always yield correct results, because this quantity is less than the main lobe displayed. The energy distribution is a function of two pulse characteristics that can be measured in real time with an oscilloscope, however; with this information and the aid of the empirical curve shown here, energy bandwidth (EBW) can be found quickly and accurately.

If the output from a pulse transmitter were a perfectly rectangular waveform of amplitude A, frequency f, and duration τ (measured at 50% points), it would have a corresponding frequency spectrum of $(A\tau)Sa(f\tau)$, where Sa denotes the sampling function ($Sa(x) = \sin x/x$). There would be no loss of generality if the waveform was one of unit amplitude and width ($x_1(t)$ in the figure); its frequency spectrum would be simply Sa(f). Under these conditions, it can be shown that EBW would be the same as the main-lobe bandwidth, $2/\tau$, measured by a spectrum analyzer.

But no transmitter has a rise or fall time of zero, and so the pulse would be more accurately approximated as a trapezoid. A trapezoid is equivalent to the convolution of two rectangular pulses, and its resulting frequency spectrum is therefore the product of two sampling functions, where the second function $x_2(t)$ is regarded as a correction factor.

Consequently, $x_3 = x_1 * x_2 \longleftrightarrow (AK)Sa(Kf) \cdot Sa(f)$, where $K = K_1/\tau$ (K_1 is the measured fall time of the pulse), and τ is the large-pulse normalizing time. Clearly, the main-lobe bandwidth is determined by x_1; x_2 acts only to sharpen the skirts of the spectrum. The EBW thus no longer coincides with the main-lobe bandwidth. Fortunately, however, it can be determined without much trouble.

The total energy, E, is determined by taking advantage of the Rayleigh Energy Theorem:

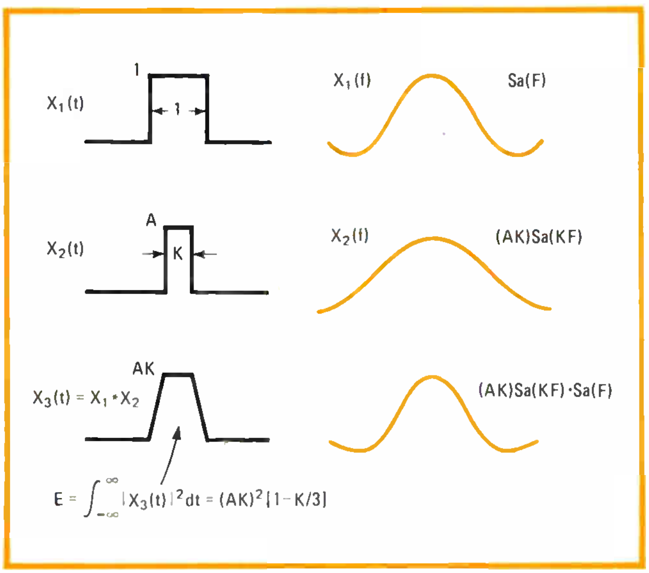
$$E = \int_{-\infty}^{\infty} |x(t)|^2 dt = \int_{-\infty}^{\infty} X(f)^2 df \qquad (1)$$

It necessarily follows that EBW $= f_2 - f_1$ when:

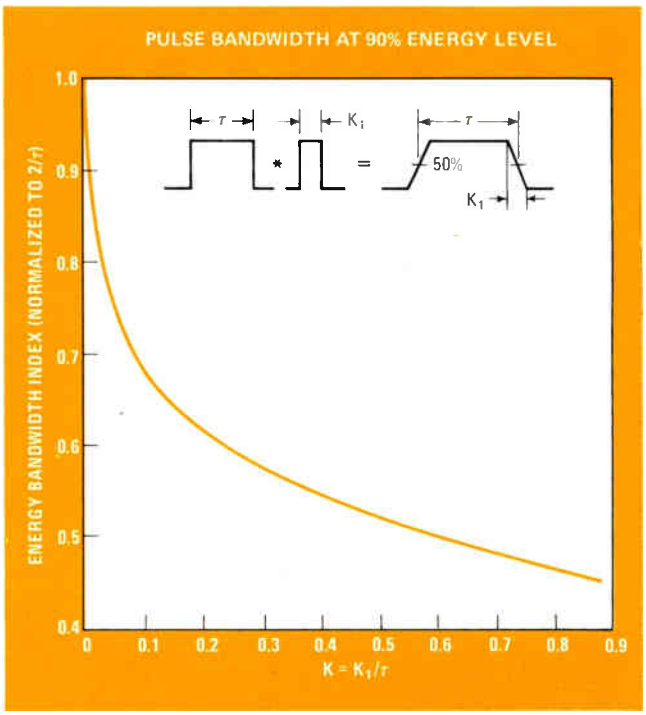
$$0.9E = (AK)^2 \int_{f_1}^{f_2} [Sa(f)Sa(Kf)]^2 df \qquad (2)$$

where E is the square of the area under the trapezoid, equal to $(AK)^2(1-K/3)$. EBW may be numerically found by using this last equation and letting $(AK)^2 = 1$. With the aid of the resulting curve plotted by solving Eq. 2 (see figure) for $f_2 - f_1$, and a scope to measure K_1 and τ, EBW can then be found.

As one can see from the curve, when $K = 0.6$, the EBW index is only one half of the main-lobe bandwidth. At $K = 0.2$, the EBW index is 0.62. Thus, if $K_1 = 200$ nanoseconds, and $\tau = 1$ microsecond, EBW $= 0.62(2/10^{-6}) = 1.24$ megahertz. □



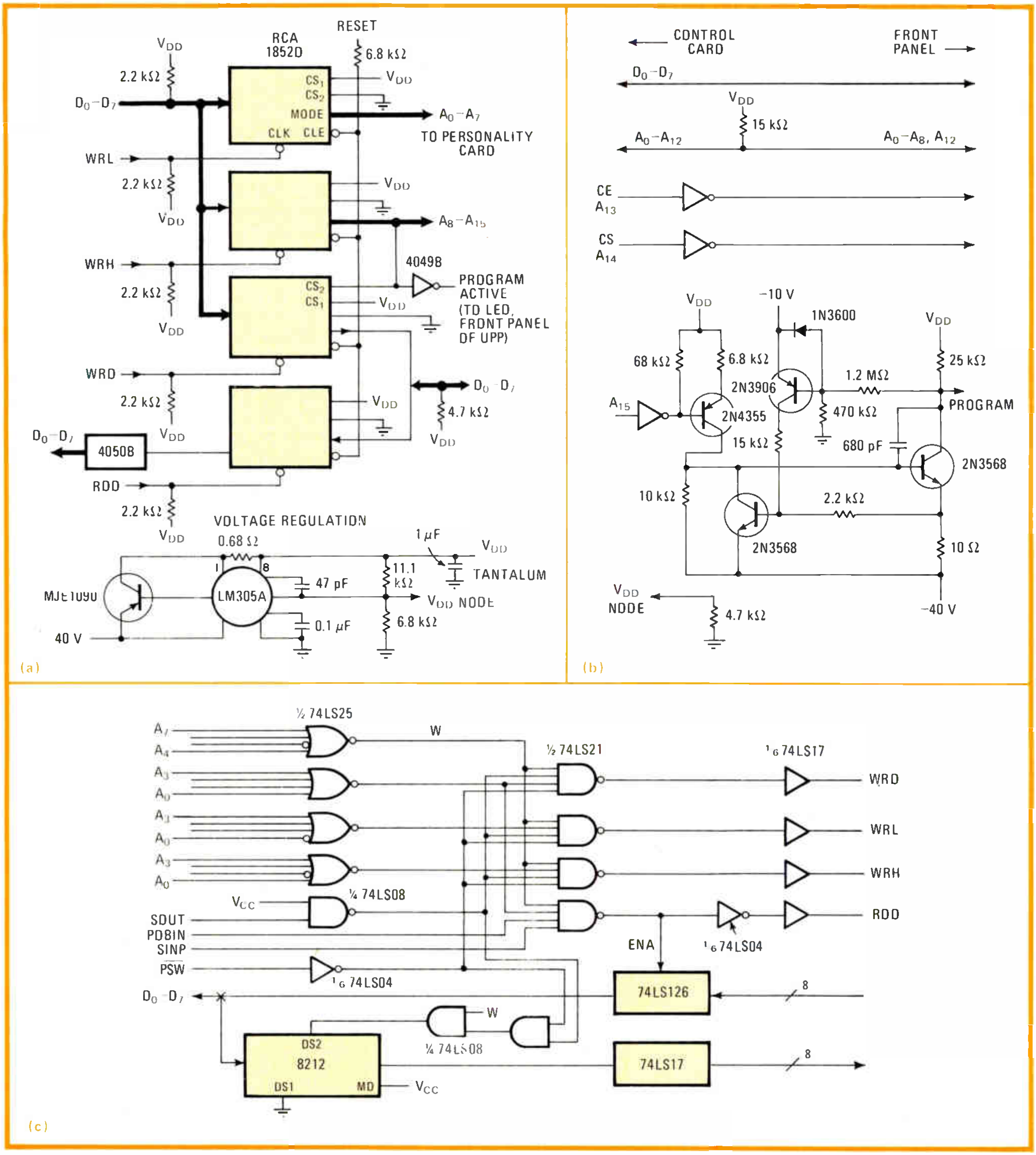
Convolution. Idealized output from pulse transmitter (top) must be convolved with second waveform (middle) that simulates transmitter's switching times, in order to determine the true bandwidth of pulse at the 90% energy level (EBW). Numerical solution of energy equation (bottom) enables plotting of general EBW-index curve.



Software-based controller simplifies PROM programmer

by R. F. Hobson
Simon Fraser University, Burnaby, British Columbia, Canada

While Intel's popular Universal PROM Programmer (UPP) works effectively in its intended capacity as a system development tool, it has two major drawbacks. First, the so-called personality cards that are required for manually programming each type of programmable read-only memory are expensive and much too complicated to build. Second, it is restricted to Intel PROMs, so that the newer complementary-MOS erasable-PROM



Burning softly. Complexity of control board (a) and personality cards (b) in universal PROM programmer are reduced if software-based controller leads system's host computer through various read/write burn-in phases. Personality card is shown for the IM6604 PROM. S-100 bus interface (c) units UPP to 8080 host processor. Small program (table) guides 8080 through write-and-verify sequence.

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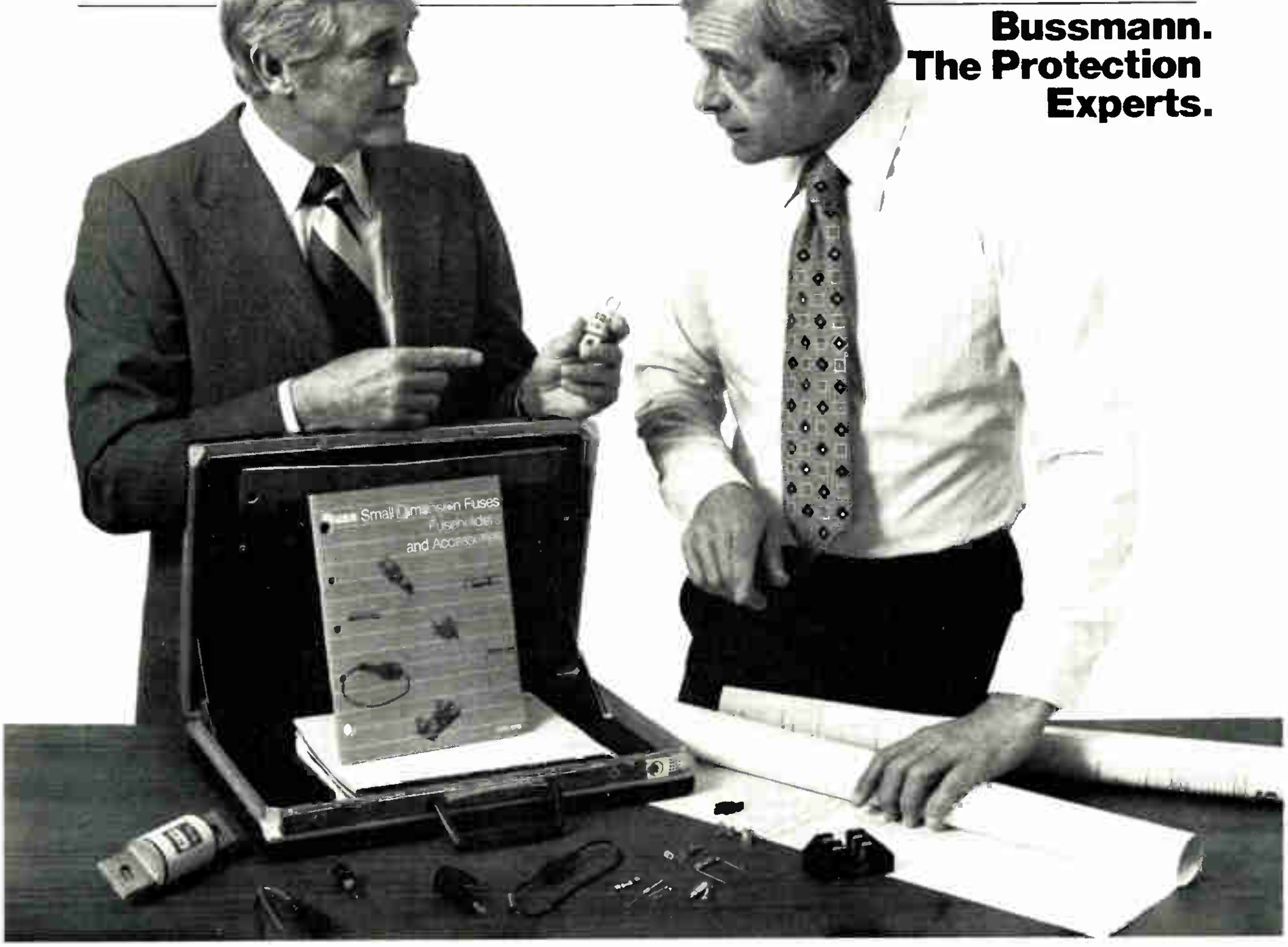

WRITE-AND-VERIFY SEQUENCE: IM6604 E-PROM

Write/Verify Routine

```
        Statement                 Comment

COUNT:  DS 1
WRITE:  PUSH  B
        PUSH  PSW
        CALL  DOUT    ;   LATCH DATA BYTE.
        XRA   A
        STA   COUNT   ;   INITIALIZE COUNT.
        POP   PSW
        CALL  ADDRL   ;   LATCH ADDRESS.
        CALL  INFO0   ;   INITIALIZE CRT.
WLP:    CALL  PULSE   ;   SEND A PROG PULSE.
                      ;   VERIFY
        MOV   B,A     ;   SAVE DATA BYTE.
        LDA   COUNT
        INR   A       ;   BUMP UP COUNT.
        STA   COUNT
        CALL  READ    ;   GET CELL CONTENTS.
        CMP   B       ;   COMPARE WITH DATA.
     JZ BURN          ;   EXIT IF VERIFIED.
        CALL  INFO1   ;   UPDATE CRT.
        LDA   COUNT
        CPI   030H    ;   PULSE LIMIT ...
        MOV   A,B
     JC WLP           ;   EXCEEDED?
        STC           ;   IF SO EXIT.
        POP   B
     RET
BURN:   ......        ;   LAST WRITE OK,
                      ;   BURN AND EXIT.
```

Pulse Routine

```
        Statement                 Comment

PROG    EQU   80H     ;   CONTROL BIT.
PULSE:  PUSH  PSW
        PUSH  B
        MOV   A,D     ;   ADDR/CTL BYTE.
        ORI   PROG    ;   SET PROGRAM BIT.
        MVI   B,0EH   ;   SET 14MS COUNT.
        CALL  HOUT    ;   START PROG PULSE.
        CALL  MSDLAY  ;   HOLD IT.
        XRI   PROG    ;   CLEAR PULSE BIT.
        CALL  HOUT    ;   RESET PROG PULSE.
        MVI   B,07H   ;   7MS COUNT.
        CALL  MSDLAY  ;   WAIT (2/3 DC).
        POP   B
        POP   PSW
     RET
```

chips cannot be programmed. The personality cards can be simplified and the UPP peripheral device made more versatile, however, if a software-based controller guides the system's host computer through the various read/write phases required to program and verify the contents of PROMs.

