DECEMBER 25, 1975

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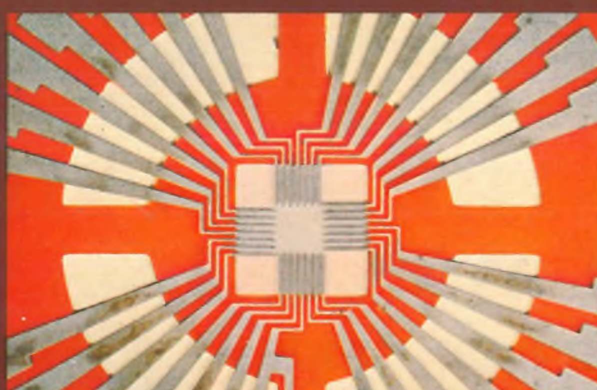

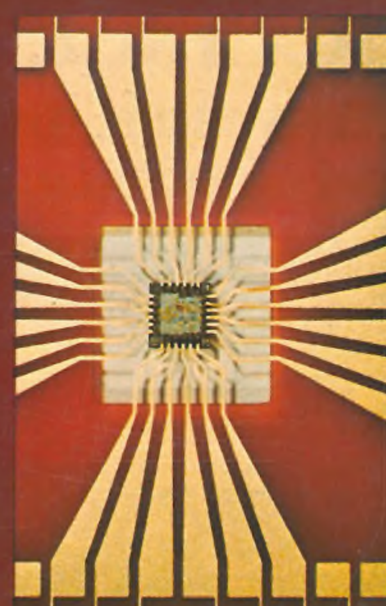

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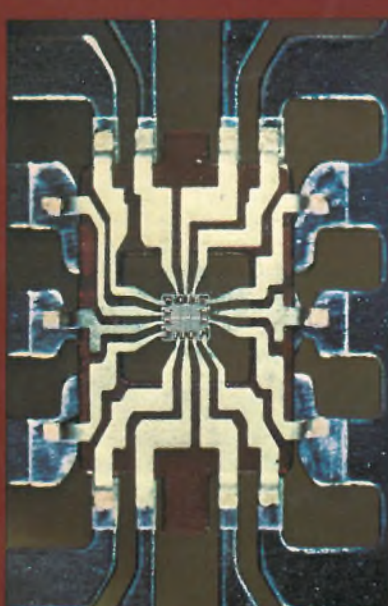

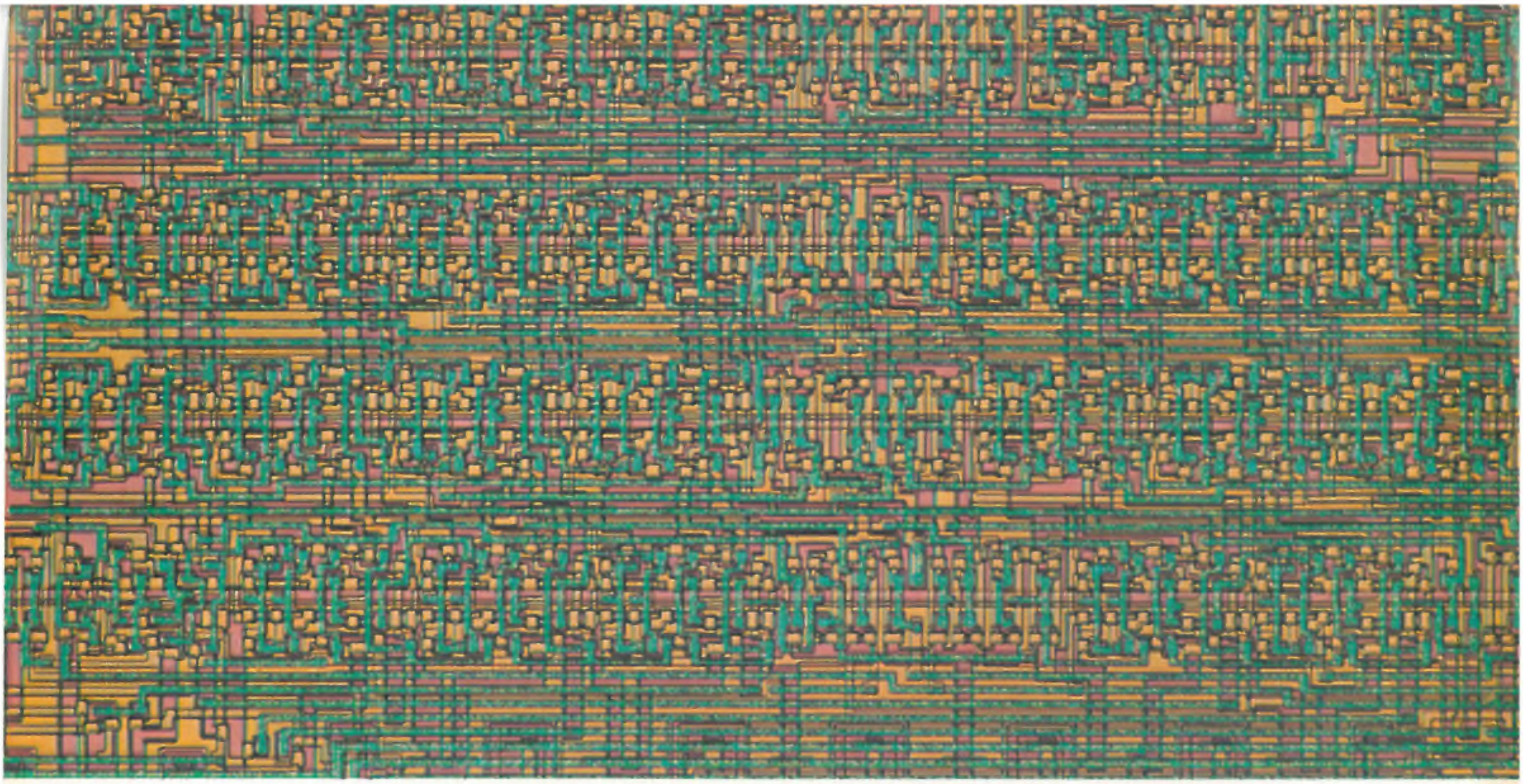

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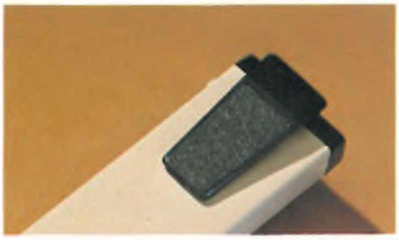

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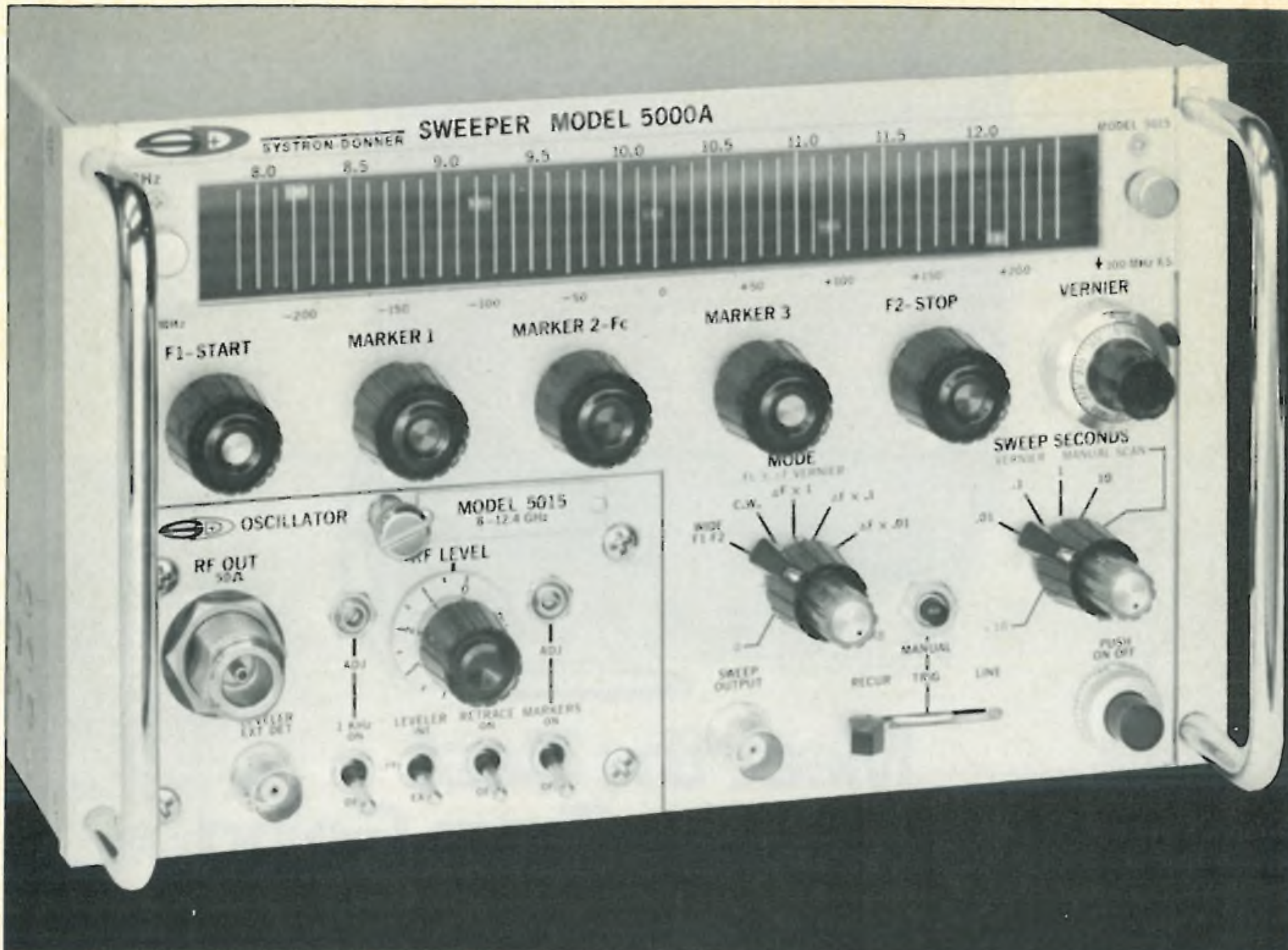

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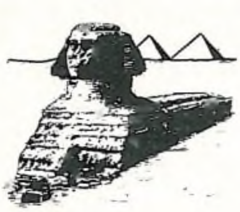

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Electronics
The International Magazine of Electronics Technology
Vol. 48, No. 26 • December 25, 1975

Highlights

The cover: Film carrier stars in IC production, 61
To cut labor costs, both makers and users of integrated circuits are investing heavily in the film-carrier approach to IC packaging. Equipment bonds chips automatically to copper interconnects on film base.

Cover design is by Associate Art Director Charles Ciatto.

Good times are coming for digital watches, 54
Half the watch market will belong to digital types by the early 1980s, predicts John Bergey, president of Time Computer Inc. For continued success, he plans to turn his company into a worldwide organization.

New C-MOS analog switch rivals bipolar type, 69
When dielectric isolation replaces junction isolation in a C-MOS analog switch, the device no longer needs expensive external protection against power surges and overvoltages—and it still uses much less power than a bipolar switch.

Lead/lag modules fine-tune process control, 78
Circuitry that advances or delays the arrival of control signals can ensure that processing equipment will compensate precisely for both sudden and slow changes in a process variable.

And in the next issue . . .
Annual market forecast for the U.S., Europe, and Japan . . . readers' views on the EE's mid-career crisis . . . what the top electronics executives are worried about.

Electronics

Publisher's letter

Film carriers are the vehicle for a major evolutionary step in integrated circuit production. Armed with reels of nonconductive film, which carry copper IC interconnection patterns, more and more semiconductor makers are speeding device assembly and cutting costs at a critical production step.

Jerry Lyman, our packaging and production editor, who wrote the special report on film carriers that starts on page 61, points out that the technique enhances reliability because IC terminal pads are protected against corrosion by built-in metalic barriers, pull strength is at least doubled, and the copper leads, which are some five times fatter than bond wires, dissipate much more heat.

"In addition," says Lyman, "the film-carrier method presents an engineer with a new option. Instead of buying the film-carrier ICs already in DIPs, he can buy them on reels or strips of film to be soldered directly to rigid or flexible pc boards or hybrid substrates. In effect, the new method has produced an IC package—a frame of film—ideal for high-density packaging."

"One aspect of film carriers that never made it into the special report," he notes, "is the great secrecy that shrouds film-carrier work. Since much of the work is proprietary and difficult to protect, many companies simply won't let anyone see what they are doing. In fact, one machinery maker sent a crew to a major IC maker, where they were told to do all the final adjusting to some new equipment in a side hallway. When the machines were moved onto the production floor, the installation men were barred. They still are not sure just how their machines are being used."

The C-MOS process has made quite a name for itself in digital applications. Yet the approach is at home in analog switching, too. On page 69, you'll find an article detailing the design considerations in applying complementary metal-oxide-semiconductor technology to that job.

Until recently, such switches were built with junction-isolation and were difficult to design into analog multiplexers and other devices. They latched-up easily, electrostatic charges could detroy them, and input voltage spikes and power transients could burn them out. Thus external protection circuits were employed. Now, though, with the development of another isolation technique called dielectric isolation, the design of C-MOS analog switches can be far less of a headache.

If any of you readers are looking through this issue for the promised results of our questionnaire on the experiences of over-40 EEs, you can stop looking. It is not here. When we scheduled the summary for this issue, we thought we would have about the same number of responses as we had for other questionnaires. But more than double the expected number of readers responded, making the statistical chore more time-consuming. We had better not promise the report for the next issue, but that is our plan.

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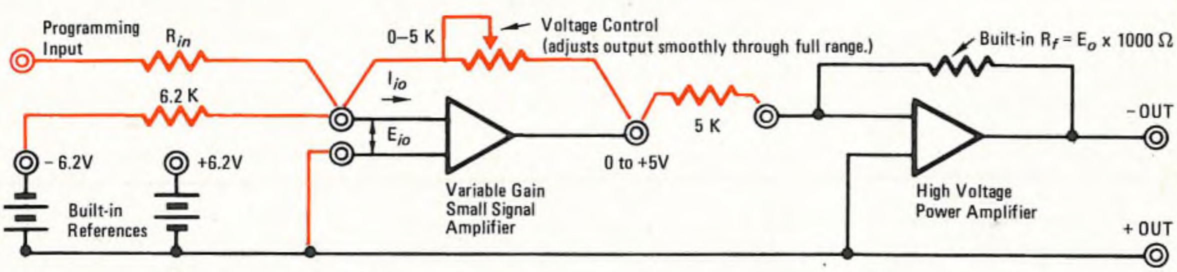

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Readers' comments

Ensuring EE careers

To the Editor: Your comprehensive article on the mid-career crises of EEs past 40 delved into the many problems faced by the older engineer, but completely ignored the major reason for the problem—the patent preassignment agreement. The PPA prevents the employed engineer from owning title to "intellectual property"—his basic line of business. Since this agreement is in force 24 hours a day, the employed engineer can never use his creative engineering ability to build an enterprise of his own that could grow and multiply to provide income and future security.

Nothing can be more demotivating to an engineer than an employer who claims all one's ideas and then shelves most of them. These ideas are lost forever. After this happens a few times, creative employees learn to withhold ideas valuable to employer, employee, and our entire economy. True corporate management is reserved for managers of people and budgets. This policy is bleeding the life blood out of careers in engineering. How can one justify getting advanced degrees or even keeping up with the state of the art when the real advancements are reserved for the management career?

Two solutions seem most obvious:

- The broadly worded PPA should be banned as a restraint of trade because it obviously kills a multitude of new technical products, businesses and jobs, making U. S. workers appear less productive.
- Promote passage of the Moss Bill (H. R. 5605), which would restore the freedom to create, as well as the incentive to do so.

If engineers were allowed to participate in free enterprise as the above solutions would guarantee, the often repeated complaints listed in your article would largely disappear. Under present conditions, the engineer's situation closely compares to an individual trying to exist under the rules of socialism in a capitalistic economy—he'd starve.

Name withheld

News update

■ Legislation requiring stiff security at Government computer installations and limited access to individual files by Government personnel [July 24, 1974, p. 78] has been approved by President Ford and has raised eyebrows since. An inventory of Federal record systems, not yet completed, has turned up more than 1,400 computerized records systems, says Ruth Davis, director of the Federal Institute for Computer Sciences and Technology. She says there are more than 700 computers processing the 1,400 systems, out of a total of 8,200 central processors in the Federal inventory.

Meanwhile, the National Bureau of Standards, parent of the computer sciences institute, recommended in August that sensitive file systems have electronic access controls. But the privacy-security issue is still unsettled. "People are going to a software approach [using coded messages] but it isn't going to work," notes Robert Browne, a privacy expert. "If the Mafia can get hold of an IBM System/370, they can do anything," he adds.

■ While concerning itself with computer security on the one hand, the Congress is anxious to expand its own network on the other. Although its IBM System/370-145 and peripherals, used to keep track of the thousands of pieces of legislation proposed each year, are less than two years old, they are already overworked [May 10, 1972, p. 80]. So a six-month test starting in February will link 30 congressional offices with Federal data banks. New Hazeltine terminals and a 370-158 mainframe, which will push the Congress's annual CPU rental fees over the million-dollar mark, are part of an experiment to see if congressional staffs and elected officials can make use of the bureaucracy's data bases on incomes, tax formula alternatives, and predicted revenue growth patterns. The new hardware will also be part of an experiment to produce hard-copy summaries of congressional debates within 10 minutes.

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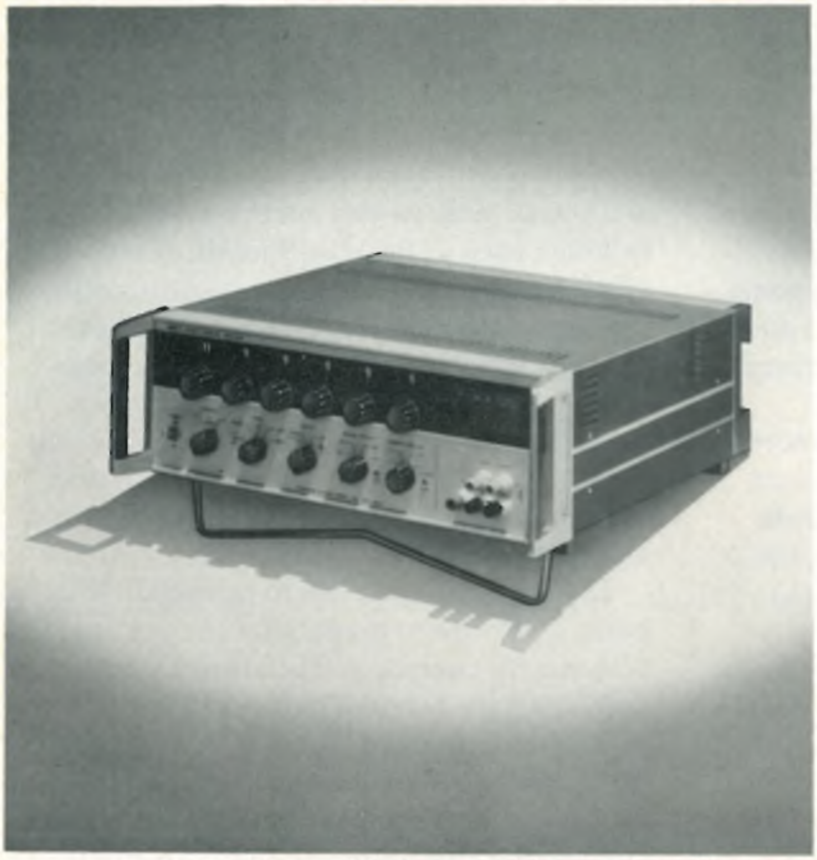

The YEW Type 2552 is a programmable high-precision DC voltage standard which delivers output voltages of 0 to ±1,200V, all at a ±0.005% accuracy. Output is set from the front panel in 4 ranges of 1,000mV, 10V, 100V and 1,000V by six decade dials.

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Editorial

Starting on the road to professionalism

Is it possible that a decline in professional standards is one of the root causes of the engineers' somewhat-less-than-professional status today? That opinion is held, for one, by Eric Lidow, a European-educated engineer who is chairman and president of International Rectifier Corp. What's more, initial returns on our recent questionnaire about the over-40 EE indicate that a wide majority of EEs hold much the same view.

Among the points he makes about the engineers' lot are:

- "Engineers are second-class citizens in this country—they're not treated as professionals, but as skilled workers."
- "We must clarify our academic qualifications. As they are now, degrees in themselves don't mean anything."

His remarks echo what a growing number of EEs have been saying. It is becoming increasingly clear that the profession to which the EE belongs is, at best, drifting and, more likely, in a serious decline.

Many see the main problem to be the continuing lack of a professional infrastructure, the kind that lawyers, for example, maintain. There are, of course, many reasons why the supply of students entering engineering schools, say, should not be arbitrarily controlled.

But the present approach, with no controls at all, may be in its way even more dangerous. In times, such as the post-Sputnik years, when engineering turns glamorous, students enter the engineering career path. Later the lustre, as well as the gold that created it, disappear, leaving today's mid-career crisis and other problems spawned by too many people vying for too few jobs. What's more, the quality of education varies widely from school to school and from decade to decade.

The question, then, has to be asked: What is being done now to prepare for the next sudden demand for engineers? The answer, unfortunately, is "nothing."

What's needed is a thorough-going study of engineering as a profession—and concrete proposals based on the study's conclusion. In engineering education, all standards-oriented aspects of EE training should be reviewed—from entry requirements through course content to examination quality.

Not only should the Institute of Electrical and Electronic Engineers tackle this thorny question on behalf of its membership, but other organizations, such as Wema and the Electronics Industries Association would seem to have a vested interest here, too. But, regardless of which group takes on the project, it must be started because it is a crucial step toward making the profession truly professional.

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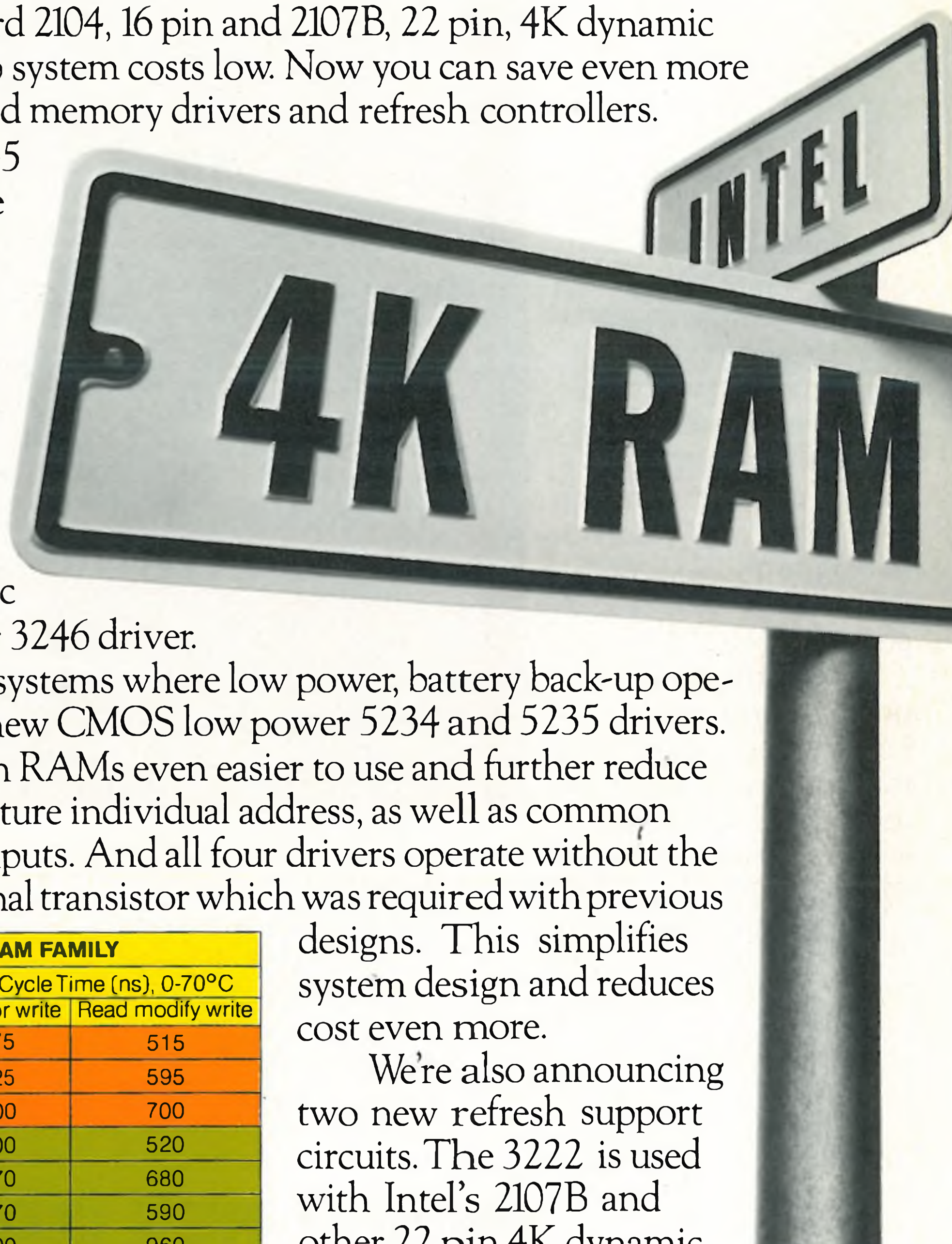

The new bipolar 3245 TTL to MOS driver is the first quad driver that does not require an extra 15 volt supply or an external transistor to generate and maintain the MOS clock level. The 3245 is a plug-in replacement for our 3235 and other MOS clock drivers. For ECL logic systems, choose the bipolar 3246 driver. For CMOS and TTL logic systems where low power, battery back-up operation is required, use our new CMOS low power 5234 and 5235 drivers.

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D2104-4	16	300	425	595
D2104	16	350	500	700
2107B	22	200	400	520
2107B-2	22	220	470	680
2107B-4	22	270	470	590
2107B-6	22	350	800	960

We're also announcing two new refresh support circuits. The 3222 is used with Intel's 2107B and other 22 pin 4K dynamic

to go for 4K RAMs, refresh controllers.

RAMs, while the 3232 is designed for Intel's 2104 and other industry standard 16 pin 4K dynamic RAMs. Both of these new circuits operate from a single +5 volt supply, help you simplify system design, reduce power and reduce the number of discrete packages required.

Intel 16 pin and 22 pin 4K MOS RAMs are helping engineers cut system design costs. Now our new quad drivers and refresh controllers make Intel 4K RAMs even easier to use.

16 PIN QUAD MOS DRIVERS FOR INTEL 2107B 22 PIN 4K RAMs
Note: Intel 16 pin 2104 4K RAMs are TTL compatible

Part Number	Technology	Input Levels	Worse Case Delay & Rise Time 0-75°C	Power Supplies	Power Dissipation Channel
D3245	Schottky Bipolar	TTL	32ns	+5, +12V	75mW
D3246	Schottky Bipolar	ECL	30ns	−5.2, +5, +12V	110mW
D5234	CMOS	CMOS	100ns	+12V	3mW @ 0Hz, 39mW @ 1MHz
D5235	CMOS	TTL	125ns	+12V	
D5235-1	CMOS	TTL	95ns	+12V	

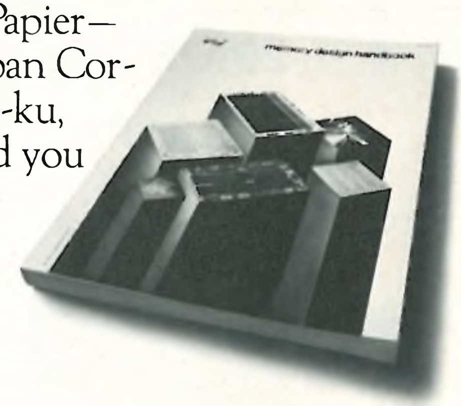
REFRESH CONTROLLERS FOR INTEL 16 & 22 PIN 4K RAMs

Part Number	Pins	Maximum Address Input to Output Delay 0-75°C	Power Supply	Used With
D3222	22	12ns	+5V	2107B
D3232*	24	8ns	+5V	2104

* Available 1st quarter 1976

Save dollars, save space, and eliminate extra power supplies and discrete components. Start saving now. To order, contact any of our franchised distributors.

For data sheets on the new drivers and refresh controllers write our European headquarters: Intel International, 51, Rue Du Moulin A Papier—Boite 1, 1160 Brussels, Belgium (Telex: 24814) or Intel Japan Corporation, Kasahara Building, 1-6-10 Uchikanda, Chiyoda-ku, Tokyo 101, Japan (Telex: 781-28426). For $5.00 we'll send you our new 288 page "Memory Design Handbook." This handbook contains applications notes and useful design information on our line of RAMs, ROMs, PROMs and support circuits.



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People

Air Force's McLucas brings hardware bias to the FAA

Recently sworn in as administrator of the Federal Aviation Administration, John L. McLucas takes a strong stand against recent industry allegations that the FAA has too many advanced systems in development [*Electronics*, Dec. 11, p. 36].

New head. FAA administrator John L. McLucas wants to exploit technology.

"We have to pursue many hardware techniques [through the prototype stage] rather than eliminate them in advance," states the man who for the last five years was Secretary of the Air Force. This could be good news for aviation electronics companies anxious about R&D cuts at the FAA.

Moreover, McLucas, a 55-year-old electrical engineer and former president of Mitre Corp., one of the aerospace industry's major "think tanks," says he is biased toward hardware. "Coming from a technical background, I think 'gadgets' have a lot more to offer than has been exploited," he explains.

But he'll have much less money than he's used to. The FAA's total fiscal 1975 operating budget of $2 billion is one tenth the size of the Air Force's treasury.

Aerosat decision. His first tough decision as the FAA's chief may be to cut or delay one of its more expensive projects. The international aeronautical satellite is expected to cost more than $100 million and therefore is particularly vulnerable in a year in which Congress has cut the agency's over-all $96 million R&D budget by $15 million.

"I don't want the program to collapse," says McLucas, "but I am asking if we can rethink the whole thing, since traffic growth has not built up as expected." He must decide Aerosat's future by the end of January, when international financial commitments are due.

Development of the microwave landing system is safe, though. McLucas points out that the pressures to put a ceiling on the R&D program will require more careful justification for each project, and "we have support for MLS development—it is not a deployment issue yet." However, he is not convinced there is a compelling need for the curved landing patterns or improved interference-resistance features of C-band MLS compared to current lower-frequency, L-band instrument landing systems.

Buying begins to pick up, says Allen-Bradley's Schaefer

"Nobody here is super-bullish," concedes Allen-Bradley's Kenneth C. Schaefer, "but we're all convinced that the pickup in business is real. The last two months have been especially reassuring," he adds.