The basic UPP interface has eight data-input and eight data-output lines, along with read-data, read-acknowledge, and read-status ports. Also included is a write-data line, a write high-address and write low-address line, and an interrupt line. A pulsed control signal required for programming each PROM location is handled via a 4-bit 4040 microprocessor on a control card in the UPP.

The best way to simplify such a peripheral is to have the host computer provide the timing, control, and logic necessary for programming, reading, and verifying the contents of PROMs and E-PROMs. The complexity of the UPP's control card is then reduced to that shown in (a) of the figure, where the 4040-based setup is replaced by four C-MOS I/O chips (RCA 1852D).

The host computer consequently sees one input port and three output ports. The input port is used for returning the contents of a selected memory word. Two of the output ports are used for latching address and control information; the remaining output line is used for a data-output latch.

Of the 16 PROM-address lines available, 12 are used to address up to 4 kilobytes of memory. The remaining four lines can be used for program and chip control. Consider the personality card of the 512-by-8-bit IM6604 PROM, for example (b in figure). There, line A_{15} is used for a program pulse enable, A_{14} and A_{13} are used for chip select and chip enable, respectively, while line A_{12} is used for a strobe pulse. The popular 27XX E-PROM series would require only two control lines. Because the 27XX chips are powered by 5 volts, while C-MOS devices require 10 V for programming, the 27XX's personality card would interface to the host computer through open-collector devices.

In general, then, a personality card will consist of a bidirectional data bus, the required number of address lines, and a pulser circuit. It is thus used mainly to route the bus lines to the proper front-panel pin positions on the UPP. The pulse circuit must be designed to be reset by the UPP's front-panel reset button. This can be accomplished by connecting the reset line to the 1852D's CLE inputs. For completeness, the program control line (on the control card) is also connected to the program LED on the front panel.

A typical S-100 bus interface for the modified UPP is shown in (c). I/O ports 32, 33, and 34 have been decoded for a data strobe (read), write low-address, and write high-address, respectively. Interface software must include a timing subroutine and program pulse and verification routines particular to the PROM that is programmed.

As for the programming required, the sequence in the table outlines the steps necessary for the write-and-verify operation in the IM6604. The program is written for the host 8080A microprocessor. □

Engineer's notebook is a regular feature in *Electronics*. We invite readers to submit original design shortcuts, calculation aids, measurement and test techniques, and other ideas for saving engineering time or cost. We'll pay $50 for each item published.

Engineer's newsletter

Software package eases job of board designer

The Circuit Pack System (CPS) takes much of the drudgery out of designing printed-circuit boards. It's a set of automatic and interactive computer aids developed by Bell Northern Research Inc. to boost the engineer's efficiency and accuracy in laying out and documenting the circuits. It includes interactive graphic capture of schematic diagrams, as well as automatic and interactive circuit layout. What's more, it can create, modify, and control schematic symbol and component libraries and generate design documentation.

Fundamental to CPS is **an integrated design file that ensures the compatibility and consistency of design data from circuit schematic to board layout.** The file also provides the data input essential to such other design processes as logic simulation and testing.

CPS runs on the DECsystem-20 family of computers, supporting up to 16 graphics terminals. The basic system, which includes source and object code plus documentation, is available under license. Also available are symbol and component libraries, technical assistance, and training. Call Roger Fetterman at (415) 494-3942 for further information, or write to him at 3174 Porter Drive, Palo Alto, Calif. 94304.

Cash, fame awaits sixth scholar in communications

The electrical engineering community is invited to submit nominations for the Sixth Marconi International Fellowship Award. The purpose of the fellowship is to commission creative scientific works that will add to human knowledge and understanding of **how communications sciences and technologies can be applied to improve human life.** The award is both valuable and prestigious. It carries with it a $25,000 grant for completion of the recipient's chosen project or study, and it was presented to last year's winner, John R. Pierce of the California Institute of Technology, by the President of the Republic of Italy.

Nominations close Oct. 1, 1979, and the recipient will be announced in February 1980. The fellowship is administered by the Aspen Institute for Humanistic Studies at 1919 Fourteenth St., No. 811, Boulder, Colo.; (303) 443-1230.

Standards for portable or personal radios updated

Design engineers concerned with radio transmission will be happy to know that the engineering department of the Electronic Industries Association has revised document RS-316 "Minimum Standards for Portable/Personal Radio Transmitters, Receivers, and Transmitter/Receiver Combination Land Mobile Communications FM or PM Equipment, 25–1,000 MHz."

The revised standard (revision B) has been updated to **include coverage of separate receivers (for example, paging receivers) and transmitters (for example, surveillance units) as well as two-way radio equipment.** Also, references to conjugate impedance matching of external radio-frequency signal sources used for test purposes have been incorporated to remove any ambiguity in the method of connection of the signal source to the unit under test. In addition, to resolve a conflict with Federal Communications Commission regulations, the lower temperature limit for the frequency stability requirement of personal transmitters has been changed from $-10°C$ to $-30°C$.

Copies of RS-316-B are available at $9.00 each from the Standards Sales Office, Electronic Industries Association, 2001 Eye St., N. W., Washington, D. C. 20006. A free catalog of EIA Standards and Engineering Publications is also available. **-Harvey J. Hindin**

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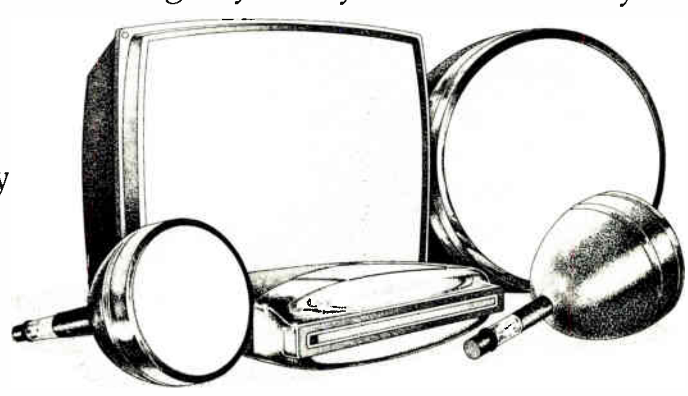

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Chip eases double data security

Monolithic device applies NBS cryptographic algorithm to data streams at rates to 400 kb/s, can down-load secondary keys to enhance secrecy

by John G. Posa, Microsystems & Software Editor

In some systems, easy access to data is a key feature, so the hardware and software strive together to make this possible. In contrast, in some private computing and communications networks, an effort is made to keep the bits a secret. Because of two related developments, the latter is now easy to accomplish. First, a data-encryption standard was recently adopted by the National Bureau of Standards. Secondly, integrated circuits like the MGD68NE data-security device (DSD) from Motorola perform the standard's cryptographic algorithm in silicon.

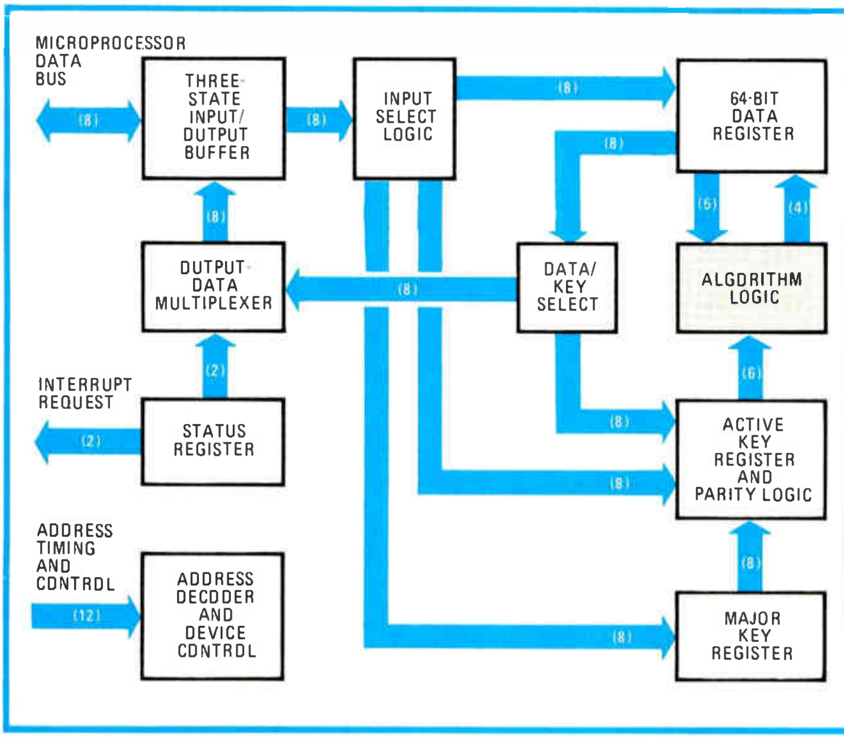
There are other single-chip data-encryption devices around, such as those from Texas Instruments, Intel and Western Digital [*Electronics*, June 21, p. 107], but according to Steve Sparks, manager of microcomputer marketing and systems applications at Motorola, at least two aspects of the MGD68NE make it stand out in the growing crowd.

The first of those features is speed. "The device is very fast," comments Sparks. "It will operate on data rates up to 400 kilobits per second." Another distinction of the Motorola chip is that "it has the ability to down-load minor [or secondary] keys to obtain a higher level of security," he adds.

According to the NBS algorithm, 64-bit blocks of data are scrambled using a 56-bit active key, which can be a major or secondary key. In a typical environment—a serially distributed network, for example—a sender uses this key to ship garbled bits to one or more recipients. They unlock the message by essentially running the algorithm backwards with the same key.

With the MGD68NE, not only can this major key be used to mask information, but minor keys can be generated to further foil nosey data tappers. In addition, minor keys can be in plain text or scrambled using the major key, and because the secondary keys are developed exclusively by the sender, they can be disseminated selectively.

The receiver must be aware that a secondary key is being transmitted, of course. If it is in plain text, he can load it directly into his active-key



OPERATIONAL AND CONTROL MODES

A_0	A_1	A_2	R/W	
0	0	0	0	WRITE DATA "C" KEY OPERATIONAL (1st 7 BYTES)
1	0	1	0	ENCIPHER DATA
0	0	1	0	DECIPHER DATA
0	0	1	1	READ DATA
0	1	0	1	READ STATUS
1	0	0	0	RESET/INITIALIZE
0	1	0	0	ENTER MAJOR KEY
1	1	0	0	ENTER PLAIN SECONDARY KEY
0	1	1	0	DECIPHER SECONDARY KEY
1	1	1	0	ENCIPHER SECONDARY KEY
1	0	0	1	TRANSFER MAJOR KEY

register. If it is encrypted, the device can be directed to decrypt it using the major key and automatically load it into the active-key register.

The n-channel MOS device is housed in a 24-pin package, requires only +5 V to function, and is directly compatible with the 6800 microprocessor. Besides V_{CC} and V_{SS}, the remaining 22 pins are divided up for an 8-bit directional data bus, 2 pins for interrupt request, and 12 for address, timing, and control, as shown in the block diagram.

The DSD's three address lines are used in conjunction with a read/write pin to select five major modes of operation: loading of data or key, data encryption, data readout, and status readout (see table). To load, encipher, or decipher a major or secondary key, the entire 8-byte block is transfered into the device over the data bus after selection of the appropriate operation with the address and R/W pins.

To encipher or decipher a block of text, however, the first 7 bytes are entered while selecting the write data/"C"-key operation. The remaining byte is written either to the encipher-data or the decipher-data register in accordance with the desired operation. In any event, the encryption process begins automatically, and the chip's busy flag is set while the encryption algorithm is in motion. All commands except read status and reset are ignored until the process is completed, at which time the busy flag is reset.

Because the encyphering algorithm is a mirror image of the decyphering algorithm (and vice versa), the Motorola device can make things even more interesting. Data or keys can be first decyphered by the sender, and subsequently encyphered by the receiver. This may sound backwards, because it is. But once again, if all involved know that the algorithm is being applied in reverse order, it works. Commercial production of the MGD68NE has just begun; pricing is not yet firm.

Motorola Inc., Integrated Circuits division, 3501 Ed Bluestein Blvd., Austin, Texas 78721 [338]

Data acquisition

Unit costing $12 has multiplexer

12-bit a-d converter accommodates four inputs, does 400 conversions/s

Monolithic analog-to-digital converters are increasingly being tailored to microprocessor systems—not a bad strategy as data-acquisition systems scale down to microcomputer size. Nippon Electric Corp. of Japan builds the latest such a-d converter, which has the bonus of a built-in multiplexer to up the number of inputs.

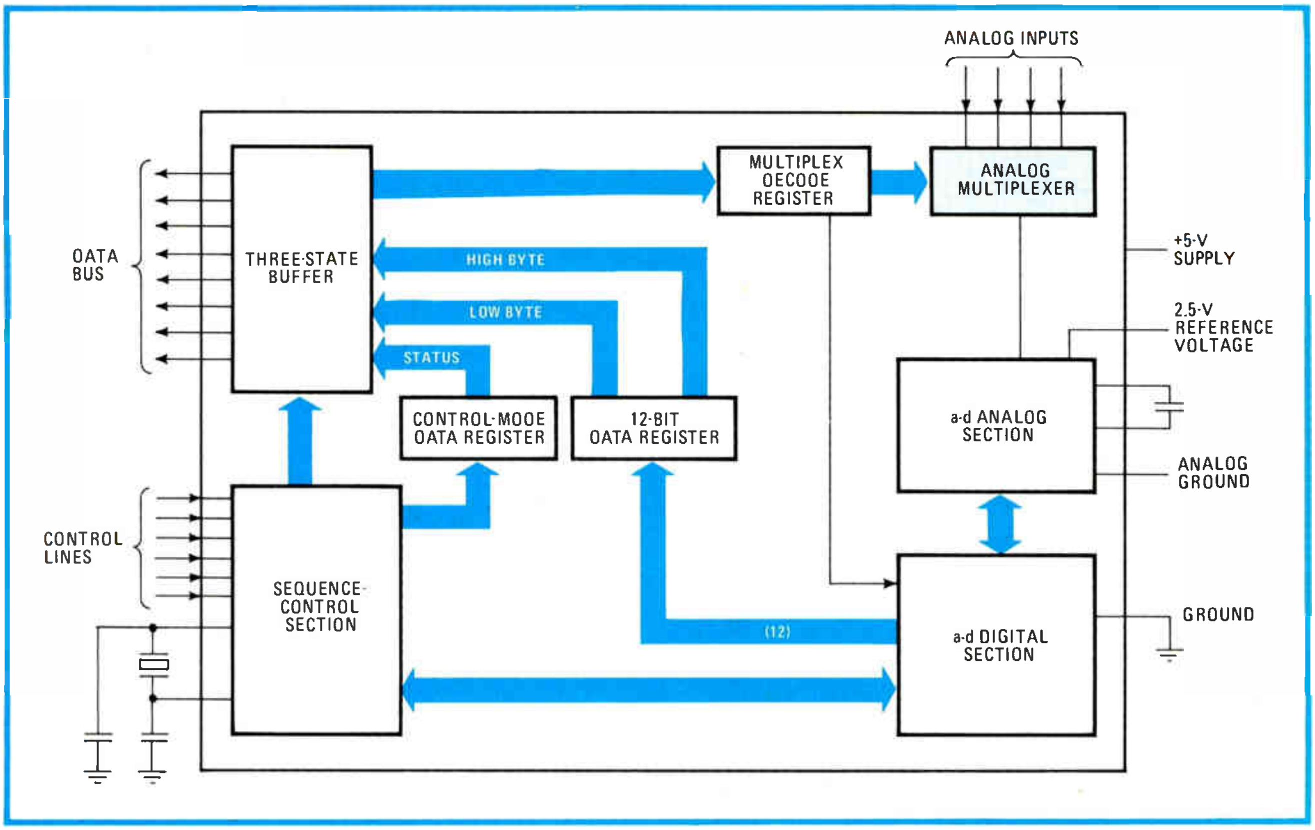
Available in the U. S. through NEC Microcomputers Inc., Wellesley, Mass., the μPD7002 is the first microprocessor-bus-oriented 12-bit a-d converter with on-board multiplexer that accommodates four analog inputs. Its conversion time is fast—typically 5 ms—making it suitable for waveform analysis and automotive applications. What's more, the chip operates with a single +5-V supply and a 0-to-3-V external reference, and since it is built with a silicon-gate complementary-MOS process, it dissipates a maximum of 15 mW.

As shown in the figure, the microprocessor bus connection is an 8-bit three-state port over which data and instructions flow. Upon receipt of a write command from the microprocessor, the converter selects an analog input port and begins conversion. The 12-bit floating-point conversion data is then passed back to the processor as a left-justified word within the 16-bit field made up of a high byte and a low byte. A status byte is also transmitted.

To support the four time-multiplexed analog inputs, NEC had to design a relatively fast conversion circuit. Kyuichi Hareyama of the second IC design engineering department in NEC's Kawasaki City, Japan IC division, explains that several new approaches were used to boost speed: "The 7002 uses a voltage-to-current converter on the front end and operates as a current-mode device, making it faster."

NEC also went to an integrating technique different from the usual dual-slope integration. A scheme NEC calls simultaneous integration integrates both the reference current and the analog-input current over shorter intervals than the simple two-slope integration. "This also allows the integrator a much larger equivalent output voltage range and improves the signal-to-noise ratio," says Hareyama. David Millet, microprocessor product marketing manager at NEC Microcomputers, adds that the external integrating capacitor can be much smaller—typically 0.015 μF. "The fastest conversion takes 2.5 ms, which works out to 400 per second," Millet explains. "But 200 conversions per second is typical."

The drift in the chip is 20 parts per million per °C at zero and full scale. The input impedance at any of the analog inputs, which are single-ended with a range between zero and



the reference voltage, is 1 GΩ. Worst-case linearity of the device is 0.05%. The 189-by-197-mil chip is housed in a 28-pin plastic dual in-line package.

At $12 each in hundreds, the 7002 is on par with the ICL7109 bus-oriented a-d converter from Intersil Inc. [*Electronics*, Aug. 7, p. 130]. It lacks Intersil's low drift and high linearity specifications, but offers a tenfold conversion-speed advantage and four inputs against one. Initial versions of the 7002 will be available for sampling in August, with production volumes in September.

NEC Microcomputers Inc., 173 Worcester St., Wellesley, Mass. 02181. Phone (617) 237-1910 [381]

Acquisition modules feature programmable gain options

Interfacing analog signals to microcomputers takes a painstaking effort when space limitations require compact circuitry. Two recently introduced data-acquisition systems, the DAS1150 and DAS1151, can ease this design effort. Compact systems with sample-and-hold circuitry and 12-bit analog-to-digital converters, the modules have true 12-bit performance guaranteed up to a 25-kHz throughput at unity gain with a maximum overall error of ±1 least significant bit. Packages for both are 2 in. by 4 in. by 0.4 in.

The 1151 features gains of 1, 2, 4, or 8 selected by a TTL-compatible digital input. With this instrumentation amplifier, where the gain is software-programmable, the module provides dynamic range expansion through subranging and also allows use of different input signal levels. The device has a maximum settling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time of 15 μs with a nonlinearity error at ±½ LSB, typically. The minimum common-mode rejection ratio is 76 dB.

The 1150, with a resistor-programmable instrumentation amplifier, has gains from 1 to 1,000—full-scale input ranges from ±10 mV to ±10 V—and a 13-kHz throughput rate. It has an overall error rate of ±2 LSB when G = 1,000; nonlinearity is typically ±½ LSB. Input settling time varies from 15 μs when G = 1 to 50 μs when G = 1,000. This device also has a minimum 76-dB common-mode rejection ratio.

In quantities of 1 to 24, the 1150 system sells for $199 and the 1151 for $249. Delivery time is from stock to two weeks.

Analog Devices Inc., P. O. Box 280, Norwood, Mass. 02062. Phone Mark Skillings at (617) 329-4700 [383]

ECL makes fast 12-bit digital-to-analog converter

Fast is getting faster with Hybrid Systems 12-bit emitter-coupled-logic digital-to-analog converter. The DAC397-12 settles to within ±0.01% of full scale in 40 ns typically and 50 ns maximum. The unit will settle to within ±0.2% in 30 ns and ±1% in 20 ns.

With a ±0.0125% nonlinearity rating, the 397 has output ranges of 0 to −16 mA or ±8 mA and a glitch area of 2.5 mA-ns. Input coding is complementary binary or complementary offset binary for unipolar or bipolar operations, respectively. The 397 has a linearity drift of ±5 parts per million/°C and a gain drift of ±25 ppm/°C.

A commercial version of the

RAM Tamer

Intel's new 8202 RAM controller makes dynamic memory behave like static.

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The 8202 interfaces directly to the 8080A bus, to the demultiplexed 8085A bus and to the demultiplexed 8086 bus. Eight 8202's can be grouped in an 8086 maximum mode system to provide control and addressing for a full megabyte of dynamic RAM.

To order any of the 28 Intel® peripheral interface and control components, contact your distributor. Or for more information on them and the 8202 dynamic RAM controller, write Intel Corporation, 3065 Bowers Avenue, Santa Clara, CA 95051.

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converter—the DAC397C-12—operates over a 0° to 70° C temperature range, while a military version—the DAC397B-12, fully processed to MIL-STD-883B—operates from −55° to +85° C. Both units are housed in 24-pin, double-width, metal dual in-line packages, and each has an internal ±10-V reference; an external reference may be used if desired. The devices operate with a ±15-V and −1.3-V power supply.

In small quantities the commercial version sells for $368 and is available in two to four weeks. The military version sells for $460 with deliveries in 8 to 12 weeks.

Hybrid Systems Corp., Crosby Drive, Bedford Research Park, Bedford, Mass. 01730. Phone Paul Goss at (617) 275-1570 [385]

Optically coupled I/O board protects series 80 computer

A central computer system governing silicon controlled rectifiers, triacs, relays, motors, and solenoids is also vulnerable to the effects of ground loops and high-voltage surges. The BLC-556 eliminates these effects for the series 80 microcomputer, protecting it from voltages up to 500 V dc with optical coupling.

The board has 48 input/output lines; three eight-line dedicated input ports, where the inputs may be either single-ended or differential; two eight-line dedicated output ports; one programmable port available as an eight-line input or output or a four-line input and output. Line-to-line maximum isolation is 230 V dc or peak ac, and for input and output 500 V dc or peak ac. Using standard 8080A I/O commands, the CPU communicates with the BLC-556. Interrupts may be enabled or disabled by jumper selection.

In quantities of one to nine, the board is priced at $355, with shipments within four weeks after receipt of orders.

National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, Calif. 95051. Phone Larry Choice at (408) 737-6716 [387]

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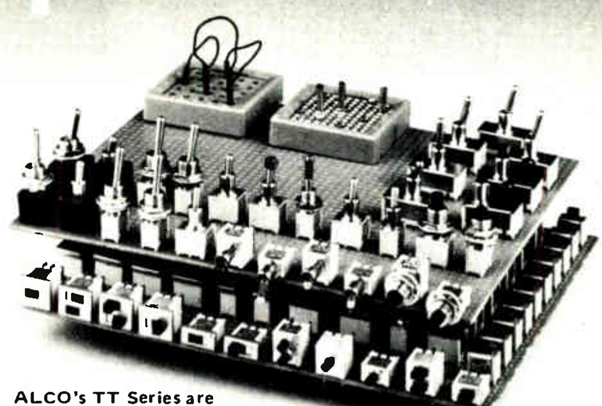

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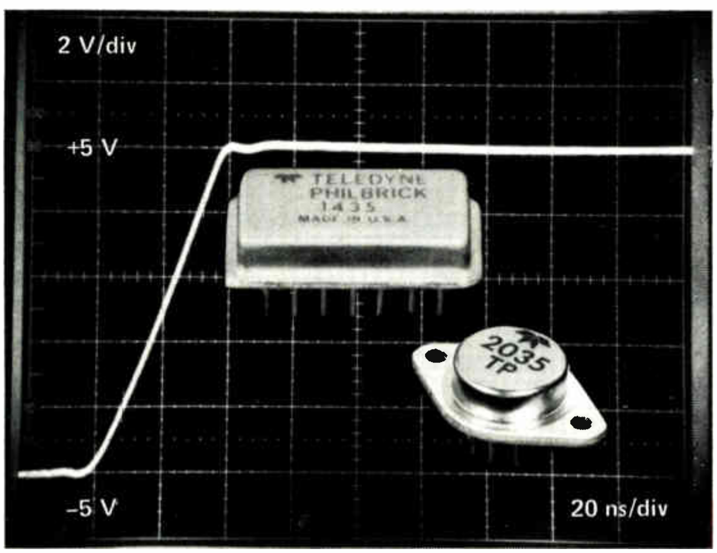

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Instruments

Counters move lab to bench

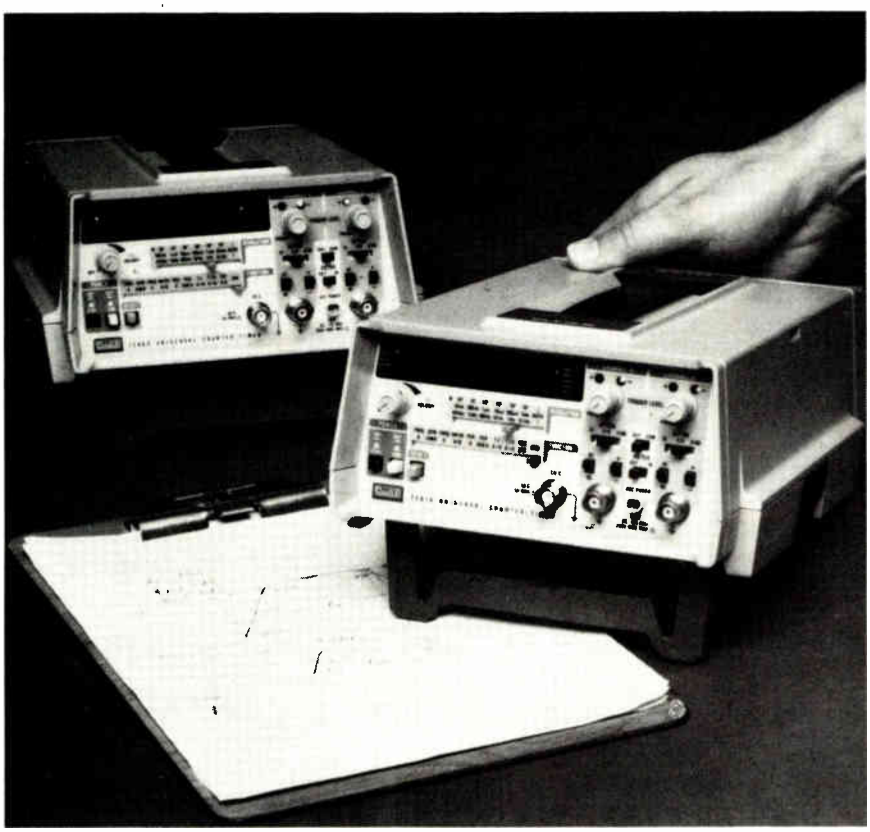
Low-cost units feature precision input amplifiers and low-pass filters

As digital systems get faster and more complex, production and test engineers find that they need frequency counters with specifications formerly found only in instruments intended for use in the measurement laboratory. To provide those specifications for under $1,000, the John Fluke Manufacturing Co. is introducing four new 7200 series units—three universal counter/timers and one frequency-only instrument.

Two of the counter/timers, the 7260A and the 7261A, are high-performance 125-MHz units with sensitive (10-mV rms) wideband input amplifiers and such standard features as a 100-kHz low-pass filter, markers, trigger-level outputs, and time-interval hold-off capability.