Schaefer has spent the last several months—since he joined the Milwaukee-based resistor giant as di-

Upswing. October sales jump means good things, predicts Kenneth Schaefer.


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rector of marketing after 20 years at TRW Inc.—grappling with the problem of trying to grow in an economy that doesn't particularly want to.

"We think people are finally starting to let go of the stored-up buying and are starting to buy on slower inventory turns," he says, citing an unexpected October spurt in the firm's sales, followed by a short November that ran close to October. "We saw a jump in October, making it our best in 15 months," he says. "And almost every market segment, except military, is contributing to the business increase we're seeing." The military market, he adds, has remained stable through the recession.

Growth. Allen-Bradley's data on the passive-components industry shows that sales are down this year by 28% to 30%, and that the industry expects to grow 15% to 16% next year, Schaefer continues. "We're not down that far, and our expectations for next year are somewhat higher. That means, we hope, that we'll come out of this depression with a greater market share than we went in with," he says.

Another plus: while the U.S. isn't winning back business that it lost to offshore firms, particularly in fixed resistors, business is not leaving as fast any more. "We still see strong price pressures from both Japan and Europe, but the rate of erosion of our market has slowed," Schaefer says. "I would think that, sooner or later, inflationary pressures will make them even less competitive."

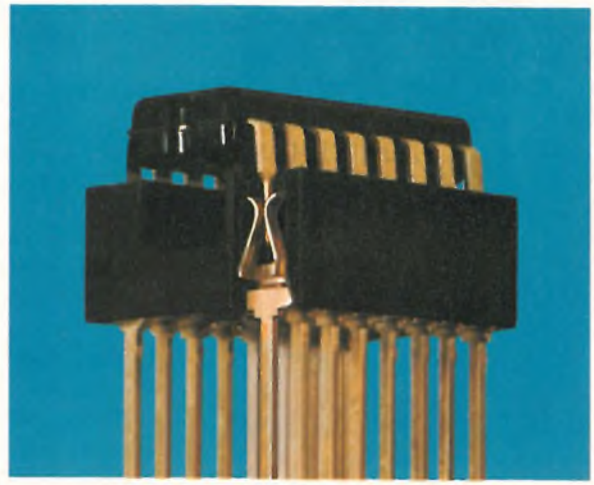
New Products. Allen-Bradley is banking on strong new-product efforts during the recession. "Our greatest growth will continue to come from our cermet-resistor line," he says, and adds that the firm will come out with improved temperature coefficients and closer tolerances for that product next year.

Other growth products include resistor networks and new potentiometers and trimmers. "Both of those product groups are hooked onto the trend to miniaturization. All of our newer products are smaller," Schaefer says.

expose 'junk' socket problems

Secret of RN high reliability 'side-wipe' DIP sockets revealed by microphotos

Here's microscopic proof that high reliability Robinson-Nugent "side-wipe" DIP sockets make 100% greater contact than any edge-bearing socket on the market. This advance design provides constant low contact resistance, long term dependability—trouble-free IC interconnects. Yet RN high reliability DIP sockets cost no more than ordinary sockets!



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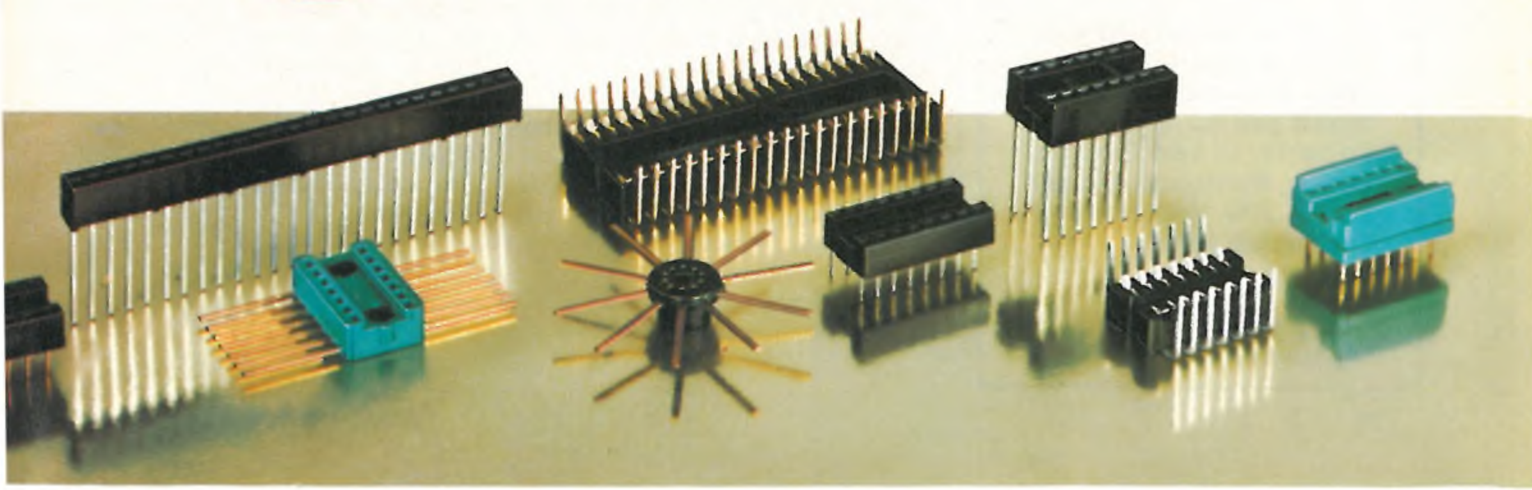

Meetings

Third Annual Symposium on Computer Architecture, IEEE, Hilton Inn, Clearwater, Fla., Jan. 19–21.

On-Line Systems, 1976-1986, American Institute of Industrial Engineers, Quality Inn—Pentagon City, Washington, D.C., Jan. 19–21.

Reliability and Maintainability Symposium, IEEE et al., MGM Grand Hotel, Las Vegas, Jan. 20–22.

Design and Finishing of Printed Wiring and Hybrid Circuits Symposium, American Electroplaters' Society (East Orange, N.J.), Fort Worth Hilton Inn, Fort Worth, Texas, Jan. 21–22.

Data Base Systems, American Institute of Industrial Engineers, Quality Inn—Pentagon City, Washington, D.C., Jan. 21–23.

Power Engineering Society Winter Meeting, IEEE, Statler-Hilton Hotel, New York, Jan. 25–30.

Modulator Symposium, IEEE, Statler Hilton Hotel, New York, Feb. 4–5.

Wincon—Aerospace & Electronic Systems Winter Convention, IEEE, Sheraton-Universal Hotel, North Hollywood, Calif., Feb. 18–20.

ISSCC-76, International Solid State Circuits Conference, IEEE, Sheraton Hotel, Philadelphia, Feb. 18–20.

Compcon Spring, IEEE, Jack Tar Hotel, San Francisco, Feb. 24–26.

Nepcon '76 West and International Microelectronics Exhibition, Industrial & Scientific Conference Management Inc. (Chicago, Ill.), Anaheim Convention Center, Anaheim, Calif., Feb. 24–26.

Federal DP Expo '76 (Data Processing in the Federal Government), Instrumentation Fair Inc. (Beltsville, Md.), Sheraton Park Hotel, Washington, D.C., March 2–3.

ACM Conference on Programing Micro/Minicomputers, Association for Computing Machinery (New York, N.Y.), Delta Towers Hotel, New Orleans, March 4–6.

IECI '76—Industrial Applications of Microprocessors, Process Measurement, and Failure Mode Analysis, IEEE, Sheraton Hotel, Philadelphia, March 8–10.

International Zurich Seminar on Digital Communications, IEEE, Swiss Federal Institute of Technology, Zurich, Switzerland, March 9–11.

Control of Power Systems Conference, IEEE, Ramada Central Convention Inn, Oklahoma City, Okla., March 10–12.

Ninth Annual Simulation Symposium, Society for Computer Simulation, Association for Computing Machinery, and IEEE, Sheraton-Tampa Motor Hotel, Tampa, Fla., March 17–19.

Eleventh Annual Meeting of Association for the Advancement of Medical Instrumentation, AAMI (Arlington, Va.), Regency-Hyatt House, Atlanta, Ga., March 21–25.

SPIE Technical Symposium, Society of Photo-Optical Instrumentation Engineers, Sheraton Inn and International Conference Center, Reston, Va., March 22–25.

Vehicular Technology Conference, IEEE, Statler-Hilton Hotel, Washington, D.C., March 24–26.

Southeastcon, IEEE, Clemson University, Clemson, S.C., April 5–7.

Second Annual Conference and Exposition of American National Metric Council, ANMC (Washington, D.C.), Washington-Hilton Hotel, Washington, April 5–7.

Applications of Electronics in Medicine, IEEE, Southampton, England, April 6–8.

Joint Railroad Technical Conference, IEEE, Blackstone Hotel, Chicago, April 6–8.

Motorola announces the 35 A bridge price GI, IR, EDI and Semtech will admit equals their 25 A bridge price.

You've heard their confessions: one avows a broad, ¾ to 25 amp bridge family with flame retarding material, low AQL and 30-day delivery. Another reports superior thermal package characteristics. A third touts 300 amp surge. Someone else is a "bridge specialist". And so on.

But we don't think anybody will admit coming even close to the MDA3500's high-current, low-cost 35 amp capability.
Like giving 10 extra amps current-handling *at the 25 amp price.* And 100 extra amps surge-protection *at the 25 amp price.* And super-efficient, 70-watt power dissipation *at the 25 amp price.*

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You'll have to admit our point: superior performance at equal cost.

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	Motorola 35 A Bridge Price 25-99	GI 25 A Bridge Price 1-99	IR 25 A Bridge Price 25-99	Semtech 25 A Bridge Price 25-99	EDI 25 A Bridge Price 25-99
200 V	$2.35	$2.60	$4.40	$4.10	$4.25
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Output level accuracy: ±0.7dB at >240MHz
  ±0.5dB at $\leqq$ 240MHz
Modulation:
- AM: 0 to 100%, 30Hz to 20kHz
- FM: 0 to 100kHz in 4 ranges, modulation frequency range is from 10Hz to 110kHz
- AM-FM: Combination of internal and external modulations
- Pulse: $\geqq$ 40dB (ON-OFF ratio), 30Hz to 100kHz
- Internal modulation frequency: 400Hz and 1kHz

Residual AM: $\leqq$ −60dB compared with 30% modulation
Residual FM: $\leqq$ −50dB compared with 10kHz deviation
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  Wide band: by means of the motor-drive of the frequency dial

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Electronics newsletter

Zilog, a new firm, to introduce microcomputer

A new name in microcomputers will surface in 1976: Zilog Inc. of Los Altos, Calif. It was founded less than a year ago, with considerable financial backing from Exxon Corp., by Ralph Ungermann, Federico Faggin, and Masatoshi Shima, all former Intel Corp. employees closely involved with the development of the 4004, 4040, 8008, and 8080 microcomputers. **During the first half of next year, Zilog plans to introduce the Z-80 system** together with software and development systems. The company is withholding details about the Z-80, but will say that it uses a quarter to half the memory of comparable machines, while delivering 25% to 100% more throughput. Zilog plans to make its own chips eventually, but they will be fabricated initially by custom houses.

Ampex working on 'core chip' 3-d memory

Ampex Corp. has built feasibility prototypes of a 3-d memory unit it calls a "core chip." The devices pack 256 cores of 18 mils diameter in an area about 1 centimeter square. The cores are lodged in a ceramic "cavity plate," and this plate also serves as a substrate for deposited wiring that replaces the threaded wires usual in 3-d core memories.

Ampex unveiled the prototypes at a components exhibition staged earlier this month by the U.S. trade center in Paris. Bernard Gillet, commercial director of Ampex-France's computer department, maintains **the core chips will lower core-memory prices**—by how much he won't say—and make design of stacks more flexible. Production versions of the "core chip," he hints, will be 4-kilobit types with 13-mil cores. However, Ampex officials in the U.S. emphasize that the company won't know for months whether the device can be produced in quantity.

ITT lists new MOS and I^2L memory devices

Look for ITT Semiconductor to introduce several totally new products next year. "We'll be in low-power Schottky in 1976," says Gerard L. Seelig, ITT's corporate vice president in charge of the semiconductor operation. "We have an active program now, and we plan product announcements in the first half of the year."

Also coming from ITT are several 4,096-bit memory devices in both MOS and bipolar configurations, plus a number of I^2L products. **Seelig says ITT is working on "probably the most sophisticated" I^2L timepiece in the U.S.** "We're not going to get involved in microprocessors at the present time," states Seelig, adding: "Our big growth in 1976 will be in memory products." Further down the road, ITT Semiconductor plans to introduce a circuit that will allow European TV viewers to switch back and forth between PAL and Secam transmission systems.

AT&T alters 900 MHz test design; industry objects

AT&T wants to change the design of its $23.4 million test of mobile telephone service in the 900-megahertz spectrum to save almost $1 million and "permit a more complete and realistic trial of cellular technology in Chicago," it says. The changes will require an FCC policy clarification expected "by late January," according to an FCC staffer, because of objections filed by Motorola Inc. and the National Association of Radiotelephone Systems. AT&T says it was not locked to its prior design, despite Motorola and NARS criticisms.

Ten zones, each with an 8-mile radius, would be operated in the test scheduled in 1978 with an omnidirectional antenna for each zone, **rather than the 4-mile radii and three directional antennas** previously considered by AT&T [*Electronics,* August 7, p. 81]. Motorola and NARS also object to AT&T plans to use 11.8 MHz of the 40 MHz available, claiming the plan would use, with spacing, more than the 12.5 MHz of bandwidth permitted by the FCC.

Carrier to close New York office

In an austerity move, MCI Communications Corp. will close its headquarters in New York and consolidate its corporate staff in Washington. The specialized carrier will maintain a sales office and terminal facilities in New York. **Further cutbacks are expected, but plans are not definite at this time,** MCI officials say. Although sales of communications services were up significantly during the six-month period ended Sept. 30 over the same period last year, MCI reported a net loss of $13 million for the period.

TI to build I²L circuits for television

Watch for Texas Instruments to begin applying I²L to television circuits early next year. Ready in January will be samples of an I²L remote-control chip that decodes and processes signals from remote ultrasonic transmitters. It will be followed in February by a horizontal/vertical countdown chip that combines linear and I²L technologies.

The horizontal/vertical sync chip, to be designated the SN74547, will replace a TI-built two-chip circuit now used by a few television manufacturers to get better fringe reception at a slight cost premium. It reportedly also will be cost-competitive with the lower-performance discrete approach, which captures the vertical sync signal with a simple vertical oscillator instead of the countdown chain, though at a sacrifice in noise immunity.