The 7261A, which is aimed at "guys working on the leading edge," according to Lee Meyer, product manager, general test and services, can make one-shot time-interval measurements with 10-ns resolution and has an averaging mode for even better performance on repetitive signals. For effective averaging of extremely stable signals, a jittered clock is available as an option. The 7260A, which Meyer thinks will be used mostly by development engineers, can resolve 100 ns. Options for both benchtoppers include a 500-MHz direct third channel, a time base in an oven, and batteries for portable operation and for keeping the optional crystal oven powered at all times.

For production-oriented operations, where cost is the main consideration, Fluke has developed the 7250A—an 80-MHz universal unit that measures time intervals with a resolution of 100 ns and offers period averaging for extra resolution in the period mode. It provides both manual and autoranging operation. To reduce the effects of noise on measurement accuracy, it has a 100-kHz low-pass filter and continuously adjustable input attenuators.



For the communications market, Fluke offers the dedicated 7220A, a frequency-only counter billed as providing 1.3-GHz performance at a 500-MHz price. It covers the 1.3 GHz in two ranges—5 Hz to 125 MHz, through a high-impedance port, and 50 MHz to 1.3 GHz through a 50-Ω port. The high-impedance channel includes a continuously variable attenuator and a switch-selectable 100-kHz low-pass filter. Standard features include burst-measurement capability, resolution that may be manually adjusted from 0.1 to 100 Hz, and a nine-digit LED display.

As the low-pass filters and adjustable input attenuators make clear, the engineers at Fluke are acutely aware of the effect that noise can have on accuracy. This awareness is also demonstrated by their development of an interference shield to protect the sensitive input amplifiers in all of the counters.

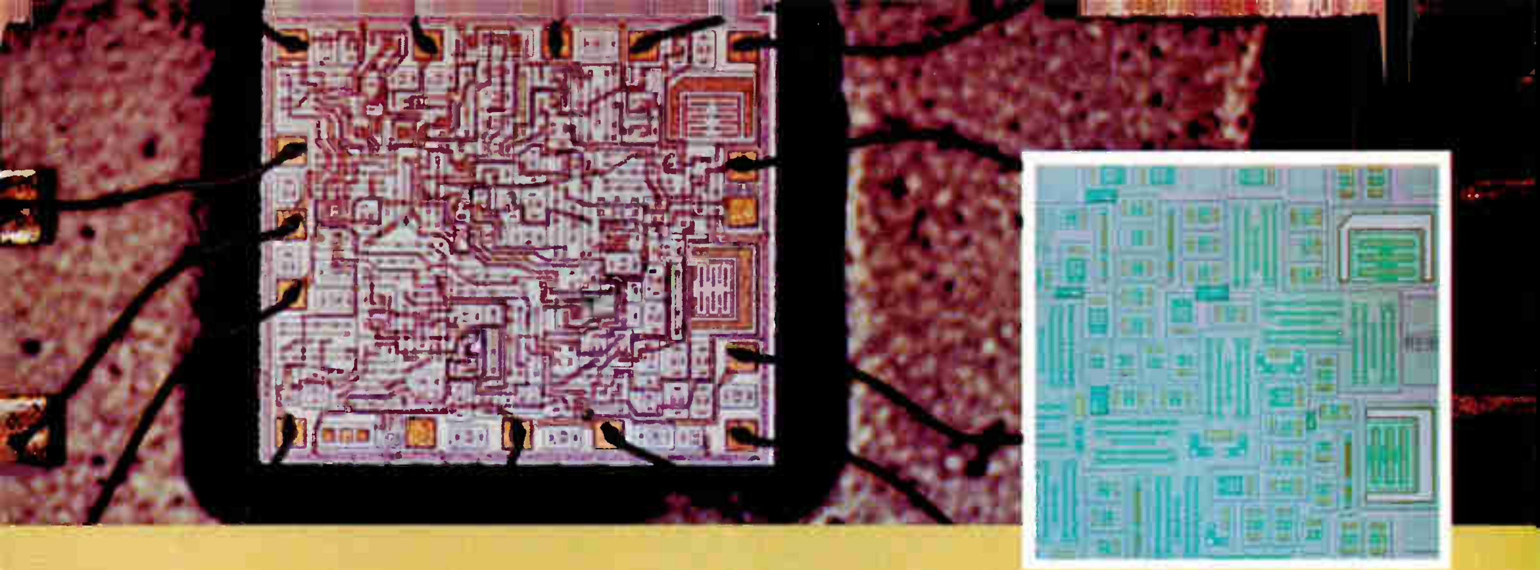
For users who may want to link any of the instruments to the IEEE-488 bus, the 1120A interface translator is also being provided. One 1120A can handle up to three instruments, and an unlimited number of 1120As may be added to a system. The counters are housed in Fluke's stackable case, which means that several of them (and other instruments) may be stacked and locked together with or without a 1120A.

Base prices for the counters are: $995 for the 7261A, $850 for the 7260A, $675 for the 7250A, and below $900 for the 7220A.

John Fluke Manufacturing Co., P. O. Box 43210, Mountlake Terrace, Wash. 98043 [351]

21-GHz spectrum analyzer combines uses for $9,500

Some engineers would like to use a microwave spectrum analyzer in a laboratory environment, while others



Section of an Exar Master Chip before customizing. Note the individual circuit components already on-chip, but still unconnected. After the customer has designed circuit connections according to his system needs, Exar prepares a final mask and fabricates the custom chip, as shown in large photograph above.

This integrated circuit was manufactured to a custom design and delivered in a matter of weeks.

YOU CAN CUT DEVELOPMENT TIME UP TO NINE MONTHS ON BIPOLAR AND I²L CUSTOM CHIPS . . . WHILE YOU SLICE COSTS TO THE BONE . . . THROUGH THE UNIQUE "SEMI-CUSTOM DESIGN PROGRAM" FROM EXAR INTEGRATED SYSTEMS. Compared to traditional development times for custom ICs, which frequently exceed one year, and tooling costs which can be five to ten times greater, this new concept allows custom chips to be justified economically at far smaller quantities than previously thought practical.

How the semi-custom idea works.

Exar's standardized circuits contain undedicated active and passive components such as transistors, resistors, logic gates, etc., fabricated onto the chip, but left unconnected. You choose how to interconnect these components to create your own custom circuit. The actual interconnection process is simple, requiring only one to three layers of tooling. As a result, development time compresses drastically, becomes far less expensive and virtually risk free.

Choose from eight different chips.

Five of the standard semicustom chips are bipolar, and are best suited for linear designs. Some (XR-A100, XR-C100, XR-F100) feature high current NPN output transistors, making them suitable for drive circuits. The others (XR-B100, XR-D100), more appropriate for signal amplification or control circuits, contain only small signal, low current transistors. All, however, present the designer a wide variety of NPN and PNP transistors, Schottky diodes, various resistors and ample bonding pads.

Exar's three I²L digital chips (XR-300, XR-400, XR-500) contain high density I²L logic arrays and bipolar interface circuitry. Outwardly they look and perform like a bipolar LSI chip, readily interfacing with TTL or MOS level signals. This feature, incidentally, makes it very convenient to retrofit I²L LSI designs into existing MOS or TTL logic systems.

And Exar has in development additional semi-custom chips offering even greater applications flexibility.

If you decide to modify your design.

Even after evaluation of initial design prototypes, if you see a need to modify the custom chip, a new design iteration usually takes less time than the original development cycle. And typical costs of additional design cycles are proportionately less than the original prototype development cost.

What about second sources?

This is one of our most asked questions. In response, Exar has made alternate-source agreements with other IC manufacturers, so you can specify and order custom circuits with confidence.

Testing, testing.

After prototype acceptance of semi-custom devices, Exar will develop software and fixtures for fully testing all production ICs. Production devices receive 100% electrical testing, and are screened to agreed-upon Acceptable Quality Level (AQL) standards. Charges for this test engineering are nominal, and vary depending on the complexity of the tests.

Semi-custom to full custom. For when the numbers get big.

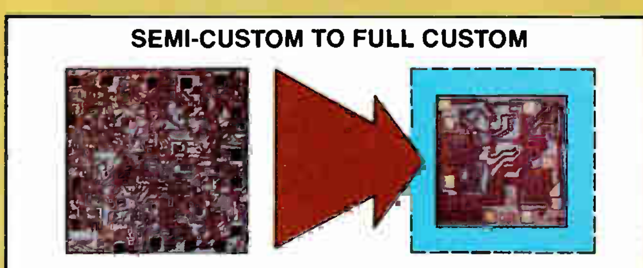
Because Exar manufactures its own wafers, it can grow with your needs. As your product matures we can convert your semi-custom chip into a customized IC. Consider the advantages: You get the quick, inexpensive turnaround of semi-custom chips, providing prototypes and intial production units; then when your design has proven itself and your market has developed, the subsequent full custom product provides further cost savings at high volume production . . . often with a significant improvement in product performance!

Design kits make it simple.

Exar provides linear and digital design kits, including circuit components for breadboarding, comprehensive design manuals and layout worksheets corresponding to Exar's master chips. These, as well as technical assistance when you need it, will speed and simplify your preliminary steps toward custom IC design.

Learn the economics and advantages of semi-custom.

Exar's entire semi-custom story is detailed in a 40-page data book, "Semi-Custom IC Design Programs." For your copy, write on company letterhead to your nearest Exar representative or to Exar, 750 Palomar Ave., Sunnyvale, CA 94086.



Exar can convert your semi-custom chip to a custom IC, reducing chip size, saving money, and often providing added performance benefits.

EXAR CUSTOM

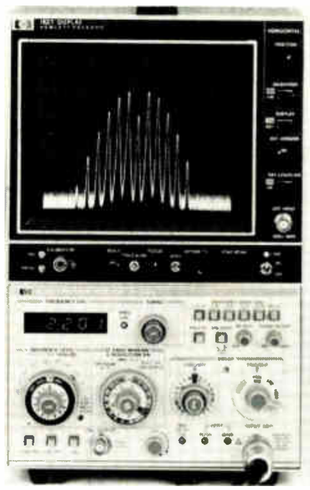
Circle 167 on reader service card

FOR THE EXAR REPRESENTATIVE NEAREST YOU, CALL EXAR AT (408) 732-7970.

might need such an instrument for product and service applications. The model 8559A plug-in now combines laboratory accuracy and portability in a 10-MHz-to-21-GHz instrument.

In the range of 0.01 to 3 GHz, the 8559A has an average noise of −111 dBm/kHz, a frequency response of 1.0 dB, and an overall amplitude accuracy of 2.3 dB. At 18 GHz, average noise is −92 dBm/kHz, flatness is 2.3 dB, and amplitude accuracy is 3.6 dB. Frequency accuracy is 4 MHz at 1 GHz and 47 MHz at 21 GHz. A five-digit light-emitting-diode display provides 1-MHz resolution.

Resolution bandwidths of 1 kHz and 3 kHz allow detailed analysis; or bandwidths as wide as 3 MHz hasten wide-span sweeps and increase the

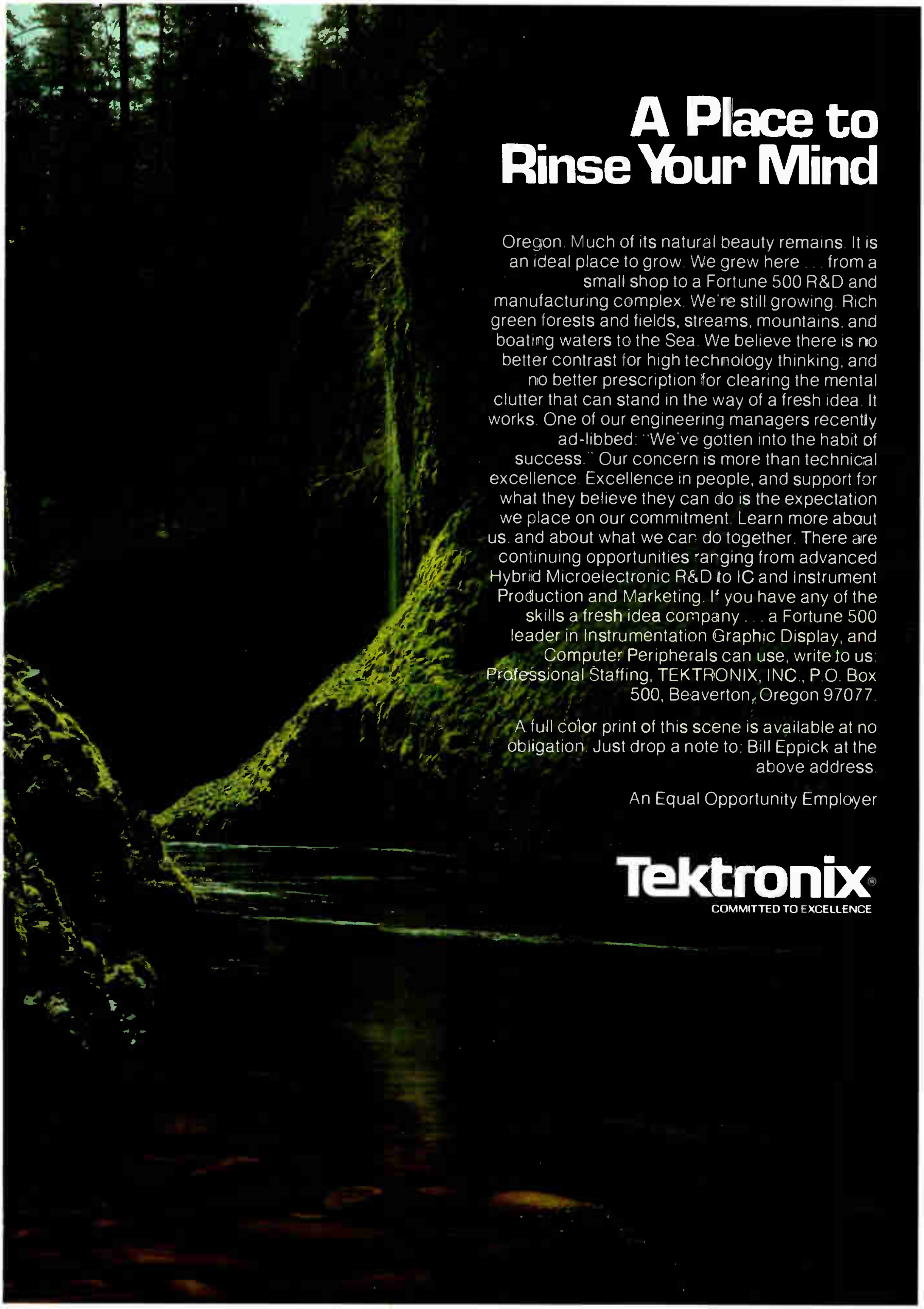


signal-to-noise ratio for pulsed rf measurements. An alternate i-f permits analysis at the unit's first i-f (3 GHz).

Weighing 38 lb, the 8559A has push-button band selection coupled with a signal identifier function that can be used over a broad range of spans—100 kHz to 10 MHz/division—to simplify operation on all harmonic mixing modes.

Complete with a model 182T large-screen mainframe, the analyzer sells for $9,600. Shipments are scheduled to begin in September, with delivery time in seven weeks.

Hewlett-Packard Co., 1507 Page Mill Rd., Palo Alto, Calif. 94304 [353]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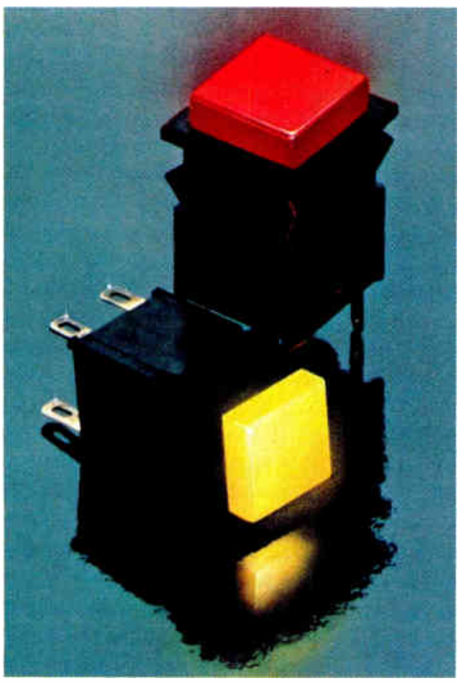

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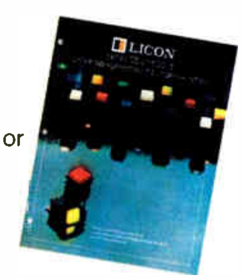

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Computers & peripherals

Board stores a megabyte

Populated with 64-K RAMs, board will run in any PDP model that uses DEC's Unibus

For add-in memory users who are willing to pay the premium associated with leading-edge chip technology, Motorola's memory systems group is promising eight-week delivery times on two new board products to be populated with Motorola's MCM6664 dynamic random-access-memory components.

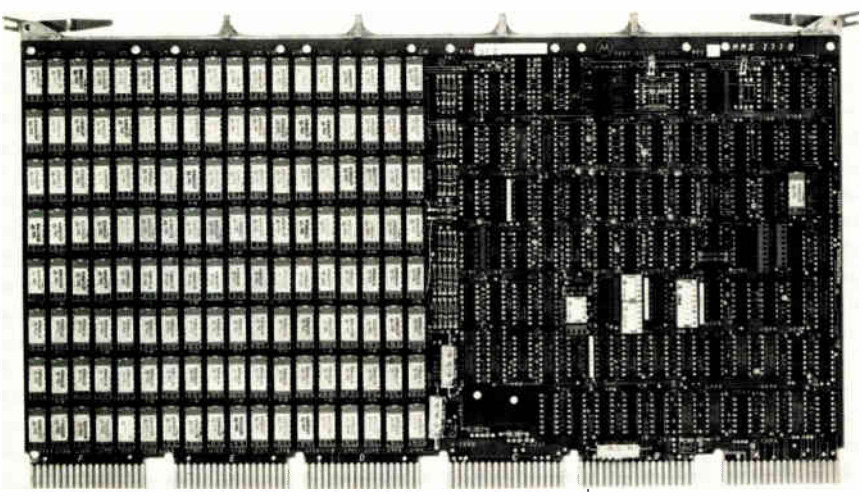
When fully populated with 144 of the 65,536-bit chips, the MMS1119 module provides a full megabyte of storage with parity on a single card for use with Digital Equipment Corp.'s PDP-11 series of 16-bit minicomputers. Another board, the MMS1102, is designed for use with DEC's LSI-11/23 and packs in a quarter megabyte with parity per board using 36 of the 64-K chips.

Organized as 524,288 words of 18 bits each, the 1119 will run in any PDP model that uses DEC's Unibus or modified Unibus, and it will allow users to quadruple memory capacity with no increase in required power. Fully loaded with the single-supply 64-K components, the 1119 requires only 20 W, compared to 23 W for a smaller 128-kiloword version populated with three-supply 16-K devices, Motorola says. Both the 1119 and the 1102 require DEC memory management for use. The 1102 hooks up to DEC's Q bus-plus.

Motorola expects to pick up customers for the new boards among DEC computer users who need additional memory capacity but have no room for expansion in existing card cages. The 1102 can reach the LSI-11/23's maximum address capability with a single card, whereas the 4-megabyte address capability of PDP-11 systems using the expanded Unibus can be achieved using only four fully configured 1119s, Motorola officials point out.

Both the 1102 and 1119 are also offered in a configuration using lower-density 16-K RAMs. As the 64-K chip technology matures, Motorola officials say they may be able to achieve some speed improvements when using the denser chips. But initially, they add, 1119 boards using the 64-K chips are specified at the same 300-ns typical/360-ns maximum read access times as are boards using the 16-K chips.

The on-board parity control provided as a standard feature on both the 1102 and 1119 does not degrade access or cycle times, Motorola says. The feature may be eliminated, however, for users who don't need it. Automatic on-board refresh capability is similarly provided as a so-called standard option.



In its maximum 512-kiloword capacity, with parity and refresh, the 1119 is priced at $52,440 in quantities of one to nine, though discounts are available on large-quantity orders to original-equipment manufacturers. The 1102, in its maximum 128-kiloword capacity with parity and refresh, is priced at $13,090 in quantities of one to nine.

Motorola Memory Systems, 3501 Ed Bluestein Blvd., Austin, Texas 78721. Phone (512) 928-6776 [361]

Display terminals match up for remote diagnostics

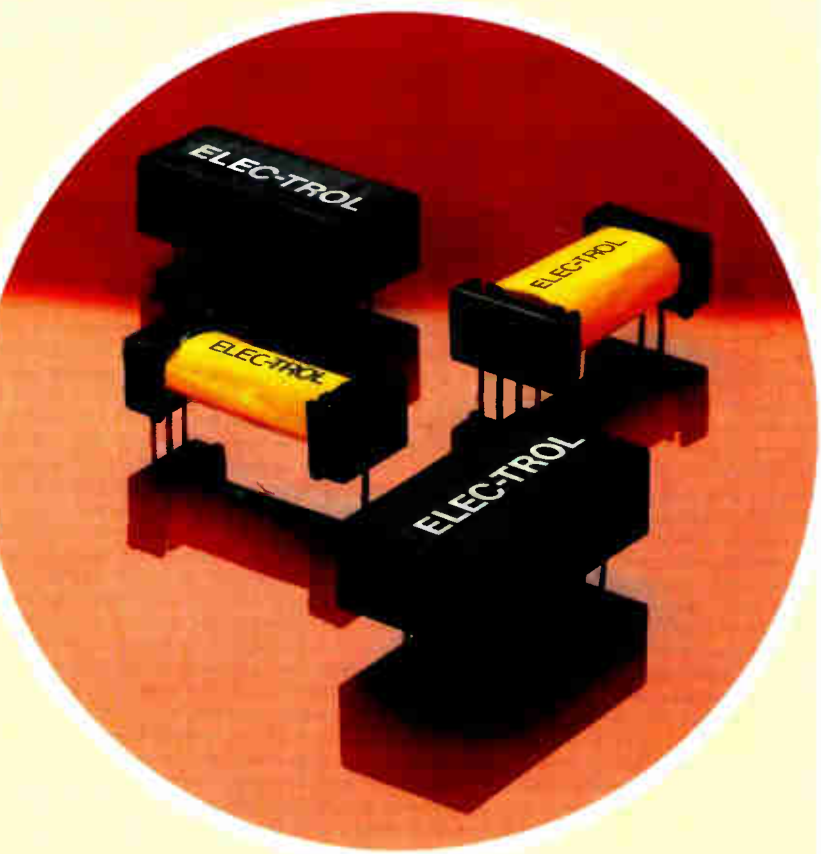
Systems engineers and applications programmers will be spending more time designing computer systems and writing programs and less attacking hardware and software problems thanks to two recently introduced display terminals that provide diagnostic system support by telephone from remote locations. The Dasher D4 is a user's diagnostic display terminal, while the D5 is a diagnostic display for the central support center. Both are integrated video/communications subsystems providing data and voice communications over a direct-dial telephone link.

A user with a problem contacts the support center by telephone, and information is exchanged via the respective terminals. For example, information appearing on the user's terminal is displayed at the center to demonstrate the problem. The support personnel then attempt to solve the problem by activating remote system diagnostics or by correcting program errors.

The D5 has an external tabletop communication controller, while the D4 uses an integral one. The terminals form a simultaneous voice and data-communications link, including a full-duplex modem with split transmission rates at both ends.

Data is transmitted from the user's terminal to the central terminal at 2,400 bauds. Information sent interactively from the control center is at 150 bauds. These terminals may

ELEC-TROL VARI-PACK REED RELAYS



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Elec-Troi now offers a line of Vari-Pack Reed Relays featuring both low-cost open units and inexpensive sealed units.

The sealed units are about the same size as the former encased models, and the new open units have narrower bobbins and are smaller than previous models for improved packing density. Both models are available with coil ratings of 5, 6, 12, 24, and 48 VDC; and they retain all the electrical performance characteristics of Elec-Trol's former open and encased lines. Terminals are 0.1" grid by 1", center-to-center. Height: .375".

Vari-Pack relays are offered with dry reed contact forms A, B, and C, and mercury-wetted contact form A, in single and multiple pole versions. All form B relays are furnished with magnetic shielding, which is available as an option on form A and C relays. The new sealed versions sell for approximately 30% less than former encased units, and the new open versions are priced about the same as Elec-Trol's previous line of open relays.

For more information, use the reader service card. For samples or off-the-shelf delivery, contact your Elec-Trol distributor.

Elec-Trol, Inc., 26477 N. Golden Valley Road, Saugus, CA 91350. (213) 788-7292, (805) 252-8330. TELEX 18-1151.

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Circle 173 on reader service card

ELEC-TROL RELAYS

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Elec-Trol's new commercial grade, form A Blue Boy Reed Relays are now offered in production quantities for as low as 59¢, and both commercial and instrument-grade units are available from distributor stock. Although completely sealed against hazardous environments, production cleaning solvents, and rough handling, these Blue Boys cost far less than standard sealed units. For more information, contact your local distributor.

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Circle 172 on reader service card

be used as applications terminals for business computers, if diagnostics are not needed, or as an added function of the system consoles.

The D4 goes for $4,500 and the D5 for $6,500. Each is available within 90 days.

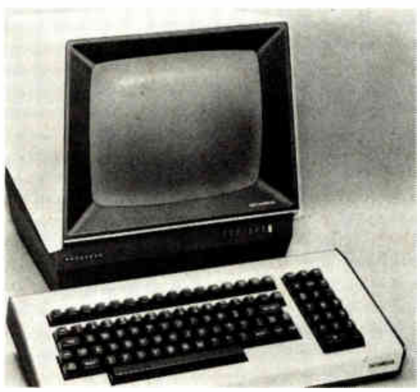
Data General Corp., Route 9, Westboro, Mass. 01581. Phone (617) 366-8911 [363]

8085-based CRT terminal has many features for $1,995

Competition is rapidly heating up in the arena of cathode-ray-tube peripherals. The latest contender is Datamedia Corp., with a compact, microprocessor-based, multifunctional terminal. The DT80/3 operates at 19,200 bauds, either asynchronously or synchronously.

The 80-column screen has a 25th line for error and status messages. Other features include multipage scrolling, composite video output, a 128-character ASCII display set, inverse video, dual intensity, underline, and character delete and insert.

Built around Intel's 8085 microprocessor, the DT80/3 has up to 16 kilobytes of E-PROM, 4 kilowords by 12 bits of RAM, and 2 kilowords by 12 bits of display buffer. The terminal has a 22-channel programmable



input/output interface, programmable keyboard interface, and an auxiliary serial interface for a printer or another peripheral.

The unit has numeric as well as function-control keys. Up to 20 functions are offered, including protected formats, character/line insertion and deletion, and tabbing forward or backward. Communications speeds are set from the keyboard.

Weighing 37 lb, the DT80/3 measures 14 by 14 by 14 in. The unit has a built-in function alarm and a series of self-diagnostic tests.

The terminals will cost $1,995 each, although quantity discounts are available. Shipments are to begin in the fourth quarter, with a 90-day delivery time.

Datamedia Corp., 7300 North Crescent Blvd., Pennsauken, N. J. 08110. Phone (609) 665-2382 [365]

Serial matrix printer weighs 14 lb and sells for $760

The recently introduced Microline 80 is compact and lightweight, and has such features as program-controlled font selection, condensed printing, and microprocessor-controlled interfaces.

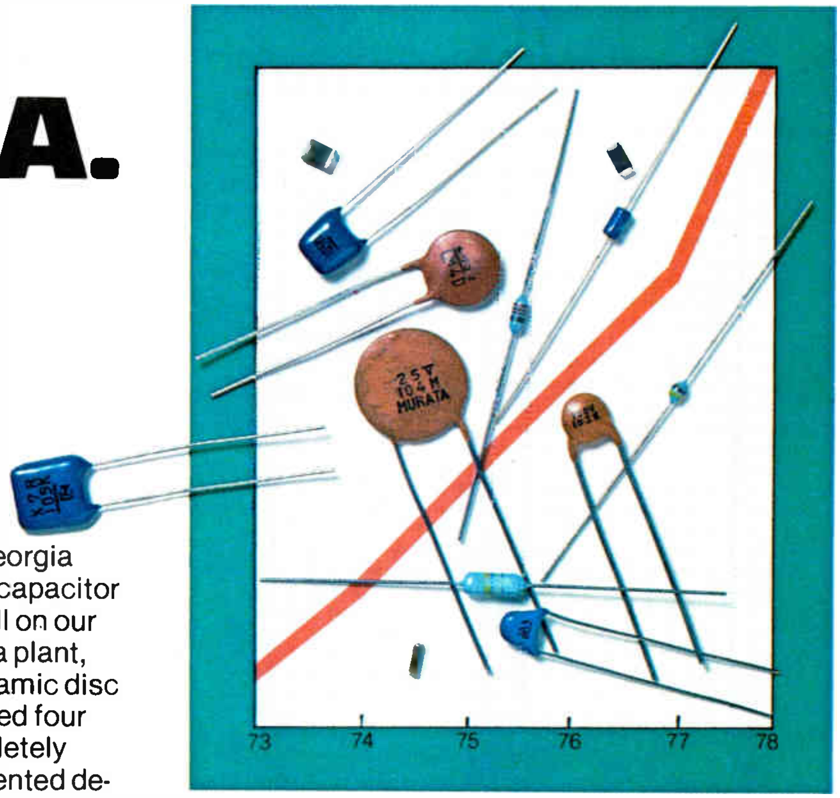
At 14 lb and measuring 4 by 13.4 by 9.4 inches, the printer operates at 80 characters per second across an 80-column page. Condensed characters are printed at a density of 16.5 per in., accommodating 132 columns. The unit will print 28 lines per minute at 80 characters per line, and 17 lines per minute with 132 characters per line. Line spacing at six or eight lines per in., character spacing, and font are all selected by software.