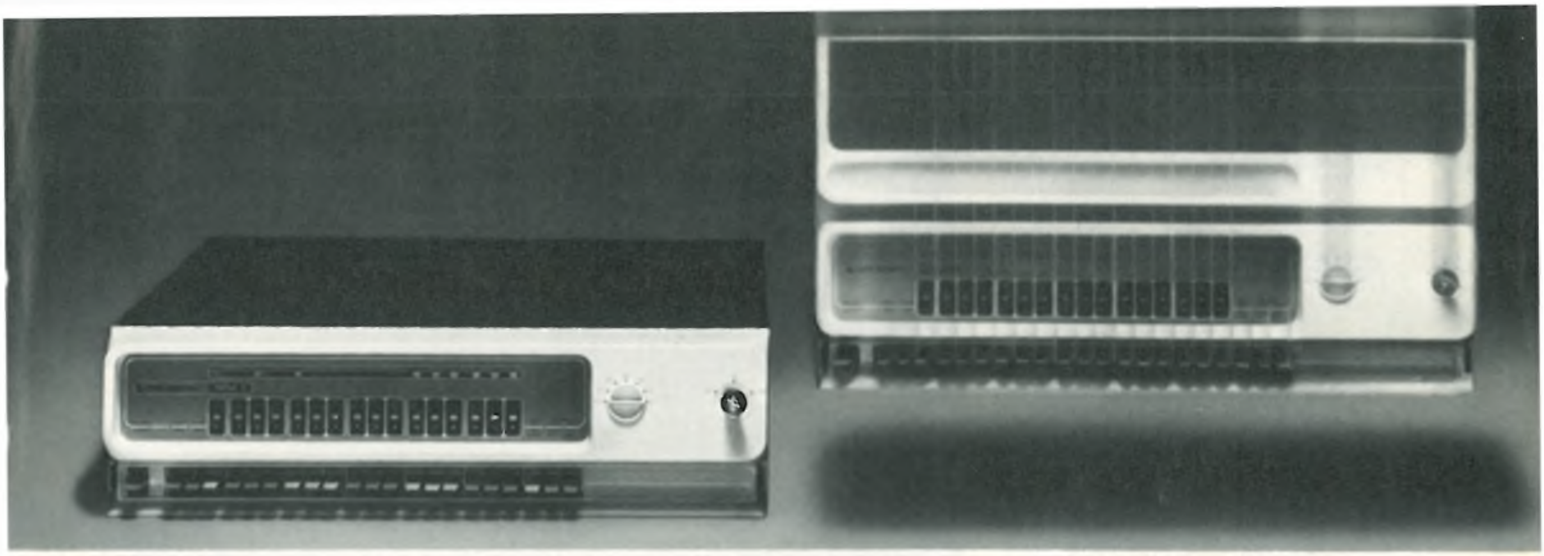
Motorola TV entry weds I²L, ECL

Motorola also plans to wed I²L and ECL in a new phase-locked-loop and control chip it's designing for a standard TV tuner addressing system. **Sample devices will be ready next September** on what will it will call the MC8000; all other components required for the Motorola-proposed system are being shown as samples or are in production now.

Other chips needed for the five-chip black box include and ECL divide-by-four prescaler, a new bandswitch IC, one of a variety of BCD-to-seven-segment decoder/drivers, and an op amp used for the tuning voltage generator. Motorola's Semiconductor Products division estimates that the total cost of such a system—including two varactor diodes, two transistors, and a pin switch for amplifying the local oscillator signal for the prescaler—will run between $12 and $15.

Addenda

Royden C. Sanders Jr., recently deposed president of Sanders Associates, Nashua, N.H., **has bounced back with a new company bearing his name:** Sanders Technology, also based in Nashua. Its first acquisition is the former SYS Computer Corp. of Hackensack, N.J., a manufacturer of intelligent terminals. . . . William Baker, former general manager of Fairchild Semiconductor's Isoplanar bipolar memory division, who moved to Monolithic Memories Inc. a month ago as a vice president, has resigned. Baker will become **group director of microprocessor operations at National Semiconductor.** The move is seen as an attempt to beef up National's microcomputer effort, because not only will Baker direct marketing, but will direct start-up of a line devoted exclusively to MOS microprocessors.



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Yet for all its bigness, there is one small feature in the Nova 3. Price. You can get a 64K word MOS memory Nova 3 with Memory Management Unit, Automatic Program Load and Power Fail Protection for just $16,800.* (Or a smaller Nova 3 for an even smaller price. A 4K MOS system for $2,600.*)

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Specifications of 16-k RAM memories beginning to emerge

by Laurence Altman, Solid State Editor

Compatibility sought with 16-pin 4-k products so that memory boards may be replaced one for one

Even before semiconductor manufacturers have gotten their 4,096-bit products on stream, 16,384-bit RAM samples are already appearing. Once in production, they will obsolete all but the fastest 4-k products and dominate the main-memory market until 1980.

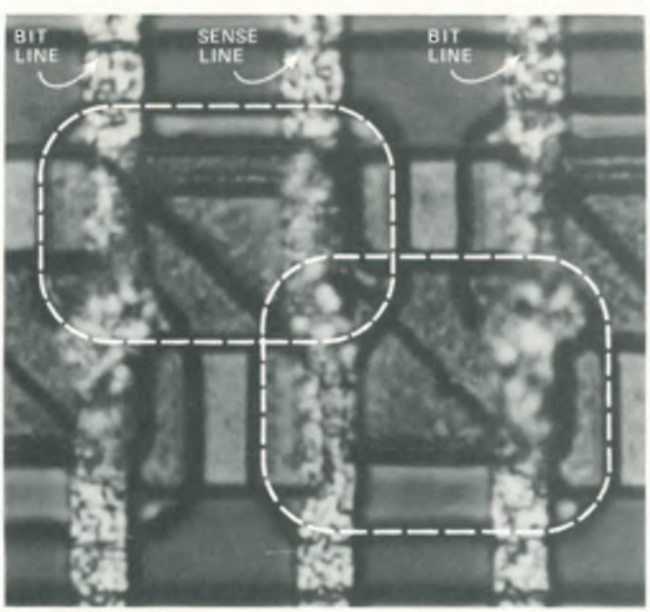
Capable of speeds as fast as 200 nanoseconds, the 16-k RAMs are an impressive testimonial to the muscle of n-channel MOS technology. Although semiconductor manufacturers are closely guarding the details of individual devices, here are the key specifications that users can expect from the first parts:

- Organization: 16,384 words by 1 bit, using a single-transistor cell.
- Package type: 16 pins (though Texas Instruments could be using a 22-pin version at first).
- Access time: 200, 250, 300, and 350 nanoseconds.
- Cycle time: 450 ns.
- Maximum refresh time: 2 milliseconds.
- Maximum operating power dissipation: 500 to 900 milliwatts, depending on the speed and sense-amplifier design.
- Chip size: 32,000 square mils on average, shrinking as designs are iterated.
- Maximum standby power dissipation: 24 mw.
- Power supply: +12 volts, ±5 V.
- Output voltage: minimum, 2.4 V; maximum, 9 to 12 V.
- Compatibility: TTL.

Happily, semiconductor suppliers have learned from their chaotic experience with 4-k RAMs, where a half-dozen package types vie for acceptance. They have gone to great pains to make their 16-k designs functionally compatible with soon-to-be-standard 16-pin 4-k products. That's why almost everyone is using a 16-pin design, with a multiplexing operation much like that of 16-pin 4-ks (the chip-select input is replaced by the multiplexed address bit). The same power supplies that work for boards of 4-k RAMs will work with 16-k boards. In most cases, the same number of refresh cycles (either 64 or 128) is required.

Moreover, the 16-k RAMs are not trading off speed for density. They will stay in the speed range of the 4-k RAM, allowing users to replace 4-k-memory boards with 16-k boards when they are available.

It's new. Making it all happen is a new n-channel RAM process that reduces cell size. It squeezes each bit site into about 1 mil²—half the area needed by 4-k designs—by placing the cell's switching transistor and storage capacitor one over the other instead of side by side as in 4-k designs. It does this by relying on a two-level conductor technique that gives the process its name—the double-poly (or folded-gate) process.



Small size. Two cells from Mostek's 16-k RAM are shown within the dashed lines. Each measures less than 36 by 17 micrometers, or half the size of 4-k cells.

Clearly, two levels of access per cell—one for the transistor and one for the capacitor—mean using some form of electrical isolation between conductor planes. Most designers went to a double layer of polysilicon to get the two levels, but it's also possible to use a metal gate for the switching transistor. This metal-polysilicon connector system is what Mostek Corp. used for its first 4-k RAM three years ago, anticipating the 16-k RAM's requirements.

"Even then we knew we'd need some form of double-level connection to get very dense chips," explains Bob Proebsting, Mostek's RAM designer, "so we developed our metal-poly 'spin' process. For 16-k designs we've switched to double poly because it gives us better performance in dense arrays. Nevertheless, we think the double-connector process we're running on 4-k RAMs gives us a leg up on the industry for 16-k production. Double level is a new process for them."

Not quite. Most manufacturers have been running a double-level process in the laboratory for months. It's the same process type used to build dense charge-coupled device arrays. In fact, it's the familiarity of double-level systems that allowed manufacturers to develop a 16-k RAM process so soon after their 4-k process. "The 16-k process is evolutionary," says Colin Crook, director of LSI systems at Motorola Semiconductor Products in Phoenix. "Once the industry realized that something like double poly was needed for the 16-k design, we began running the process. We've had double-poly in design for months."

The industry agrees that the 16-k RAM will be around—probably as the main-memory product—for at least five years. According to Les Vadasz, Intel's vice president of engineering, the next level of RAM density is probably 65-k, and that will require substantial innovation, both in memory design and technology. "Once the single-transistor-cell was introduced and double levels perfected, it was possible to begin building 16-k RAMs. Something fundamental will be needed for 65-k. But we're working on it." □

Which 16-k supplier is delivering when?

For the semiconductor-memory supplier, the money is down in the high-stakes 16-kilobit RAM game. And how well he plays that next big card will determine his share of the pot over the next five years.

The pressure is enormous. Estimates are that the market in dynamic RAMs will exceed $100 million next year and $500 million by 1980. Clearly the first suppliers out in volume with a 16-k part that has acceptable performance will dominate that market, since the 4-ks just cannot compete in cost.

The crunch has developed because the 16-k programs have moved faster than anyone expected. Intel Corp., Santa Clara, Calif., is already supplying some parts to some users, and Texas Instruments, Dallas, is about to follow [*Electronics*, Dec. 11, p. 26]. Although neither supplier expects volume production to begin for a year at least, the prospects of even minimal 16-k production before then has forced many others to pour money and manpower into accelerated 16-k design schedules, often to the detriment of their 4-k production. The 16-k RAM programs among today's 4-k suppliers are at different stages:

- Intel is now selling samples with a 16-pin package.
- TI will have samples available in three months. Package type is still secret, but the first design may well be a 22-pin part that puts speed above board density and uses no multiplexing. Rumor has it that TI is also working on a 16-pin version.
- Mostek Corp., Carrollton, Texas, is aiming its 16-pin version for the second quarter.
- Motorola Semiconductor Products, Phoenix, and American Microsystems Inc., Santa Clara, Calif., are shooting for third-quarter samples, also with a 16-pin part.
- Fairchild Semiconductor, Sunnyvale, Advanced Memory Systems Inc., Santa Clara, and Rockwell International, Anaheim, Calif., all expect to have some parts by the end of 1976; Fairchild and Rockwell a 16-pin package, and AMS either a 16-pin or 22-pin version.

National Semiconductor Corp., Signetics Corp., and Intersil Inc., Santa Clara, Calif., Advanced Micro Devices Inc., Sunnyvale, Calif., Electronic Arrays, Inc. Mountain View, Calif., Western Digital Corp., Newport Beach, Calif., and RCA Solid State division, Somerville, N.J., are all evaluating the results of their programs before they commit to a time and type.

Memory

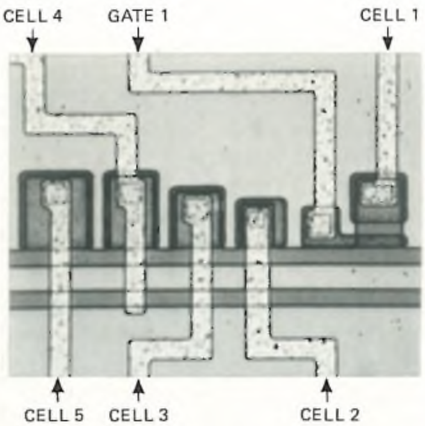
Will 65-k RAMs use charge coupling?

Now that 16-kilobit random-access-memory designs are well along, designers are looking for a circuit approach that takes them to the next level of integration: 65-k bits. Most are convinced that today's switched-capacitor or single-transistor cell won't be good enough—it probably will run out of gas well short of the 0.3-to-0.5-mil^2 cell sizes needed for 65,536-bit chips. So while design choices are still wide open, attention is being focused on charge-coupled-device techniques—especially now that Texas Instruments has disclosed an experimental CCD RAM cell [*Electronics*, Dec. 11, p. 25].

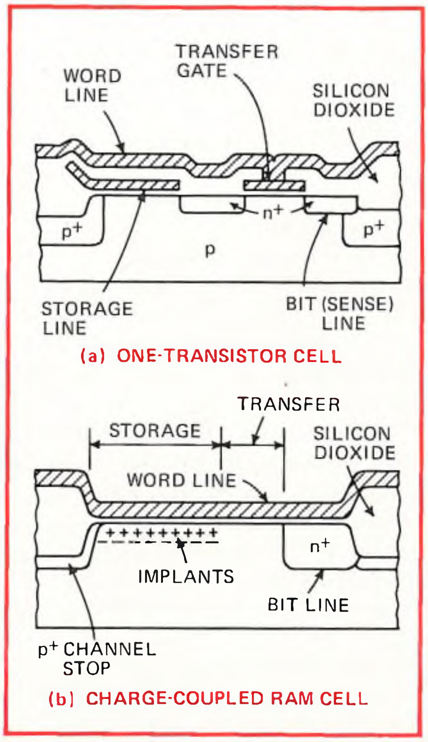
Same process. What makes TI's CCD approach so attractive is that it lends itself easily to the same silicon-gate process that's used for the single-transistor cells of 4-k and 16-k RAMs. There's a difference, though: the transistors themselves are eliminated.

Known among designers as the no-transistor RAM, the devices store data in switchable CCD capacitor regions implanted beneath an MOS gate. That makes an entire memory cell no larger than a single gate, which, even with today's relaxed fabricating rules, can measure less than half a mil square.

Most significantly, even with this very compact cell, no speed need be lost, since CCD operation can be as fast as conventional MOS transistor switching. Moreover, by combining the storage and transfer gates into a single gate region, designers no longer need to lay out two separate gate regions, as they must for the one-transistor cell. (Even the new double-poly cells have two separate gate regions.) This not only drastically simplifies the cell structure, but allows much more of the cell area to be used for charge storage. And as for the memory as a whole, the CCD RAM saves still more chip space by



Test pad. TI's test structure has four CCD cells of varying sizes and a single one-transistor cell, 5, used for comparison. Signals can be sensed from even the smallest CCD cell, which performs quite well in comparison with the 1-mil² single-transistor cell.



Simpler design. Charge-coupled-device random-access-memory cell (b) is simpler than today's single-transistor cell (a) because it switches data in the implanted region under part of the gate. This eliminates need for a transfer gate line.

requiring only two access lines per cell—one to the storage or word line for writing, the other to a sense line for reading. All of today's RAMs need three lines per cell.

How it works. TI's CCD RAM cell achieves its simplicity through a two-level CCD storage region built beneath part of the gate. The cross section (b) of the accompanying figure compares a single-transistor RAM cell (a) with a CCD RAM cell. Here the lower storage level is achieved by a p-type implant into the silicon at a depth of several thousand angstroms, while the upper level is achieved by a shallow n-type implant.

With this arrangement, once data is stored in one of the storage levels, all that's needed to sense a bit is to remove the potential on the gate and allow the charge to transfer between levels. This transfer charge is sensed by an adjoining n^+ region connected to the sense line.

To write a 1 into the storage cell, the bit-line voltage is lowered to or near ground. This allows electrons to flow into a potential well that fills the storage region. On the other hand, to write a 0, the bit-line voltage is set high, and no charge enters the storage region. In either case, the word line is then turned off to complete the write operation and isolate the storage cell from the bit line. This is the store mode.

Next, to read. With the gate voltage off (store mode), the potential well still exists for storing charge. Now, when the word-line gate voltage is turned on, the surface potential in the transfer region becomes more positive than in the storage region, so that charge can flow between the bit line and the storage region. Any charge present in the storage cell is simply dumped onto the bit line and sensed.

TI's Al Tasch, who designed the cell, says it is still too early to tell whether TI will use his RAM cell approach in future 65-k products. But he feels that the concept is attractive "because it results in the densities and speeds needed for the next-generation product and does it with standard processing. Whether it's manufacturable in large chips with high yields is another question."

TI has built test structures like the one shown in the figure, which compares (from left to right) several CCD RAM cells of varying design rules with a 1-mil² single-transistor cell. Tasch is encouraged by tests with this structure, although either sensing voltages will need to be boosted or a more sensitive sense amplifier implemented. The sense lines are very long in an array complex enough to contain some 65,000 sites. □

Consumer

TI designs device for TV power supply

A voltage-regulating transformer is the fashionable way to reduce a television set's energy consumption and to isolate its line voltage. Texas Instruments, however, thinks there's a better way, one that will strip some of the cost and much of the size and weight from the power supply, while providing equal or better performance.

It's the switching-mode power supply, till now too costly an approach because of its complexity, turn-on problems, poor production consistency, and radiation. But the firm's subsidiary in Bedford, England, has developed a new semiconductor that provides the high-frequency switching necessary to cut the size of the power system's transformer and associated output capacitors.

"We think the total system cost will be about $1 to $1.50 under that of a VRT [voltage-regulating-transformer] system," comments Jeff Hendy, import marketing manager at TI's Dallas headquarters. He estimates that TV power supplies now cost about $11, with the VRT alone running between $7 and $10. Moreover, such systems require extensive filtering to get rid of harmonic distortion, he adds. And since VRTs operate at the 60-hertz line frequency, a massive iron-core transformer with copper windings is needed to compensate for core losses.

New Darlington switch. In contrast, the switching-mode power supply that TI has designed runs at

20 kilohertz, and can use a ferrite-core transformer one fifth the size and weight of a VRT's. TI's approach requires a new Darlington transistor at the switch, plus control circuitry to sample the output and regulate the switching period of the transistor to keep output voltage constant. Hendy points out, however, that TI doesn't want to sell power supplies, only semiconductors.

Performance of the supply will depend on the system design. But the version TI is showing exhibits an output voltage variation of about 0.1% between line voltages of 100 to 130 volts; VRTs typically used in TV sets vary by about 5%, says Hendy. "The key to the system is the transistor we've developed," Hendy says. It's a typical integrated Darlington-connected power transistor, but TI has integrated a diode across the base-emitter junction to speed up the long switch off times—from about 10 microseconds in a typical power Darlington to about 300 nanoseconds in the TI device.

The speed-up diode is a recognized technique for Darlingtons used in high-frequency switching applications, Hendy points out. But previous implementations have either been too expensive or have not met their power requirements.

TI puts the diode on a substrate that is also the collector terminal of a high-voltage power device, making the diode essentially a low-gain transistor, Hendy says. "The trick is to get the gain of that transistor very, very low, so you don't reduce the gain of the whole Darlington." The resulting device, designated the BU180A with a collector-base voltage rated at 400 V went into limited production in Bedford earlier this month. It will sell for less than $1 in 100,000 quantities, he says. TI has also integrated a damper diode with the device so it can also be used in horizontal deflection systems. □

Military

DOD budget for laser programs could grow nearly 20% in fiscal year 1977

Despite strong White House efforts to keep a lid on Federal spending in fiscal 1977, military-laser budgets are expected to grow nearly 20% to almost $261 million from the present level of just under $220 million, according to Government and industry sources. More than half of that growth, however, will go for in-house programs at Government laboratories, as military laser users push to develop applications and expand facilities.

Why lasers? The projected gain for lasers was made possible "because the program dollars are relatively small and scattered through a score or more programs that make them even less visible to the budget cutters," explains one military research-and-development budget specialist. On the other hand, he points out, cutbacks are proposed for big, highly visible procurements.

The narrow and often invisible laser beams are the only things that make many of the military systems possible. In addition to such multiple programs for lasers as air-to-ground and ground-to-ground target designators for missiles and ordnance, he cites rapidly increasing outputs of chemical lasers and their potential for all-weather communications, electronic warfare, including countermeasures, and potential applications as high-energy weapons.

Air Force leads. Government and industry estimates that military-laser programs, which amount to $219.5 million this fiscal year, are led by Air Force expenditures of $67.3 million, followed closely by the Army with $64.2 million. Navy funds, these sources say, stand at about $60 million, but are expected to expand rapidly during the next two years as the Navy becomes more active in high-energy laser efforts, while the Defense Advanced Research Projects Agency spends about $28 million. Darpa is coordinating laser standards for all three services, as well as coordinating classified high-energy efforts.

Growth. The Air Force is expected to retain its spending lead in lasers in the coming fiscal year as its budget is expanded to an estimated $84 million, sources report. The rest of the $261 million in DOD programs is expected to provide nearly $78 million for the Army and just under $70 million for the Navy, while Darpa funds hold essentially flat at $30 million.

Perhaps the biggest in-house Air Force program involves the Electro-Optical Research Facility at Cloudcroft, N.M. Cloudcroft's long-range, high-resolution telescope will collect, record, and analyze transmissions from the 405B Laser Communications Space Flight Test System after it is launched in late 1979. The 405B program is designed to test a 1-billion-bit-per-second transmission stream between orbiting satellites and ground stations.

For its new task, Cloudcroft will be modified with new, high-speed optoelectronics for beam steering, optical detectors, and other meteorological hardware.

Emphasis. With emphasis in all services expanding in countermeasures, as well as target designation, the Air Force's Pave series of programs represents one of its key ongoing efforts. The Pave Strike countermeasures system is now being installed on later McDonnell Douglas F-4 fighters, along with Pave Tack for all-weather target acquisition and delivery of laser-guided weapons.

Both the Air Force and Army foresee a major laser market developing in remotely piloted vehicles for line-of-sight command and control, as well as target acquisition and weapons delivery. And the Army is also devoting efforts to laser target designators, rangefinders and trackers, and air defense and ground countermeasures systems.

Major Navy programs, like the Air Force's, are aircraft-oriented. In

Navy develops compact pulsed-power source

Occupying 1% of the space of conventional capacitor-bank units, an energy storage system developed by a Naval Research Laboratory team could provide power pulses up to 10 megajoules.

Anthony Robson and William Lupton are the principal laboratory investigators. In their "inertial-inductive generator," they rely on a rotating Faraday disk, or homopolar generator. The system stores mechanical energy in a pair of high-speed flywheels 4 feet in diameter and then extracts it in electrical form by applying a magnetic field parallel to the axis of the wheels. The radial current so generated charges a storage inductor, they explain. The energy-storage coil doubles as the excitation coil, to make the system yet more compact.

Until now, capacitor banks have provided pulsed power for high-energy systems, such as lasers, and for electron-beam and plasma generators in high-intensity radiation sources. A capacitor bank able to store 10 megajoules would occupy at least 20,000 cubic feet, the laboratory reports, while the Robson-Lupton system requires only 200.

Currently operating at about 1 MJ, the system should eventually transfer a 5-MJ load in 500 microseconds. That's equivalent to a pulsed-power output of 10 gigawatts. Series-parallel combinations of the basic 10-MJ module should permit the construction of power supplies of several hundred megajoules, says the laboratory.

addition to airborne lasers for target designation and tracking, the Navy is considering use of lasers for rangefinding for shipboard gunfire control, perhaps modifying the existing Mark 86 gunfire control system. The Navy is also studying laser countermeasures for close-in ship defense against attacking aircraft, missiles, and ordnance. □

Communications

Air Force going digital in Europe

The Department of Defense is preparing to implement a digital microwave radio communications system, called the Digital European Backbone, at 50 sites in Italy, Germany, Belgium, and England. Upon its completion in 1979, the program, which will upgrade the existing analog equipment used in tactical situations for both voice and computer data, could cost as much as $100 million. Col. D.J. Radtke, head of DEB efforts at the Air Force's Electronics Systems division at Hanscom Air Force Base, Mass., says that requests for proposals are to go out by year-end, and the first installations are to be started next spring.

Two approaches had to be considered for going digital. One would involve purchasing completely new digital transceivers; the other less costly approach would be to add conversion circuitry being developed at the Rome Air Development Center at Griffiss Air Force Base, N.Y., to existing analog units to convert them to digital operation.

Parameters. The digital DEB equipment will operate at a frequency of 8 gigahertz with a bandwidth of 14 megahertz. It will have a bit stream of 28 megabits per second, with an efficiency of 2 bits per second per hertz, Radtke says. This speed will effectively double the present number of channels from 192 to 384. Transmitter power will be either 0.5 or 2.5 watts.

Present military communications in Europe are in the crowded 4-GHz region of the spectrum, and the jump to the relatively uncrowded 8-GHz band will ensure interference-free transmissions. Another plus, points out Radtke, is that a digital system will be easier to encrypt to prevent possible enemy deciphering of messages. The present analog system doesn't lend itself to encryption at all locations.

Bandwidth efficient. Richard Northrup, chief of the digital communications section at Rome, points out that the analog-to-digital conversion system, called the digital appliqûe unit, is the culmination of three years of investigation in bandwidth-efficient modulation techniques for line-of-sight microwave communications. An independent full-duplex unit, it multiplexes pulse-code-modulated analog channels into a digital waveform, which is fed to the transmitter of the analog radio. An engineering model of the DAU, developed by Aeronutronic-Ford, has already undergone in-plant testing, and the Air Force has nearly completed field tests.

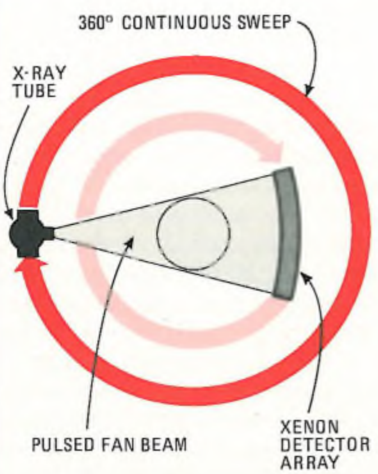
Using a four-level amplitude-shift-keying technique with special filtering, the DAU effectively doubles the number of channels over a given bandwidth. Present analog transmitters send 1 bit of data per second over each hertz in the 14-MHz bandwidth; the DAU puts 2 bits of data per second into each hertz. This modulation technique is also tolerant of nonlinearities from the power amplifier, Northrup says. □

Medical

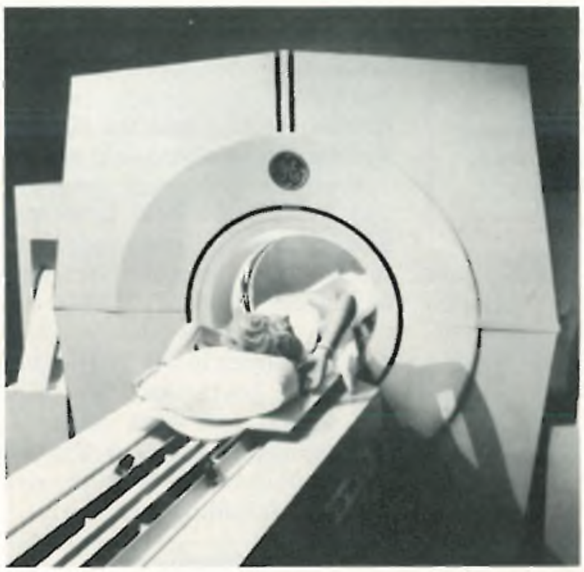
GE introduces X-ray body scanner

General Electric Co., the U.S. leader in X-ray equipment, has finally unveiled its own version of the much-heralded "super" X-ray, the total-body scanner. The firm's Milwaukee-based Medical Systems division has come up with a computerized tomographic scanner that's simpler and four times faster than that of its nearest competitor, EMI Ltd. [*Electronics*, July 10, p. 34].

Realization. "Last year we belatedly began to realize that there was a market [of up to $1 billion worldwide] for this equipment," says Wal-



In the round. Pulsed X-ray source in GE's computerized tomographic scanner makes a single revolution in 4.8 seconds to yield a "snapshot" of a thin slice through the body. Directed by a Data General Eclipse minicomputer which processes data from the xenon detectors, the scanning is priced at $615,000.



ter L. Robb, the division's vice president. But now the firm has all but forgotten the first-generation head scanner it introduced last year in favor of its total-body unit, which will scan either heads or bodies with low-level X-rays in an unprecedented 4.8 seconds. It goes into clinical trials in January at the University of California at San Francisco. GE also shipped a prototype of the industry's first breast scanner to the Mayo Clinic in October.

GE joins more than a half-dozen other domestic firms who unwrapped new computerized tomography systems at the Radiological Society of North America meeting in Chicago earlier this month [*Electronics*, Dec. 11, p. 26].

In essence, computerized tomography uses scanned X rays, detected and reconstructed by a computer, to build cross-sectional "snapshots" of differing tissue densities across thin slices of the body. Pioneered in head-scanning equipment by EMI in Middlesex, England, in the early 1970s, the technique delivers pictures that are more detailed than those recorded on film, and with less radiation. It also is noninvasive, unlike some X-ray techniques that rely on the injection of a contrast material.

The GE unit, being tagged at $615,000, is the most expensive to hit the market yet, but the firm feels that the fast scan time justifies the price. It virtually eliminates a shortcoming of earlier systems: image blurring as a result of involuntary body movements. "The scan time of 4.8 seconds is well within the time that most patients are able to hold their breath," explains Arthur M. Bueche, vice president of GE's Research and Development Center, Schenectady, N.Y.

To obtain such a short scan time, GE uses a 30°-wide, pulsed fan X-ray beam. This beam makes one continuous rotation around the patient, while photons are collected by a curvilinear array of 320 high-pressure xenon detectors mounted opposite the source. The resulting image, reconstructed by the computer and displayed on a cathode-ray tube, contains 320-by-320 picture elements, each measuring 1.5 millimeters on a side.

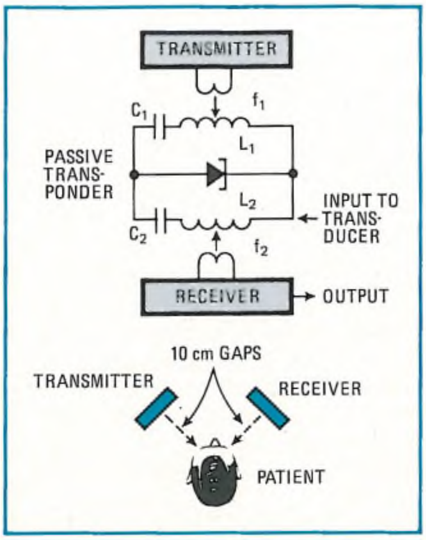
EMI's system, though it achieves the same image size, is slowed down by its reliance on both lateral and rotational scanning motions. Its multiple pencil X-ray beams and 30 detectors scan across the patient each time the source-and-detector assembly is rotated to a resting position. This occurs in 10° increments, and a scan takes 20 seconds.

In charge of the GE system is a Data General Eclipse minicomputer. Early prototype units also incorporate an Intel 8080 microprocessor as a logic controller/sequencer. "The microprocessor controls the mechanical and X-ray systems, it monitors the system from a safety point of view, and it gives us flexibility in design—we can keep as many parameters variable as long as possible," says Lonnie Edelheit, who was project manager on the breast scanner. But GE has hardware in design that will replace the microprocessor when production units are built next summer.