The Microline 80 uses a nine-by-seven-dot-matrix print head and has a full 96-character ASCII set, as well as a basic graphics set. It will make one original and two copies in three feed modes: friction feed to 8.5 in. wide; tractor feed from 4.5 to 9.5 in. wide; and pin feed at 10 in. wide. The printer has a Centronics-compatible parallel interface and an RS-232-C serial interface.

Prices for the Microline 80 begin at $760 for typical OEM quantities and can go below $600 for even larger orders. Initial deliveries should begin in September, with full production by early next year.

Okidata Corp., 111 Gaither Dr., Mount Laurel, N. J. 08054. Phone (609) 235-2600 [367]

It's no coincidence that Murata-Georgia is the fastest growing ceramic capacitor manufacturer in the U.S.A.



In 1973, we made a decision: Murata-Georgia would create an unsurpassed ceramic capacitor capability and we'd do it fast. We're well on our way. Since 1974, our Rockmart, Georgia plant, already one of the most automated ceramic disc facilities in the world, has been expanded four times. We're presently building a completely automated plant to meet the unprecedented demand for monolithic glass, epoxy and chip capacitors in Douglasville, Georgia. Our corporate headquarters in Marietta, Georgia ties it all together with one of the most sophisticated data processing systems in the industry for inventory control and customer service.

Combine Murata-Georgia's rapidly expanding production capability with a line of ceramic discs, monolithics and high voltage units based on over 30 years of ceramic capacitor experience, and it's easy to understand why Murata-Georgia is the fastest growing manufacturer in the field.

Coincidence? Not on your life. We've planned it that way.

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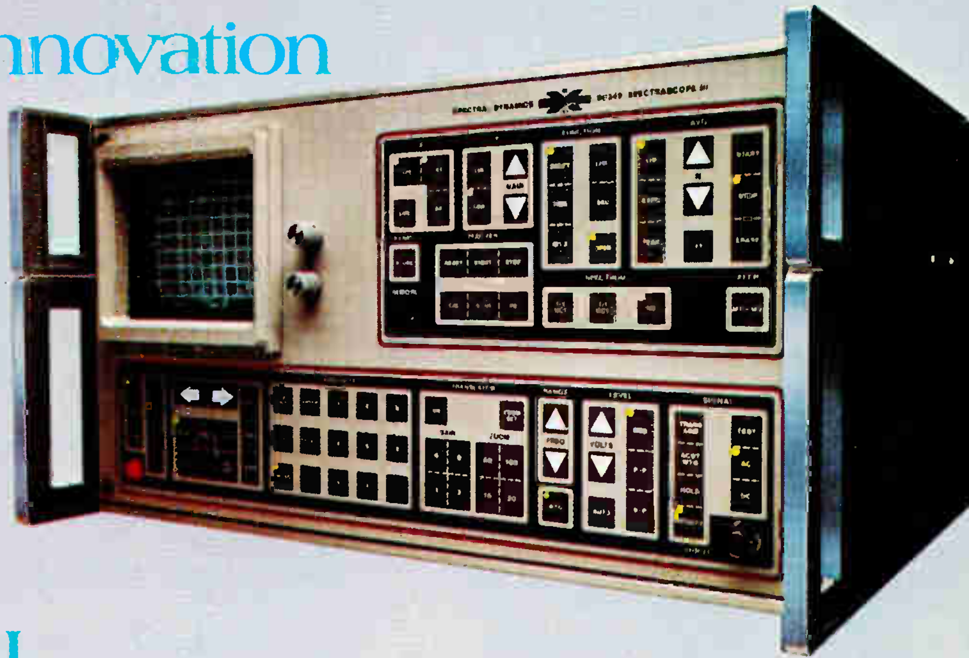
(as Spectral Dynamics did)

with Centralab MONOPANEL...



Spectral Dynamics (a Scientific-Atlanta subsidiary), a leader in spectrum analysis, selected Centralab's Monopanel touch switch system for their new SD345 FFT signal analyzer because they demanded:

- Ultra dependable life for millions of failure free switching cycles.
- Unlimited choice of graphics for maximum flexibility of functional panel design and esthetic appeal.
- High density, custom designed front panel complete with switches and graphics for simplified installation.

Monopanel gives them all of that and cost effectiveness too! We've done the same for scores of other manufacturers. Monopanel is the proven touch switch in test and measurement instruments, medical apparatus, communications equipment, computers and a wide variety of industrial equipment. That's why more and more manufacturers are choosing Monopanel touch switches. They know that they can rely on Centralab's 50 years of experience in switch design, manufacture and application.

Your Centralab representative listed on the opposite page is your best source of design and application assistance. Ask him for a demonstration to see how you can add the touch of innovation to your product.

Products you need from people who care.

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Circle 178 on reader service card

Semiconductors

Power V-FETs reduce noise

Units cover 2 to 200 MHz, put out up to 100 W when run off a standard 28-V supply

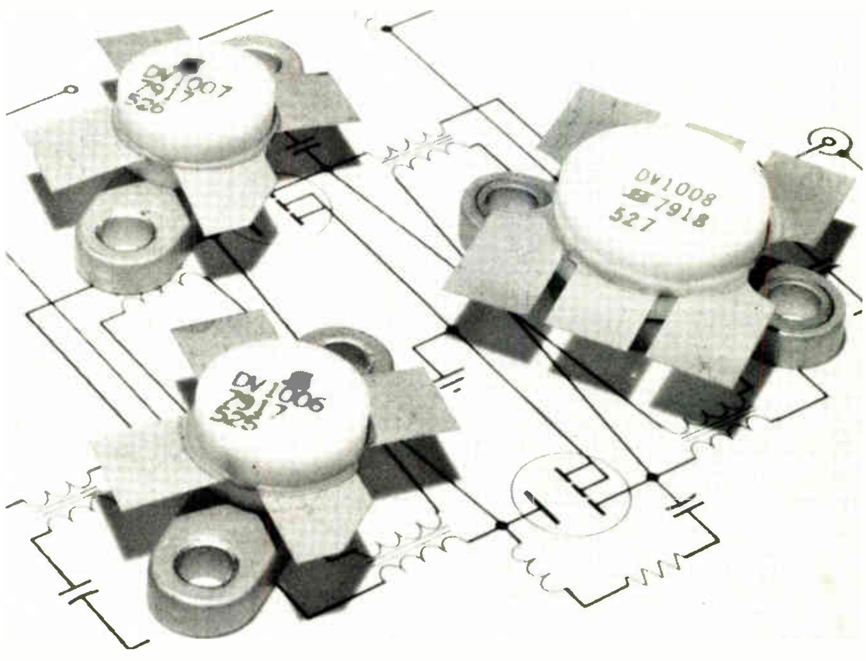
When one radio is transmitting while another sitting right beside it is receiving, noise from the former cannot be allowed to interfere with the reception of the latter. Seeking to minimize this co-location noise, Collins Radio and ITT in their work for the military Sincgars program compared bipolar broadband amplifiers with V-groove MOS power field-effect-transistor amplifiers. They concluded that the V-MOS devices, because of their lower baseband noise, would make it possible for them to improve system performance by 10 to 20 dB.

As it turns out, the V-MOS FETs are much more rugged and easier to bias than their bipolar counterparts. Moreover, being majority-carrier devices, they cannot suffer from thermal runaway—when they heat up, their silicon resistivity increases and they tend to turn off. This characteristic also makes it easy to put units in parallel because they do not exhibit current hogging.

Three V-MOS FETs from Siliconix, the DV1006, DV1007, and DV1008, cover 2 to 200 MHz and run off 28 V with outputs of 25, 50, and 100 W respectively. According to engineering manager Dick Moss, the CTC division of Varian Associates also makes V-MOS FETs, but theirs need to run at 35 V to obtain a 100-W output (28 V is a standard military voltage).

The input impedance of V-MOS FETs is not fixed, as it inconveniently is with their bipolar counterparts. "Input Q is variable depending on the circuit—much as in a vacuum-tube circuit," Moss explains. The tradeoff here is gain: the designer gets the bandwidth he wants simply by sacrificing some gain, which is high to start with anyway.

But V-MOS FETs are most competitive with bipolar amplifiers when they must be used in class A or B operation. Such applications occur in single-sideband radio in the 2-to-20-MHz range and in two-way mobile radio. According to Moss, the V-MOS devices "can run class A and dissipate 50 W with no trouble at all," whereas "it's very difficult to get bipolar devices biased in class B,



let alone class A, operation without serious specification derating." As an example, he notes that a bipolar amplifier rated at 100 W is "probably a reasonably good 10-W class A device."

"All these features will make V-MOS FETs grow like gangbusters," Moss predicts. A push-pull V-MOS package with two chips in it is Siliconix' next step.

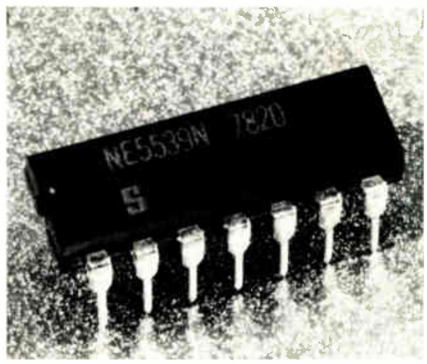
The DV1006, DV1007, and DV1008 are priced at $19.95, $35.91, and $71.82 respectively in lots of 100. Developmental quantities are available from stock.

Siliconix Inc., 2201 Laurelwood Rd., Santa Clara, Calif. 95054, or call Ed Vopat at (408) 988-8000 [411]

Monolithic op amp offers wide bandwidth coverage

Operational amplifiers that cover a wide bandwidth are finding ever more uses in circuits like radio-frequency oscillators and high-gain video amplifiers. The new NE5539 op amp integrated circuit boasts a very high gain-bandwidth product. The product is 2 GHz for a gain of 100 and 1.2 GHz for a gain of 7.

Typical open-loop gain is 48 dB at 5 MHz, and slew rate is typically 800 V/μs with an output current of 40 mA into 150 Ω. At all video frequencies, the output voltage swing is 4 V. The device has a typical full-power response of 64 MHz. The NE5539 is capable of driving a 75-Ω coaxial cable, although not at full power. Operating over the temperature range from 0° to 70°C, the device accepts a maximum power



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Microsystems Division

Circle 181 on reader service card

supply voltage of ±12 V.

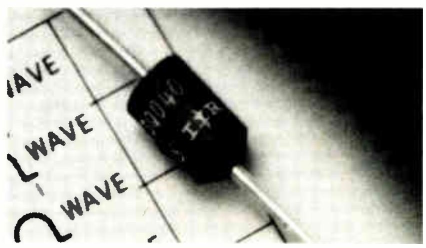
The NE5539 is priced at $10 in quantities of 100 and is available from stock.

Signetics Corp., 811 East Arques Ave., P. O. Box 9052, Sunnyvale, Calif. 94086. Phone (408) 746-1836 [413]

8-A Schottky power rectifiers like it hot

Heat is the major enemy of rectifiers in digital panel meters, switching power supplies, computers, or computer terminals. So International Rectifier has produced some that will operate at high temperatures. The 80SQ series of 8-A Schottky power rectifiers—numbered 80SQ030 through 80SQ045—feature a leakage of only 12 mA at 125°C and have no voltage derating to 175°C junction temperature. With voltage ratings between 30 V and 45 V, these rectifiers have a 20% safety margin on repetitive peak voltage. Because these units are Schottky majority-carrier devices, reverse recovery is almost immediate, restricted only by the characteristics of the axially leaded packages.

The 80SQ030 through 80SQ045



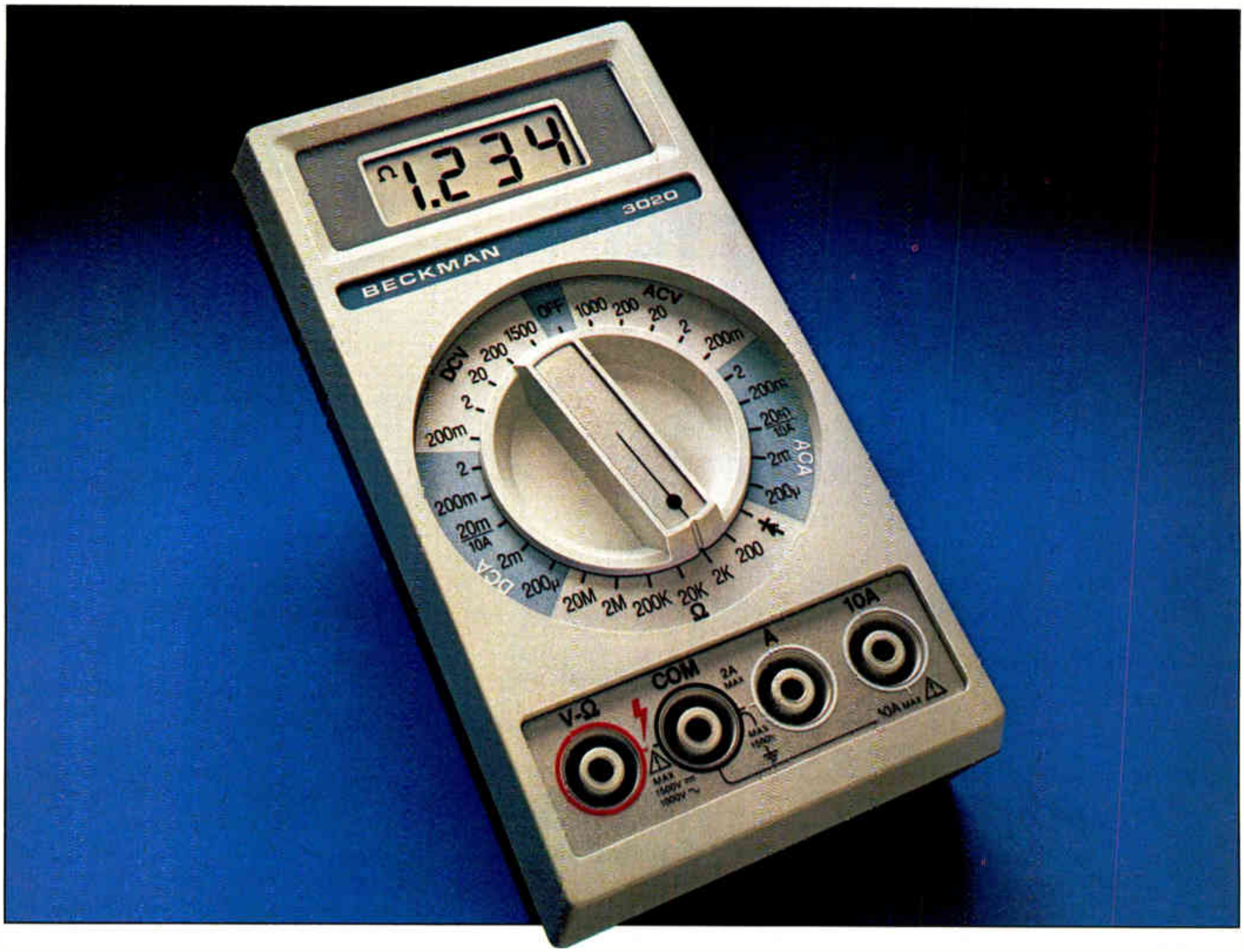
rectifiers are priced at $3.06 to $4.00, in prototype quantities of 1 to 49.