Present prototypes use an Eclipse with 80 kilobits of core memory. "That's clearly too much," Edelheit points out, "but we don't know yet what kind of interface the radiologists want." The scanners use a disk operating system, with magnetic tape for data storage. □

Sensors use radiated power

Because many biotelemetry units require battery-powered sensing elements, they are bulky and prone to failure when implanted in a patient. Turning to passive transponder techniques, a University of Manchester group in England has built a biotelemetry system that needs no implanted batteries and promises monitoring applications in dentistry, neurosurgery, and cardiology.



Powerless. Transponder measures bit pressure without battery implants. Tuned circuit oscillations, a function of pressure, are picked up by remote receiver.

This small and potentially cheap encapsulated transponder could even be used for long-term monitoring of patients. A disadvantage is that the receiver, which "tends to be complicated," would have to be specially built for each application.

The first system, built to enable dentists to register the pressure of a patient's bite, consists of a transmitter about 10 centimeters away from a small passive transponder placed in the patient's jaw. A receiver is also placed about 10 centimeters away on the other side of the jaw.

Basically, the transducer contains a small inductance pressure gauge imbedded in a dental plate, a coil to pick up a signal, a series-tuned circuit, a tunnel diode, another series-tuned circuit, and a secondary coil acting both as pickup from the transducer and antenna to the receiver. The whole unit measures 3 by 20 millimeters.

A small sinusoidal voltage from the transmitter will cause the tuned secondary to oscillate. That ringing frequency, which is in direct relation to whatever is being measured, can be picked up by the receiver.

Transponder. The key to the system is that the tunnel diode in the transponder acts as a harmonic generator, explains Barry E. Jones, lecturer at the electrical engineering laboratories. Essentially, the tunnel diode converts the sinusoidal voltage into "a lot of harmonics" that can be applied to any secondary circuit in parallel to the tunnel diode.

Jones likens the principle to "hitting several bells with the same hammer." The bells would all ring at their natural frequencies. The transponder receives at 200 kilohertz and sends at 10 megahertz.

Filtering. The wideband receiver must filter noise from the system. Jones says that to do this, it averages out the noise by adding cycles from the transponder's tuned circuits before it gives out its first sample or result. This integration process is essentially digital, but the final result is analog, although Jones is reluctant to describe the receiver in detail.

Backed by a three-year Science Research Council grant, Jones' group is developing a unit to measure cranial pressure for victims of concussion or brain tumors. Also on tap is a multichannel system, which Jones says could be built by adding tuned circuits in the transponder. These would operate, say, at 10, 5, and 2 MHz. Jones also is considering a cardiac-monitoring unit. □

Computers

Government buys fewer computers

Marketers of large mainframe computer systems endured a 33% drop in business from the Federal Government in the fiscal year that ended last June, according to a report from the General Services Administration. And the future for Government buys looks still blacker, officials say.

Approximately $156 million worth of central processing units in the Government's $4.2 billion inventory of automatic data-processing gear was bought in fiscal 1975, compared to 1974's $224 million.

What's more, total CPU and peripheral purchases also dropped by a third, to $494 million in fiscal 1975 from $725 million in 1974.

"Government expenditures [on data processing] have reached their peak," confirms Theodore Puckorius, commissioner of the Automated Data and Telecommunications Service, the organization within the General Services Administration that buys about 40% of the Government's computer systems.

More for less. Because of reduced budgets, users have moved away from large units to minicomputers [*Electronics*, Jan. 9, p. 49]. "New technology, coupled with the smaller dollar cost of computer power, are giving agencies more capability with less computer," Puckorius explains. The cutback in funds and surge of mini buys hurts IBM Corp. and Sperry Univac, the Sperry Rand Corp. division, but has been a boon to Digital Equipment Corp.

The Maynard, Mass., minicomputer maker now supplies 19.6% of the computer CPUs in the Federal Government's inventory. In fiscal 1974, DEC had been in second place to Univac with a 17.8% unit market share. IBM, which had 17.4% of the units compared to Univac's 17.9%, dropped to 15.3% in 1975.

Moreover, IBM's dollar share of the inventory grew less than 1% in 1975, to $1.54 billion, while DEC's share grew 33% to $98 million from $74 million in 1974. The dollar share for Univac and other large-system suppliers, such as Control Data Corp., grew about 5% in 1975, the report says.

Down still more. Industry and Government officials predict that IBM's position will continue to deteriorate. "About three quarters of IBM's hardware have been in the inventory for five years or more, so pressure from Congress and White House budget cutters will make the mini even more popular as a replacement for hundreds of IBM 360 computers," notes a knowledgeable procurement officer in Puckorius' organization. Also, the biggest civilian growth market, the Energy Research and Development Administration's numerous computerassisted research projects, is virtually a DEC stronghold. More than 50% of the 1,904 computers in use at the agency are from DEC, whose biggest competitor, IBM, has only about a tenth as many there.

Even in the military marketplace, where more than half the Government's 8,649 computers are located, DEC's share is increasing. The traditional military suppliers, IBM and Univac, still remain on top, though the two lost 30 and 26 computer systems, respectively, in fiscal 1975 to such competitors as DEC. The minicomputer giant gained 64 systems in 1975. Univac's 25% unit share and IBM's 16% share of the 4,245 units in the military inventory will be eroded each year by DEC advances, predict officials of the General Services Administration. However, classified tactical systems are not included in the report and seem to be the primary new markets for large mainframe manufacturers. □

Meet the family

The three members of Burroughs Corp.'s new 800 family have one and one-half to four times the throughput of their predecessors in the company's older 700 family, says Burroughs chairman Ray W. Macdonald. The B 2800, B 3800, and B 4800 are aimed at users of medium-scale to large-scale computers. To protect users' investments in software, the object code of the 800 family is compatible with that of the 700 family.

Peripherals being introduced to go along with the mainframes include: a head-per-track disk file that can store from 5.5 to 472 million bytes with a 5-millisecond average access time; a disk-pack subsystem storing from 65 million to 1.04 billion bytes with 33.3-ms average access time, and another disk-pack subsystem storing from 349 million to 2.8 billion bytes with a 30-ms average access time; and a high-speed printer operating at 1,500 lines per minute with a 48-character set. A powerful new input/output subsystem offers up to 64 channels, each of which has its own Data Link processor, which accepts I/O commands and executes them independently of the central processor.

The B 4800 central processors operate at 8 megahertz and have bipolar main memories of 200,000 to 1 million bytes with cycle times of 250 nanoseconds. Typical purchase prices range from $850,000 to $3,725,000, and monthly lease rates range from $19,500 to $85,500.

The B 3800 central processors operate at 4 MHz and use MOS main memories of 100,000 to 500,000 bytes with cycle times of 500 ns for two bytes of data. Typical purchase prices range from $605,000 to $1,135,000, monthly lease rates from $14,000 to $26,500.

The B 2800 processors operate at 3 MHz and use MOS memories of 100,000 to 500,000 bytes with cycle times of 650 ns. Typical purchase prices go from $485,000 to $750,000, monthly lease rates range from $12,000 to $18,500.

Burroughs prefers own current logic

Emitter-coupled logic wasn't good enough for Burroughs Corp.'s new 800 family of medium- to large-scale computers. To get lower power consumption and slightly higher speed, the company designed its own brand of current-mode logic and uses it throughout the 800 systems [see "Meet the family," above] for everything from small-scale integrated circuits up to large-scale integrated gate arrays.

Half swing. The circuits, dubbed Burroughs current-mode logic (BCML), resemble commercial emitter-coupled logic in using constant current sources. But while the output of ECL circuits is taken from an emitter-follower stage, and output swings are from 0 to -800 millivolts, the Burroughs circuits' output comes from the collector and has half the swing—from 0 to -400 mV.

This reduction in swing makes the circuits "a little faster than Motorola's MECL 10,000 series circuits," says Burroughs. "Raw" gate speed is about 1.2 nanoseconds.

Another advantage, according to Burroughs, is that the new circuits are source-terminated with a resistor built directly on the chip. High-speed logic circuits require terminated transmission lines, and the single-resistor termination at the source is much the easier design option. ECL, which must be terminated at the load, causes real difficulties when single sources fan out to drive multiple loads.

"The beauty of it is that by using internal terminations, we don't have to use any external discrete resistors. You can depend on your own source termination rather than looking for the right place to hang the terminating resistor," says the Burroughs spokesman.

The new chips contain other nice touches, according to Burroughs. Each has built-in voltage-regulator and temperature-compensation circuits that occupy about 5% of the chip area. By allowing the dc voltage supply to vary by as much as 30% in either direction, the voltage regulator eliminates many decoupling capacitors and allows more ripple to be present on the dc supply lines. Yet it hardly adds to the heat dissipated by the chips, which don't need cooling fins found on some custom-designed ECL circuits.

Burroughs has checked the new circuits out in earlier systems, where they were used with the company's own complementary-transistor-logic circuitry. The new circuits are being manufactured at the company's Rancho Bernardo, Calif., semiconductor facility. □

Computers

Air Force gets nearer self repair in space

A self-repairing computer, which will greatly increase a space mission's chance of success, is moving closer to the hardware stage. Under development by Raytheon Co.'s Equipment division, Sudbury, Mass., the fault-tolerant spaceborne computer is in the latter stages of design under a $2 million award from the Air Force's Space and Missiles System Organization (Samso) in Los Angeles.

The goal is a computer that will have a 95% chance of operating five years and more in space. And the only way to achieve this is with a new "sub-element-redundancy" concept, according to Capt. Larry Kern, project officer at Samso's Computer Technology division. Relying on the miniaturization and reliability achievable with semiconductor components, the new computer has built-in backup modules that can be substituted in real time in the event of a failure.

These modules encompass internal elements that are smaller than complete subsystems, Kern points out, but they are not quite at the chip level. Usual redundancy approaches require entire backup computers to be substituted, but even these lack the necessary reliability after the first year in space, according to Kern.

Configuration controller. At the center of the fault-tolerant computer is a configuration-control unit that acts as a traffic director to monitor and switch modules when a failure is sensed. Studies have shown that failures occur most often in the computer memory, so it is in this area where the sub-element redundancy-concept "pays off best," observes Kern.

In addition to 15 plated-wire-

News briefs

General Instrument sues Fairchild . . .

General Instrument Corp. of New York is suing Fairchild Camera & Instrument Corp. on the grounds that Fairchild developed its F-8 microprocessor from confidential information obtained from a former GI employee. The suit seeks a permanent injunction against Fairchild's production and sale of the F-8 microprocessor, as well as compensatory and punitive damages. In its complaint, filed in New York Supreme Court, General Instrument claims that in 1973 Fairchild hired David Chung, who as manager of GI's microprocessor development program had been working on an 8-bit microprocessor system that GI alleges was the source of the F-8. After joining Fairchild, Chung headed its F-8 development program.

Replying to the suit, Wilfred J. Corrigan, president and chief executive officer of Fairchild, says: "We believe the real reason for the complaint is that General Instrument is embarrassed because it agreed to deliver an 8-bit microprocessor to a customer and after more than two and one-half years of effort still cannot make a viable product."

. . . and Litronix sues Fairchild, too

Litronix Inc. is also taking Fairchild to court. The Cupertino, Calif., firm is asking for $20 million in punitive damages and trying to restrain Fairchild from using information in the possession of one of its employees, John Haynes. Haynes was formerly a buyer concerned with Litronix' electronic watch business. Litronix regards Haynes' knowledge of vendors as tantamount to a trade secret, but Fairchild president Wilfred J. Corrigan argues that such knowledge was a normal part of the job. Besides, he says, Fairchild "neither needs nor wants whatever trade secrets Litronix might have, if any."

RCA's Satcom I goes into orbit. . . .

NASA early this month launched the first of RCA Corp.'s domestic communications satellites—the Satcom I—from the Kennedy Space Center at Cape Canaveral, Fla. The three-axis-stabilized satellite with its 24 transponders can handle twice the traffic of any commercial spacecraft now in orbit, according to the company.

Satcom I has been designed to handle voice, video, and data transmissions to Alaska, Hawaii, and the 48 contiguous states. Also, telephone and public-health services will be provided through low-cost earth stations at many small Alaska villages. RCA plans to launch its second Satcom next March, and a third is to be checked out and stored for possible future use.

. . . as Canada orders its own domsat

RCA Corp. has won a $19.1 million contract from Telesat Canada to design and build a new domestic communications satellite to be delivered by February 1978. The Canadian satellite will have 12 channels in the 4- to 6-gigahertz band, compatible with existing Telesat ground facilities. Additional channels will operate in the 12- to 14-GHz band, planned for the Communications Technology Satellite, scheduled for launch early in 1976 under a joint Canadian-U.S. program. RCA's Astro-Electronics division, Princeton, N.J., also developed the Satcom I.

Reed picked as AF secretary

Thomas C. Reed, 41, has been nominated Secretary of the Air Force by President Ford, as was predicted [*Electronics*, Nov. 27, p. 59]. Reed, now Director for Telecommunications and Command and Control Systems for the Defense Department, should be confirmed easily by the Senate.

Bell to test fiber-optic cable

When Bell Laboratories begins tests next March of its fiber-optic telephone transmission system [*Electronics*, Sept. 18, p. 25], the cable will contain more than 100 separate glass fibers. The field trial at Bell's Atlanta, Ga., facility also will probably try out Bell's new splicing techniques and a recently developed connector [*Electronics*, Oct. 30, p. 25].

The cable itself will be 2,000 feet long; individual fiber ends will be joined to simulate many miles of cable. Tests will be conducted at 1.544 megabits per second and at 44.7 Mb/s. At the faster rate, 24 one-way conversations can be carried simultaneously, and gallium-arsenide laser sources will be used with feedback circuits to compensate for temperature effects. At the lower speed, light-emitting diodes and silicon detectors will be used.

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memory modules providing approximately 65,000 words, there are also nine redundant modules. Each memory module has 4,000 32-bit words, with 6 extra bits for error-detection codes and three additional spare bits. Memory data is transmitted in 8-bit bytes. For other functions, including the central processor, power supply, and data bus, only single or double backup modules are needed, says Kern.

The configuration-control unit itself will be triply redundant, with three separate control units on a single LSI chip. They will operate simultaneously in the computer system, performing identical functions with each decision voted upon.

The actual sensing of failures in the sub-elements is handled by a series of switching networks—simple sensing switches attached to each module that determine failure when a designated key signal is absent. Then they shift the circuit connection to a backup module.

Overall, the fault-tolerant computer has general-purpose characteristics that include 200,000 operations per second, enabling it to handle up to 60 spacecraft functions such as guidance, power control, jet maneuvering, and experiments. Ultimate goals of 1-cubic-foot volume and 30-pound weight are judged "fairly achievable" by Kern, as is the 25-watt power requirement.

October milestone. Next milestone in the Samso project is the completion next October of the present "brassboard" phase. Kern calls this phase more than a test breadboard, but short of final hardware. The Air Force will use the brassboard to complete the prototype specifications with which it will solicit competitive bids for final hardware.

In the brassboard, bulk complementary-MOS logic fabricated on cards will simulate computer logic and memory designs. Eventually, Kern intends to incorporate silicon-on-sapphire logic because of its inherent radiation resistance and nonvolatility; he hopes that commercial SOS circuits will be available when final hardware fabrication begins. □

Washington newsletter

Military to hike aerospace sales, AIA forecasts

U.S. aerospace sales, bolstered by increased defense outlays, will climb 2.5% to a record $29.2 billion in 1976 from an estimated $28.4 billion this year, according to a year-end forecast by the Aerospace Industries Association (AIA). Nevertheless, next year's aerospace **exports are expected to slip to $7.6 billion from this year's $7.8 billion record** and industry jobs will continue to decline further to 900,000 at year's end from the 1975 level of 921,000. Most industry members agree that electronics accounts for about one third of aerospace sales.

Inflation continues "to erode the apparent gains" in 1975 aerospace business, AIA reports. "In constant 1968 dollars, total sales will be $10 billion less than seven years ago." Next year's U.S. sales in billions of dollars (compared wtih 1975) by major categories break down to $9.7 for military aircraft ($8.9), $4.9 for civil aircraft ($6.9), $6 for missiles ($5), $3.5 for space ($3.2), and $5 for non-aerospace products ($4.4), including basic research.

FAA to require transponders on all aircraft

The Federal Aviation Administration will require all aircraft to have an altitude-encoding transponder to meet a congressional mandate for a collision-avoidance system, says a senior Government official. **Although people in general aviation and congressmen sympathetic to them will balk at the $120 million requirement**—a minimum $1,500 for encoders and transponders aboard each of 75,000 aircraft, while another 45,000 craft would have to add only $700 encoders—the FAA will say that the avionics is necessary for even the least expensive of several suggested CAS [*Electronics*, Oct. 30, p. 29].

FCC inquiry set on interference by car ignitions

The Federal Communications Commission has launched an inquiry into ways to cut radio-communications interference caused by spark-type ignition systems in motor vehicles. The new Docket 20654 was established in mid-December after FCC receipt of a Stanford Research Institute contract study that concludes that a **10-decibel decrease in ignition-system radiation could be achieved** at low cost in mass-produced automobiles. The FCC is soliciting comments and information by March 19, 1976, to support or refute the SRI findings. Possible alternatives, are the effect of ignition interference on television, as well as microwave, amateur and land-mobile radio services.

ERDA scrambles to revise program as funds are cut

Eleventh-hour changes in the photovoltaic power-cell R&D budget have left Federal officials scrambling to revise their program. "I had anticipated about $29 million for the current fiscal year, but all of a sudden **Congress gave us only $21.6 million, so we've got to review the program.** We've made commitments based on a larger appropriation than we now have," notes a senior program official of the Energy Research and Development Administration.

Congressional advocates of solar energy had authorized a budget-busting $36.3 million photocell program for the current fiscal year, as part of a $172.5 million solar-energy program, but the plan doubled the ERDA budget request and strained Congress's self-imposed budget ceiling.

Washington commentary

Commerce's moves to expand its bureaucracy

An unreleased report from the Commerce Department is generating strong and apparently valid criticism inside and outside of Government. Entitled "Lowering Barriers to Telecommunications Growth" in the United States, it was undertaken earlier this year at the urging of Betsy Ancker-Johnson, assistant secretary for science and technology, and put together by a task force from her Office of Telecommunications. The 95-page draft is currently being circulated to industry for comment.

Fundamental to nearly everyone's objections is the report's definition of telecommunications to include home-entertainment electronics, as well as broadband cable distribution systems, direct broadcast satellites, land-mobile radio, and optical-fiber networks for "non-common-carrier use." Equally distressing to critics is the report's call for increasing the role—and presumably the size—of the Office of Telecommunications to help "recapture" the U.S. consumer-electronics market from imports while operating other specific programs to accelerate development of U.S. markets for other telecommunications technologies. Privately, industry executives who have seen the study call it "dilettantish," "incompetent," and "a blatant power grab by OT in order to justify its existence."

Industry's objections

For the record, the Electronic Industries Association urged in a letter to assistant secretary Ancker-Johnson that "the report either in whole or in part not be implemented" until its Communications division can review it during EIA's annual meeting in March. The EIA division says its members allege that the study includes misstatements as to the communications industry and some inaccuracies and that they even complain about some of the premises on which the report is based. Other letters of criticism, from individual companies dealing with specific segments of telecommunications of interest to them, are reportedly equally as strong as EIA's.

To support its criticism of the new and expanded Office of Telecommunications program, EIA invoked the White House and President Ford's program to reduce Federal regulation and intervention in the free market. "This type of Government involvement," EIA wrote, "runs directly counter to the Administration's goal of less Government involvement and less regulation of business." Beyond contradicting White House policy, EIA members "contend that technology cannot be pushed into the marketplace; rather, the marketplace is the pertinent factor in determining the use of technology."

Government complaints

Within Government, the Ancker-Johnson task force has produced criticism within the Commerce Department itself, the White House Office of Telecommunications Policy, and the Federal Communications Commission. Initially, Ancker-Johnson proposed a single study treating international telecommunications trade issues as well as domestic applications. That was quickly squelched by Travis Reed, assistant secretary for domestic and international business, who noted that trade issues were his turf.

At the FCC there is more disdain than enthusiasm for the office's move "to ensure that regulatory decision-making processes take account of long-term technical economic impacts by providing comprehensive analyses and action recommendations on critical regulatory decisions." To staffers at the FCC and OTP, Commerce is treading on their turf as well by trying to carve out a new and larger role for its telecommunications office. On the industry side, one communications industry practitioner before the FCC summed up reactions by moaning, "My God, I thought the process was complicated and slow enough already."

Beyond treading on lots of toes, many of the Commerce study's recommendations reflect a shallow piece of work. By way of "recapturing" the long-lost consumer electronics market, for example, the office wants "to identify innovations with low potential for foreign transfer and, in collaboration with other Government agencies, speed their development and transfer to private-sector users." At the same time, it would "identify nonmarket forces which are responsible for the rapid exportation of U.S. technology, and take appropriate steps to eliminate or minimize the effects of these . . . forces."

Those unconvinced that such statements reflect no more than the high level of development of bureaucratic gobbledygook should read the report's 12-point program for helping recover that market. The first point is a recommendation to "expand the investigation already begun," and the last advises "writing final report of the program, including recommendations concerning the disposition of outstanding problems."

—Ray Connolly

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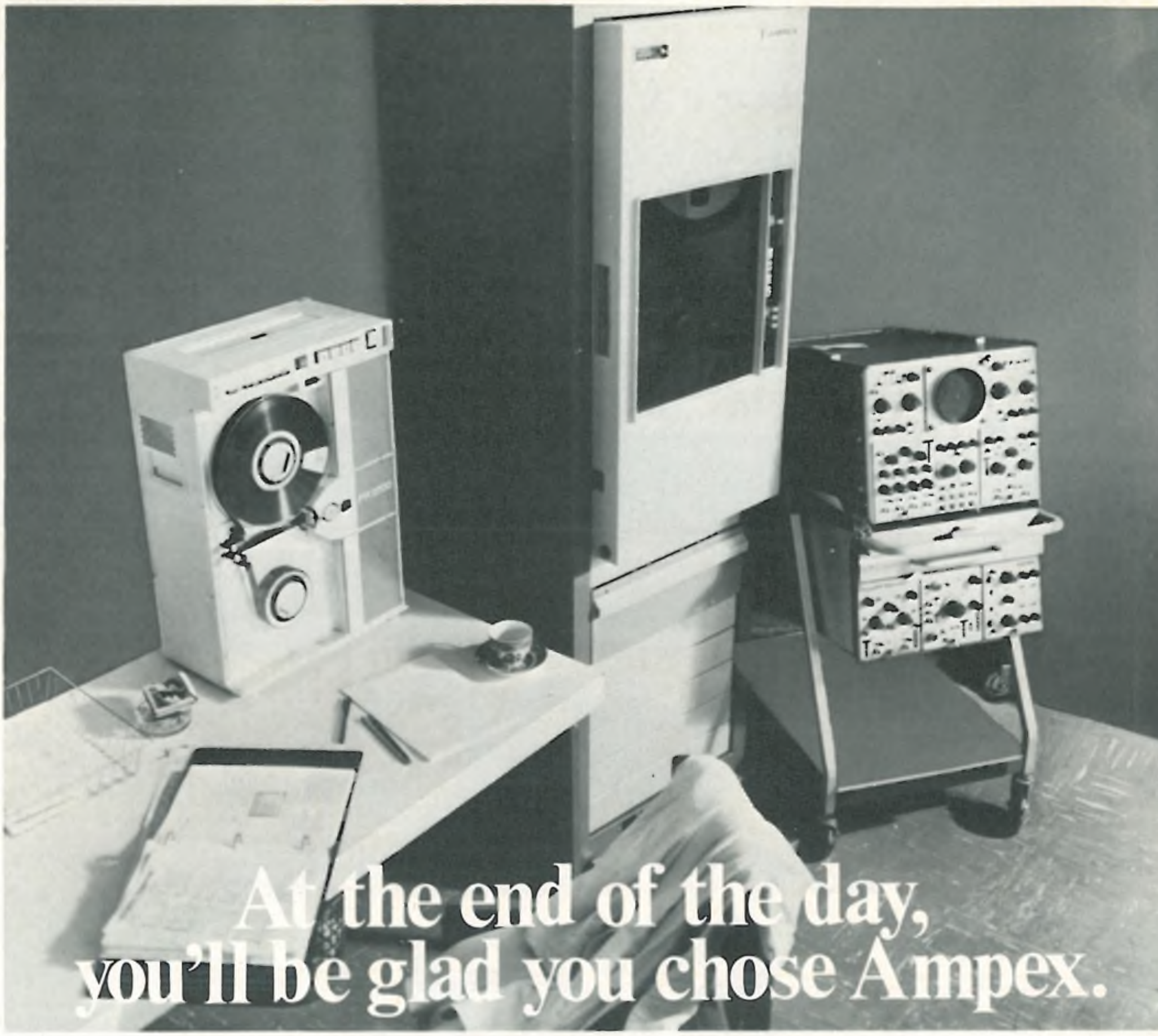

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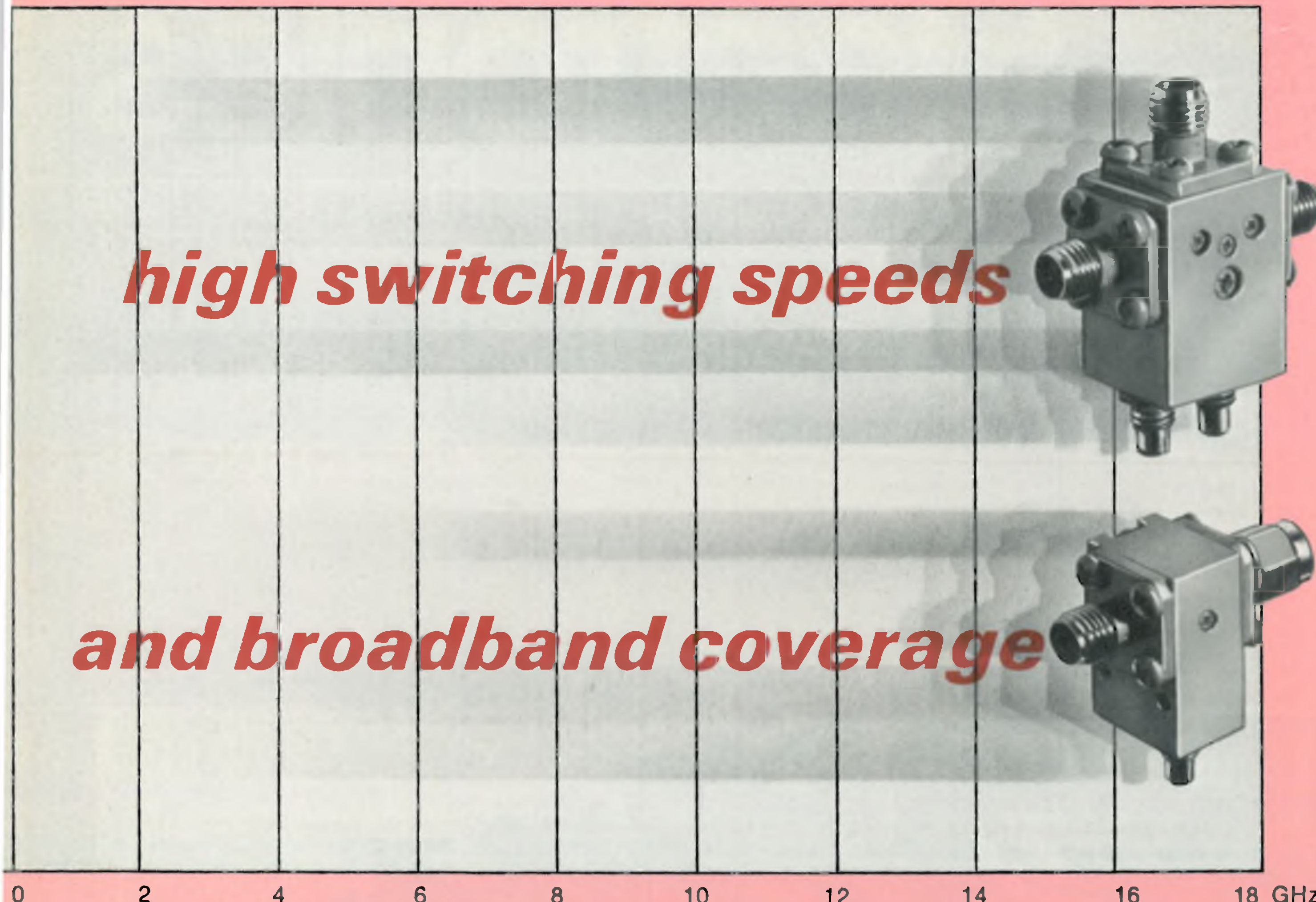
French market report

A better year ahead after poor 1975: page 5E

Communications equipment, such as this Thomson-CSF air-traffic-control center in Copenhagen, is biggest growth area for French electronics

Pin Diode Switches



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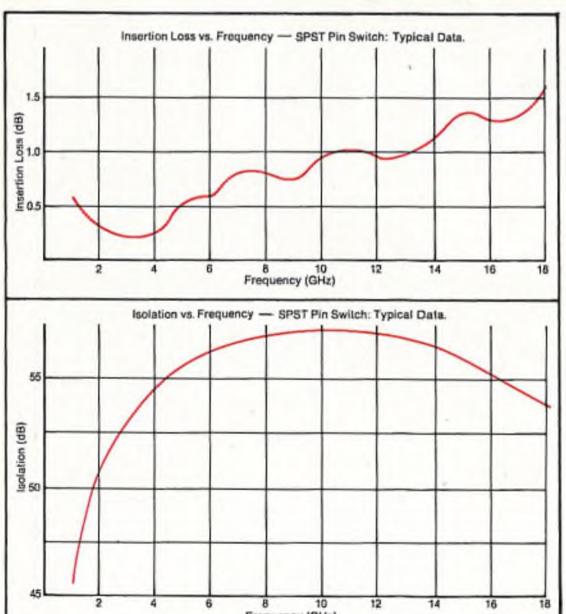

The broadband coverage from 1 to 18 GHz combined with a switching time of less than 10 nanoseconds, high isolation and low insertion loss make these new devices particularly attractive in ECM applications as microwave switches, modulators or attenuators. The microstrip construction provides the benefit of inherently small size and light weight. These Pin Diode Switches are immediately available in SPST or SPDT with or without integral drivers which are TTL compatible and available in either logic polarity. Switch and driver models are available for operation from positive or negative power supplies.
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International newsletter

Space-division race narrows to CGE and ITT subsidiary

Insiders say that ITT's French subsidiary CGCT and rival group, CGE, are the finalists in the hotly disputed competition for big space-division switching contracts due to be awarded soon by the French telecommunications ministry. **In the preliminary shakeout, Philips, Siemens, and Thomson-CSF—which has a license from Canada's Northern Electric—have been eliminated.** That leaves the CGCT Metaconta system in competition with the Japanese D-10 system and the Axe-Ericsson system, both licensed by the CGE group. In fact, the French telecommunications industry may retain only one space-division technology, but in that case, some of the losers may share in Metaconta manufacture.