International Rectifier Corp., Semiconductor Division, 233 Kansas St., El Segundo, Calif. 90245. Phone (213) 322-3331 [417]

Diodes generate white noise for ECM and sonar systems

White noise is an essential—and diodes that produce it therefore a frequent—ingredient in electronic

NEW DIGITAL MULTIMETERS THAT WORK THE WAY YOU DO.



Featuring new continuity function.

You do your job as well as it can be done. Now there's a line of digital multimeters from Beckman that does the same. A new generation of 3½-digit multimeters a step above all other digital and analog multimeters. We've combined the best of both to give you useful and easy-to-use features found in no other multimeter.

Features like a unique continuity test function. With Beckman's new Insta-Ohms™ quick continuity indicator, you no longer need an analog VOM for fast, convenient continuity checks.

There's also 10-amp current ranges, in-circuit measurement capability in all six-ohm ranges, a dedicated diode test function, and up to two years normal operation from a common 9V battery.

The Model 3020 with all these features, 7 functions, 29 ranges, and 0.1% Vdc accuracy, is only $170.

These features are also available in the Model 3010 with a 0.25% Vdc accuracy for just $130.

Then the Model RMS 3030 features true RMS ac current and voltage measurement capability, and 0.1% Vdc accuracy, for only $190.

Whichever model you choose, you get long-term accuracy and reliability, assured through the use of band-gap reference elements, thin-film resistor networks, custom-designed CMOS LSI chips and more.

So get the Beckman digital multimeter that does its job as well as you do yours. For information on the complete line and accessories, write or call your local distributor or the Advanced Electro-Products Division, Beckman Instruments, Inc., 2500 Harbor Boulevard, Fullerton, CA 92634, (714) 871-4848, ext. 3651.

BECKMAN

New products

countermeasure systems, sonar systems, radar and sonar simulators, and test equipment for high-fidelity audio, data communications, and other telecommunications gear. KSW Electronics has recently announced an evalution kit that includes several diodes that should prove very practical in white-noise applications.

There are two high-output noise diodes (KN1301); each typically provides 120 μV-Hz$^{-1/2}$ of white noise over a bandwidth of 1 Hz to 150 kHz. A single KN1401 diode with an output of 250 μV-Hz$^{-1/2}$ also comes with the kit, along with a temperature-compensating thermistor and a few resistors.

A single noise evaluation kit is priced at $39.95, with delivery from stock.

KSW Electronics Corp., South Bedford St., Burlington, Mass. 01803 (617) 273-1730 [415]

Single chip meets IEEE Standard 488-1978

Since the re-working of the IEEE 488 standard for bus interfaces last year, few general-purpose interface bus adapters have been available. But the TMS 9914 performs this adapter function with talker, listener, and controller capabilities. All communication between the device and the microprocessor passes through 13 memory-mapped registers at rates up to 250 kilobytes per second.

The 9914 uses a supply voltage of 5 v, dissipates 1 w, and sells for $26.50 in 100-piece quantities.

Texas Instruments Inc., P. O. Box 1443, MS-6404, Houston, Texas, 77001 [416]

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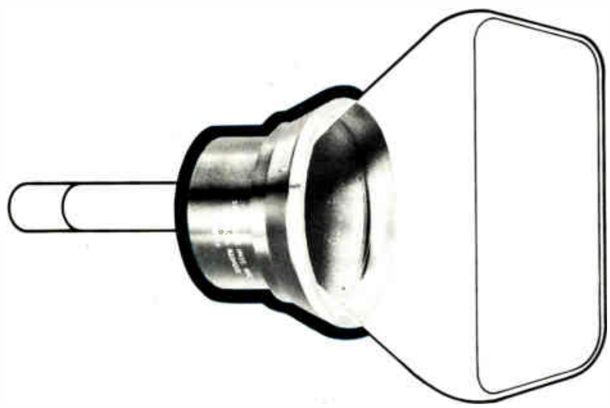
CRT Yokes For Flight



Take a plane-military, commercial, or private. Chances are 9 out of 10 you'll find Syntronic Deflection Yokes and Focus Coils in critical cathode ray tube display equipment; weather radar, navigation, weapons systems, landing, monitoring, communicating. The U.S. Navy's Lockheed S3A anti-submarine plane uses 14 Syntronic components in 7 critical displays. Other aircraft display applications include the B52 Retrofit, F4—(D&E), F5E, A6, A7, F111, A10A, S3A, F14, F15, F16, F18, AWACS, MRCA, Mirage, Viggen, 707, 727, 737, 747, DC-8, DC-9, DC-10, L1011 and many private aircraft. Call or write Syntronic Instruments, Inc. (312) 543-6444. Ask for Syntronic's Yoke Selection Guide to high-flying, high-performance yokes.

syntronic

Syntronic Instruments, Inc., 100 Industrial Road, Addison, IL 60101

Industrial

Two-unit system cuts s/r-d costs

14-bit converter and four-channel multiplexer offer precision and economy

At best, a 14-bit synchro/resolver-to-digital converter is not an inexpensive item. A system—be it a ship's navigation system or a multi-axis machine tool—that requires several of them is certain to be a costly proposition, with many opportunities for creative cost-cutting. Now two new families of multiplexed s-d and r-d converters will make cost-cutting easier in many multiple-input applications that do not require real-time tracking.

Each family consists of two modules that make up a four-channel multiplexed system. The MSDC-700 modules each measure 3.125 by 2.625 by 0.43 in. and feature transformer input isolation. The HMSDC-8700 units are thick-film hybrids with wideband, differential, solid-state inputs, housed in 36-pin dual in-line packages measuring 1.7 by 0.78 by 0.21 in.

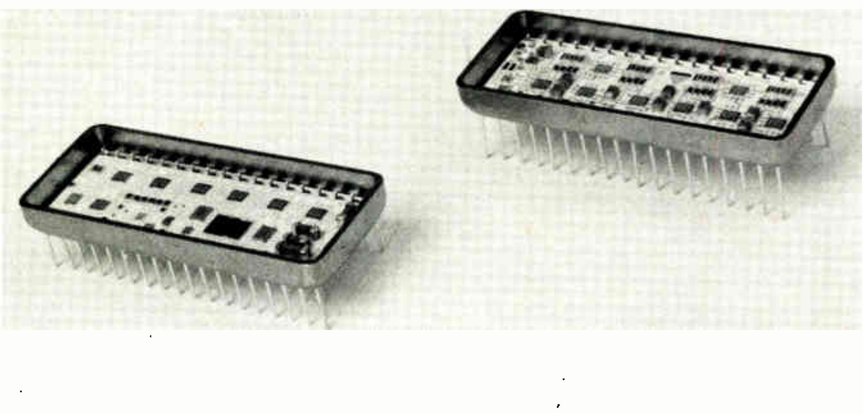
Separate. For both series, one module houses a 14-bit converter and the other contains four signal-input channels, one reference-input channel, four dual sample-and-hold circuits, a sample-time generator, and the multiplexing switches. Input modules for all common synchro and resolver line-to-line voltages and frequencies are available. For systems requiring more input channels, several input modules may be multiplexed together into the same central converter.

In a typical conversion process, the four inputs are sampled simultaneously at each positive peak of the reference waveform. The held sine and cosine voltages are multiplexed to the central converter in any desired order. Since the central converter has a conversion time of 100 μs, 22 channels can be converted at 400 Hz and 150 at 60 Hz. If desired, the system may be set up to inhibit sampling until all channels have been converted, thus ensuring that all angle measurements are made at the same time.

The MSDC-700 and HMSDC-8700 are available in two operating-temperature ranges: 0° to 70°C and −55° to +105°C. In both cases, maximum error over the full temperature range with up to 10% harmonic distortion in the reference and 10% signal-amplitude variation is 4 least significant bits (4.6 arc minutes + ½ LSB).

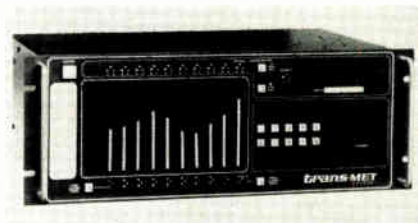
Pricing of the modules starts at $838 for the discrete series and $1,075 for the hybrid.

ILC Data Device Corp., Airport International Plaza, Bohemia, N.Y. 11716. Phone (516) 567-5600 [371]



10-channel bar-graph display improves process monitoring

Process control usually entails monitoring many different parameters, including pressure, temperature, and flow rates. Trans-Met Engineering's latest innovation—a 10-channel bar-graph display—promises to make trend-spotting particularly easy and accurate. The VG-2060 displays up to 10 process variables at once and may also act as a signal conditioner,



transmitter, alarm, annunciator, and/or controller.

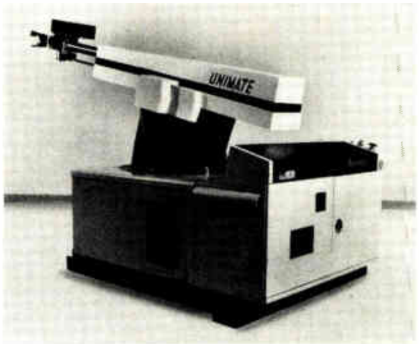
One or several single-process variables may be monitored on the display, and the measurement unit—°F, or °C, kg, etc.—is also shown on an annunciator. The VG-2060 accepts a wide variety of input signals and will generate any standard transmitter output signal; each of the 10 channels operates as an independent unit with its own options, such as inputs, outputs, and single- or dual-mode control. The system accepts not only current and voltage signals but also inputs from many transducers, including thermocouples, RTD (resistance temperature device), and pressure devices.

The price for a standard 10-channel unit starts at about $3,500, with optional features at extra cost. Delivery time is eight to ten weeks.

Trans-Met Engineering Inc., 601 South Palm St., La Habra, Calif. 90631. Phone Dolores Hagen at (213) 691-2266 [374]

$25,000 five-axis robot does heavy-duty work

Robots are becoming increasingly popular in industrial environments,



especially for hazardous and tedious tasks. The latest Unimate robot, the series 1000, takes the trend a step further—to less exotic applications. Designed for material transfer and machine loading, the robot sells for under $25,000, has five axes, and is controlled by a solid-state memory.

The user trains the robot, leading it by the hand through a maximum of 32 steps. All its movements are hydraulically powered, so it can lift substantial loads. Load capacity relates directly to the distance between the robot's wrist and the part's center of gravity. For example, in wrist-bend movements, the load rating is 500 in.-lb for the part and the robot's gripper together. Thus, when the part's center of gravity is 10 in. from the wrist, the maximum load is 50 lb. Wrist-yaw movements have a rating of 150 in.-lb.

Pneumatically controlled, wrist movements include a 90° bend at 30°/s, and a yaw of 90° at 90°/s. Radial travel is 41 in. at speeds to 50 in./s, and arm swing is a 208° arc at up to 110°/s. Vertical travel of the arm is 30° above and 27° below the horizontal plane, at up to 110°/s.

Delivery time is approximately three months.

Unimation Inc., Shelter Rock Lane, Danbury, Conn. 06810. Phone (203) 744-1800 [373]

Digital tachometer errs only ±1 count over 19,999 range

A digital tachometer measuring both revolutions per minute and feet per minute is now on the market. The GT103B measures both rpm and fpm rotational, linear, and surface

Now you can add these Mallory QPL capacitors to your approved vendor list.

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CSR 33	TXR	M
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MIL Style	Mallory Type	Life Failure Rates
CLR 10	XTM-XTK	L, M, P
CLR 14	XTL-XTH	L, M, P
CLR 17	XTV	L, M, P
CLR 65	TLX	L, M, P, R
CLR 69	TXX	L, M, P

All of these capacitors are available through authorized Mallory distributors.

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MALLORY

Circle 189 on reader service card

New products

speeds to ±1 count over a 19,999-count range. Measurements are updated every second, and the memory retains the last measurement taken prior to removal of the instrument from the moving object. All readings are shown on a large, LED display.

A single-range low-inertia drive system in the tachometer minimizes shaft loading, eliminating the possibility of internal damage caused by overspeed on too low a setting.

The GT103B comes with a carrying case, four shaft-tip adapters, and four AA cells that power up to 50,000 readings. Optional features include yard-per-minute and meter-per-minute surface speed disks, and a shaft extension. Price for the unit is approximately $200, and availability is stock to one week.

Graham Company, a unit of Stowell Industries, P. O. Box 160, Menomonee Falls, Wis. 53051. Phone Helen Breuer at (414) 251-1100 [375]

Tiny triaxial accelerometers withstand 40,000 g of shock

The Endevco family of piezoresistive triaxial accelerometers, designed for use with penetrometers at levels of 5,000, 10,000 and 20,000 g, simplifies the measurement of shock and pressure and of projectile motion. The 2263 series can also withstand shocks of 10,000, 20,000, and 40,000 g from any direction.

The small transducers—0.52 by 0.52 by 0.40 inch and weighing about 10 grams—provide steady-state acceleration response and high resonance frequency for use in many shock measurements.

The 2263 series will measure events along three axes. Piezoresistive elements are used in three mutually perpendicular half-bridge transducers, with a common integral cable serving all three axes.

In quantities of 11 pieces or more, the accelerometers sell for $1,950, with 90-day delivery.

Endevco, Rancho Viejo Road, San Juan Capistrano, Calif. 92675. Phone Tony Schneider at (714) 493-8181 [376]

Quality control. The manufacturing of integrated circuits requires an extremely exacting, vigilant quality control program. Perhaps the most stringent in industry.

Now, Nikon instruments are available to meet, and surpass, these tough standards.

The Nikon Micro-Pattern Analyzer, Model 2A is a case in point. It delivers automatic, precise measurement of line widths to an accuracy of tenths of a micrometer.

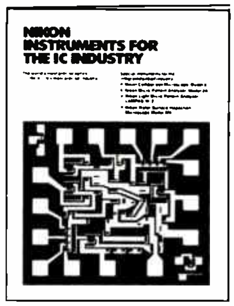
It employs a minicomputer, mirrored scanning slit, digital display and printer to achieve a guaranteed accuracy of $\pm 0.1\mu m$, well beyond the capabilities of conventional visual techniques.

With this computerized optical system, positioning error, magnification error, image distortion and human error are virtually eliminated.

IC masks from 2″ to 6″ square can be scanned at the rate of 0.5—$2\mu m$/sec. The optical system incorporates a choice of green or blue interference filters. X and Y measurements are made conveniently without repositioning the mask since the optical image can be rotated by a single control.

There is no variation from observer to observer, or reading to reading as there is with conventional microscopes. Operator decisions, perceptions and fatigue are no longer a factor, thanks to Nikon.

An informative brochure is available to introduce you to the Micro-Pattern Analyzer, Model 2A and all of the other remarkable Nikon IC instruments.

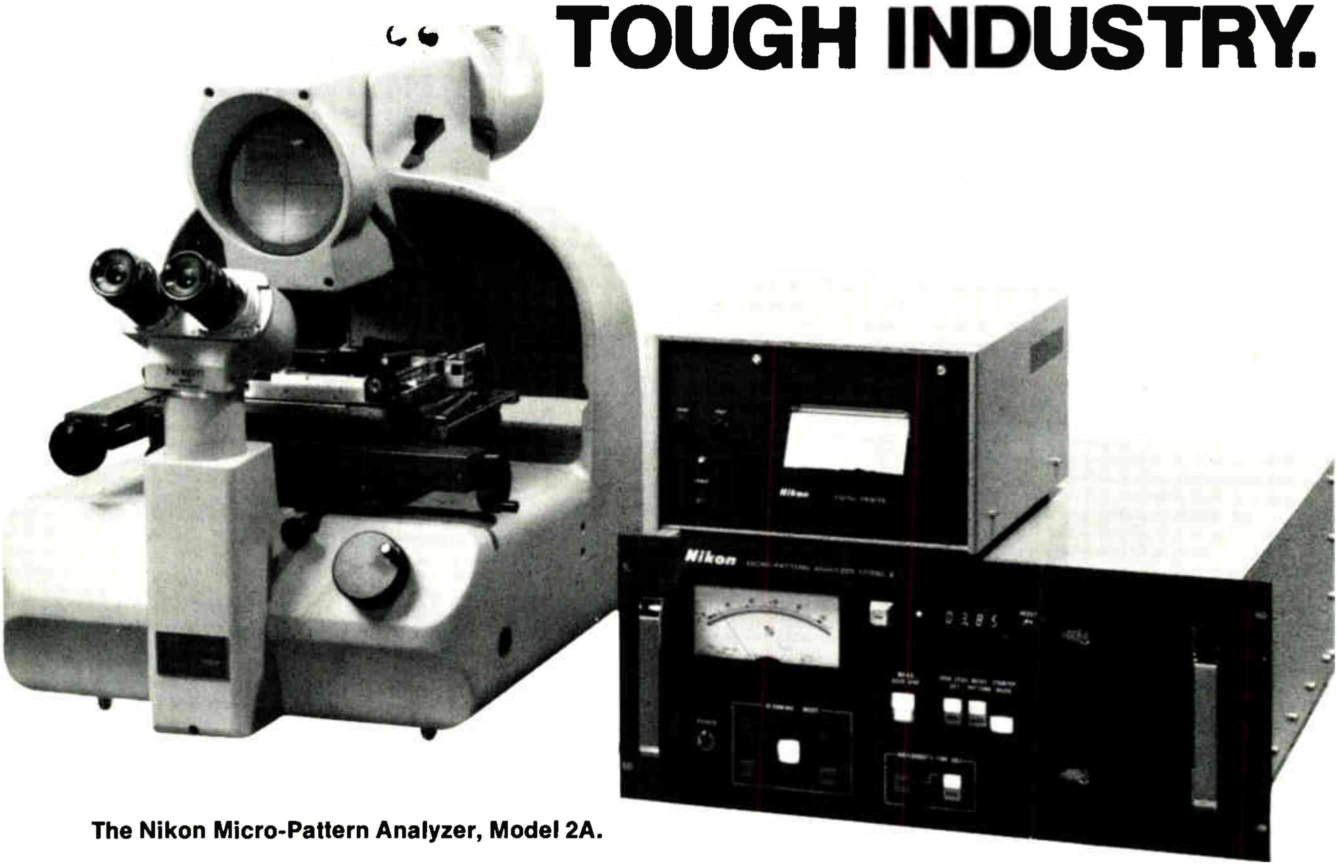


To obtain your copy, please contact:

Nikon

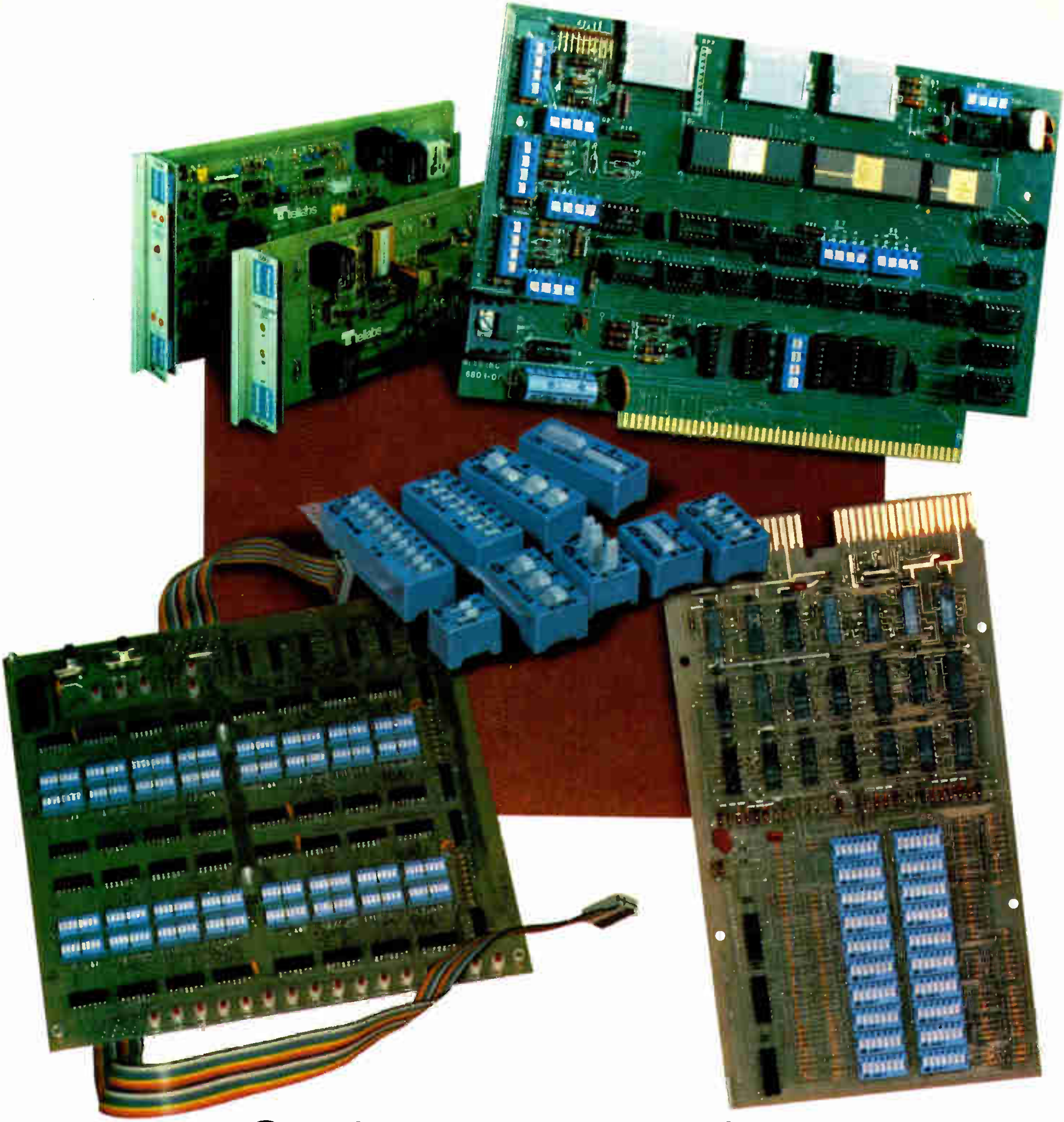
Nikon IC Instrument Division,
623 Stewart Avenue,
Garden City, NY 11530,
(516) 222-0200
or 1051 Sneath Lane,
San Bruno, CA 94066
(415) 952-8188

MEETING THE TOUGHEST STANDARDS IN A VERY TOUGH INDUSTRY.



The Nikon Micro-Pattern Analyzer, Model 2A.

Circle 191 on reader service card



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Get the facts! For prices, fast service and complete catalog, contact your CTS Distributor...or CTS KEENE, INC., 3230 Riverside Avenue, Paso Robles, CA 93446. Phone: (805) 238-0350.

CTS CORPORATION
ELKHART, INDIANA

Circle 192 on reader service card

Products newsletter

V-f and f-V converters extend price, performance

Expanding its line of voltage-to-frequency and frequency-to-voltage converters both upward and downward in price and performance, Teledyne Semiconductor, Mountain View, Calif., has just introduced two new units with the same pinout as the older 9400. **The 9401 features a maximum voltage-to-frequency nonlinearity of 0.01% and a price of $6.95 in 100s, while the 9402 has a V-f nonlinearity of 0.25% and a price of $2.25.** The 9400 has a V-f nonlinearity specification of 0.05% and sells for $3.25 in 100-piece quantities.

Bar-code scanner will speed industrial chores

Digital Equipment Corp., Maynard, Mass., has introduced an electro-optic bar-code scanner for industrial applications that **reads Code-39-format labels and converts their data into an ASCII character stream for computer use.** Priced at $995, the RT700 runs on either 110 or 220 V ac, 50-60 Hz. First deliveries are scheduled for autumn.

50-A rectifiers are rated at 20 V and 30 V

Two 50-A Schottky rectifiers have been added to Unitrode Corp.'s product line. **Designated the 1N6079 and the 1N6098, they are rated at 20 and 30 V, respectively.** Prices, in 1,000-unit lots, are $3.99 for the 6079 and $4.80 for the 6098. Both Jedec devices are offered by the Watertown, Mass., firm in DO-5 packages, with delivery quoted at four to six weeks.

175-W switcher dissipates heat better

In an effort to cool things off, LH Research Inc., Irvine, Calif., is now selling a 175-W switcher with improved heat dissipation. **The TM-34 uses staggered heat-dissipation pins, called Pins-Fins, instead of conventional extruded heat sinks,** to run 19% cooler than previous models. The pins encourage turbulent air flow, providing better heat transfer than the laminar flow promoted by parallel fins in traditional designs. Priced at $345, the TM-34 has a main output of 5 V dc at 20 A, second and third outputs of 5 to 28 V dc at up to 5 A, and a fourth of 5 to 15 V dc at up to 1.5 A.

Software packages enhance abilities of HP 1000 mini

Additions to the software packages available for Hewlett-Packard's HP 1000 minicomputer will enable the user to perform vector processing as well as to install real-time digital data capture systems. **The HP V(ector) I(nstruction) S(et) uses Fortran commands to do vector processing at speeds 4 to 10 times faster than before.** The HP Datacap/1000 is intended for use in manufacturing and distribution environments, to provide a way of designing and executing transaction specifications for gathering and validating data at its source. The Palo Alto company sells the VIS package for $1,500 and the Datacap/1000 for $3,000.

Price cuts

Recently announced price cuts include: **Motorola Semiconductor Products Inc., Phoenix, Ariz.,** has lowered the price of six Switchmode high-voltage power transistors by an average of 15%. . . . Number 810 fiber from **Valtec Corp., West Boylston, Mass.,** is now selling for 10 cents a foot in quantities of 3 kilometers or more. . . . Add-on memory prices from **Digital Equipment Corp., Maynard, Mass.,** have dropped up to 60%.

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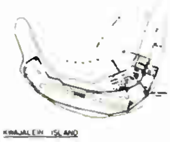

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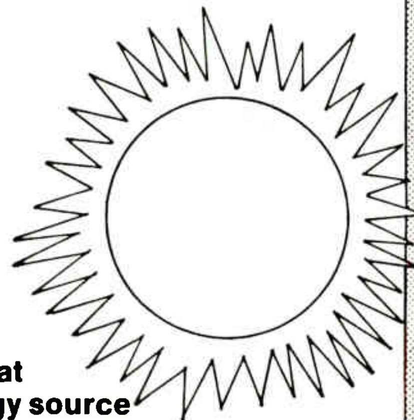

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Estimate number of employees (at this location): 1. ☐ under 20 2. ☐ 20-99 3. ☐ 100-999 4. ☐ over 1000

1 16 31 46	61 76 91 106	121 136 151 166	181 196 211 226	241 256 271 348	363 378 393 408	423 438 453 468	483 498 703 718
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
3 18 33 48	63 78 93 108	123 138 153 168	183 198 213 228	243 258 273 350	365 380 395 410	425 440 455 470	485 500 705 720
4 19 34 49	64 79 94 109	124 139 154 169	184 199 214 229	244 259 274 351	366 381 396 411	426 441 456 471	486 501 706 900
5 20 35 50	65 80 95 110	125 140 155 170	185 200 215 230	245 260 275 352	367 382 397 412	427 442 457 472	487 502 707 901
6 21 36 51	66 81 96 111	126 141 156 171	186 201 216 231	246 261 338 353	368 383 398 413	428 443 458 473	488 503 708 902
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
8 23 38 53	68 83 98 113	128 143 158 173	188 203 218 233	248 263 340 355	370 385 400 415	430 445 460 475	490 505 710 952
9 24 39 54	69 84 99 114	129 144 159 174	189 204 219 234	249 264 341 356	371 386 401 416	431 446 461 476	491 506 711 953
10 25 40 55	70 85 100 115	130 145 160 175	190 205 220 235	250 265 342 357	372 387 402 417	432 447 462 477	492 507 712 954
11 26 41 56	71 86 101 116	131 146 161 176	191 206 221 236	251 266 343 358	373 388 403 418	433 448 463 478	493 508 713 956
12 27 42 57	72 87 102 117	132 147 162 177	192 207 222 237	252 267 344 359	374 389 404 419	434 449 464 479	494 509 714 957
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
15 30 45 60	75 90 105 120	135 150 165 180	195 210 225 240	255 270 347 362	377 392 407 422	437 452 467 482	497 702 717 960

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