Facsimile system uses plasma tube for scanning

A multipin plasma tube provides the horizontal scan for electrostatic imaging in a facsimile system just announced by Nippon Electric Co. In operation, a three-phase clock steps the plasma discharge from one end of the tube to the other to provide positive voltage on a finely spaced row of pins that contacts the insulated front surface of the recording paper. At the same time, negative-going facsimile-signal voltage is applied to an electrode in contact with rear surface of paper. **Electric charge is transferred to the paper under the pin that is positive at the moment when the back electrode is negative.** Successive lines are scanned in sequence as the paper moves. The latent-charge image is developed with carrierless toner, and fixed by heat.

British sell Rapier missiles to Iranians

Beating out the Franco-German Roland surface-to-air missile system, the British Aircraft Corp. has sold $375 million worth of tracked Rapier missile systems to the Iranian army. The deal, which includes support and technical assistance so that Iran can make its own missiles, also covers identification-friend-or-foe units from Cossor, optical tracking units from Barr & Stroud, and the vehicles from FMC Corp. in the U.S. BAC export orders for the Rapier now total more than $800 million, including a previous $250 million order for the Iranian air force, that had a $40 million Marconi Blindfire radar option. Marconi may eventually receive Blindfire orders from the Iranian army.

French officials push for computer R&D

The French government is considering a plan to put new muscle into computer research and development. Industry and research minister Michael D'Ornano hopes a streamlined R&D effort will solve **the apparent paradox in the government's strategy to use Honeywell Information Systems' sales strength and brainpower to launch a vigorous French computer industry into international markets.**

There is little doubt in France that HIS and Honeywell-Bull machines will dominate the sales of the new company that will combine the U.S. partners with Compagnie Internationale pour l'Informatique. D'Ornano and his director general for industry, Hugues de l'Estoile, **have faith in France's well-proven track record in fundamental computer research.** They figure that when CII-Honeywell-Bull, the new combine, produces its first coherent line of products early in the next decade, the conception, architecture, software, and even the technology will have enough French content to justify today's claim that the merger "guarantees French independence. Our industry will only be what our own researchers make it," argues de l'Estoile.

The government plans to use its own traditionally strong research infrastructure to develop home-grown computer expertise that will be controlled by the state and not by industry. At the same time, government planners want to close what has always been a wide gap between the fundamental research organizations and industrial R&D. As de l'Estoile freely admits, the model is the United States, where electronics and computer research have flowed freely between universities and industry.

West German company readies digital fiber-optic link

For trial purposes, AEG-Telefunken has readied a digital fiber-optics communications system with a transmission capacity of 100 megabits per second. **The system allows the transmission of more than 1,000 speech channels** or, alternatively, an eight-bit-coded color-television signal. Using a multi-mode fiber, the system shows an attenuation of 8 dB per kilometer. An injection laser transmits the pulses, while a silicon-avalanche-photodiode is used for detection. Easy-to-plug connectors with coupling losses of less than 0.5 dB facilitate handling the optical cable. All system components are AEG-Telefunken's own developments. **The company won't confirm it, but the system is certain to be used in the optical communications trials that the German post office plans to conduct in West Berlin in 1977** [*Electronics*, Nov. 13, p. 56].

German-Japanese venture seeks share of U.S. numerical control market

West Germany's Siemens and Japan's Fujitsu Fanuc have decided to set up a joint venture for marketing numerical machine tool controls in the U.S. The company, called General Numeric, will be established in the Chicago area the first of the year. It will also handle servicing of the numerical controls it will distribute as well as those that the two parent firms have already sold on their own in the U.S., Canada, and Mexico.

Swiss to finish radiotelephone net by 1979

The Swiss post office plans to have a nationwide radiotelephone network in full operation by 1979. The $4.8 million system will blanket the mountainous country with about 40 fixed stations that will **eventually tie 10,000 mobile-radiotelephone subscribers into the conventional telephone network.** The first stations, in the Zurich area, will go into service in 1977, and full national coverage is to follow two years later.

Danish hi-fi firm sees bang-up year

Although most of the giant European entertainment electronics companies remain cautious about sales predictions for 1976, **the smallish Danish company Bang & Olufsen says it expects to have its biggest year ever.** The company specializes in high-ticket precision high-fidelity products. Booming exports and a solid home market will enable the Danish company to kick up its turnover about 20% to $87 million for the current operating year, which started October 1. "We're in what we call a delivery situation," says B&O's international sales manager Kjeld Harder. "We're simply having a difficult time keeping up with demand." The biggest jump has come from the U.S., with France also showing strength.

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HEF4082P	Dual four-input AND gate
HEF4085P	Dual two-wide two-input AND-OR-invert gate
HEF4086P	Four-wide two-input AND-OR-invert gate
HEF4099P	Eight-bit addressable latch
HEF4104P	Quad low-voltage-to-high-voltage translator with tri-state output
HEF4514P	One-of-sixteen decoder/demultiplexer with input latch (HIGH)
HEF4515P	One-of-sixteen decoder/demultiplexer with input latch (LOW)
HEF4518P	Dual BCD up-counter
HEF4519P	Quad two-input multiplexer
HEF4520P	Dual binary up-counter
HEF4539P	Dual four-input multiplexer
HEF4555P	Dual one-of-four decoder with active HIGH outputs
HEF4556P	Dual one-of-four decoder with active LOW outputs
HEF4720P	256 - bits, 1 bit/word RAM
HEF4721P	1024 - bits, 4 bit/word RAM
HEF40097P	Tri-state hex non-inverting buffer
HEF40098P	Tri-state hex inverting buffer
HEF40174P	Hex D flip-flop
HEF40175P	Quad D flip-flop
HEF40192P	Four-bit up-down synchronous decade counter
HEF40193P	Four-bit up-down synchronous binary counter
HEF40194P	Four-bit bidirectional universal shift register
HEF40195P	Four-bit universal shift register

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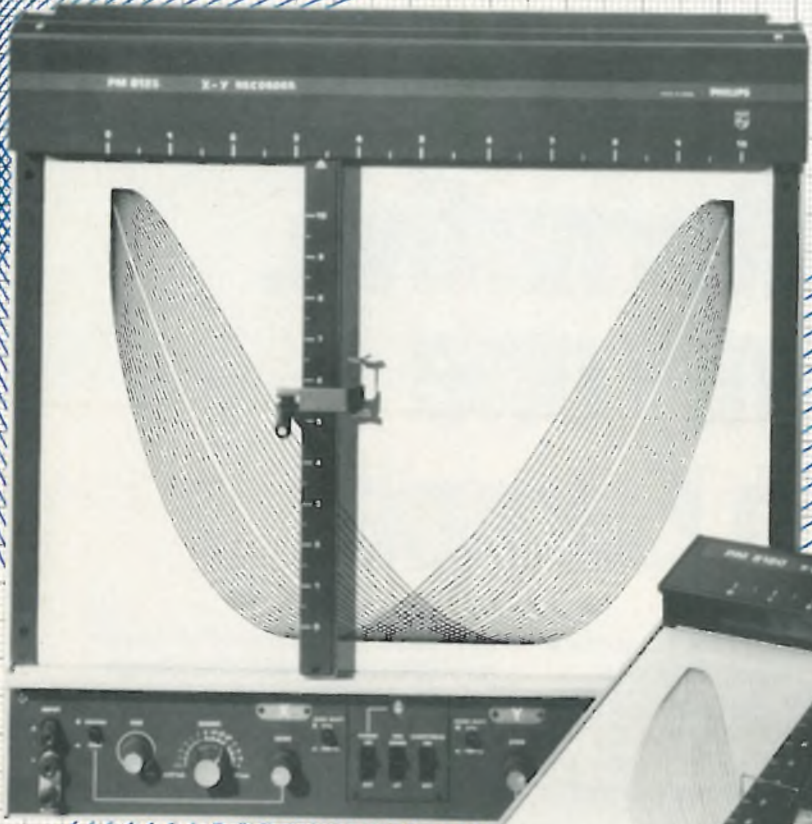
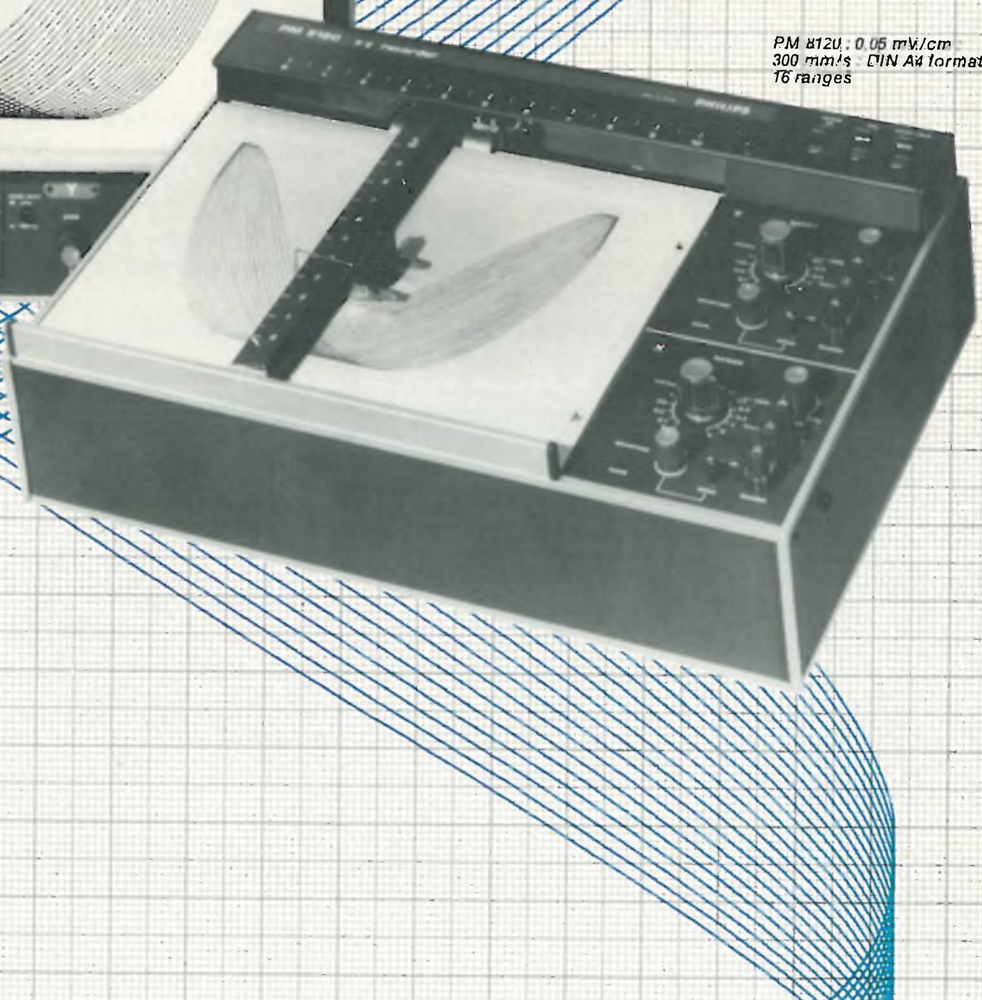
Circle 103 on reader service card



PM 8125 : 0,05 mV/cm ;
500 mm/s ; DIN A3 format ;
14 ranges



PM 8120 : 0,05 mV/cm ;
300 mm/s ; DIN A4 format ;
16 ranges

When every detail counts

High 0.05 mV/cm sensitivity, fast 500 mm/s writing speed, big A3 chart size

That's the combination that makes the PM 8125 X-Y A3 chart recorder the right choice for R&D labs, where every detail of the trace is often so important.

The high 0.05 mV sensitivity is adjustable in 14 steps to 1 V/cm, with variable span overlapping each range to give continuous adjustment. Electronic overload protection covers all ranges and the inputs are both floating and guarded to ensure high noise immunity. Most important, the 500 mm/s writing speed enables fast-changing signals to be recorded accurately.

A recording accuracy of ± 0.25 % and 0.1 % reproducibility is ensured by the null balance potentiometric measuring system which has a MOS FET chopper and DC servo system with tacho generator feedback.

The zero point, which is continuously adjustable over the full recording width, can be conveniently checked at the push of a button, while push-button selection also provides −100 % offset.

Penlift can be remote as well as manual. The writing system employs nylon-tipped felt pens. Standard drawing pens can also be fitted directly.

Electrostatic chart hold-down
A useful feature of the recorder is the electrostatic chart hold-down, which works for any kind of paper and any size up to 250 x 380 mm (Din A3). Quick chart alignment is obtained with pinpoint light guides.

These features add up to make the PM 8125 the ideal recorder for manufacturing and education as well as lab R&D. As illustrated, a smaller format A4 version is also available.

Add-on X_t, Y_t facility
The optional plug-on time base unit PM 9814 is a sweep generator designed to give both models X_t or Y_t facilities. A wide range of speeds from 0.05 to 20 sec/cm can be obtained with an accuracy of ± 3 % and 0.5 % linearity.

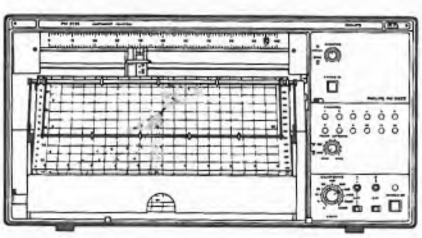
Comprehensive X-t range
As illustrated below, the Philips program features a comprehensive range of X-t recorders.

Three models have 0.25 % accuracy and 0.35 sec response times with a choice of single line, double line or multi-point (up to 12 channels).

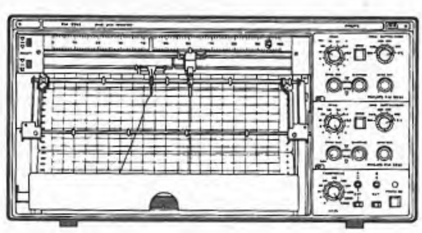
Two other compact recorders feature 0.5 % accuracy and 0.25 sec response time plus a wide range of options, making them suitable for OEM applications. The compact dimensions and convenient Z-fold paper system also make these instruments ideal for crowded bench work .

The Z-fold chart paper is a feature common to all X-t models, as is the stepper motor chart drive.

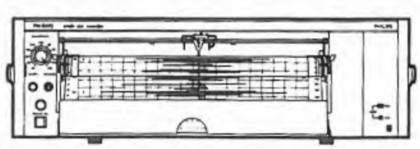
For more information on X-Y and/or X-t chart recorders please write to : Philips Industries, Test and Measuring Instruments Dept., Eindhoven, The Netherlands.



PM 8235 : multi-point recording on 1 to 12 channels using simple pin board programming



PM 8240/45 : single and double-line respectively : wide choice of input parameters



PM 8202/22 : single and double-line. OEM and end user facilities

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France awaits a better year after a poor 1975

by Richard Shepherd, McGraw-Hill World News, and Arthur Erikson, Managing Editor, International

Communications gear expected to set pace, followed by computers and consumer hardware

FRANCE ELECTRONICS MARKETS FORECAST
(IN MILLIONS OF DOLLARS)

	1974	1975	1976
Total assembled equipment	3,707	4,114	4,755
Consumer electronics	884	976	1,112
Communications equipment	925	1,072	1,310
Computers and related hardware	1,381	1,531	1,751
Industrial electronics	189	181	197
Medical electronics	136	150	167
Test and measurement equipment	136	148	159
Power supplies	55	58	59
Total components	1,055	1,037	1,139
Passives	627	636	706
Semiconductors	237	202	226
Tubes	191	198	208

(Exchange rate: $1 = 4.4 francs)

Note: Estimates in this chart are consensus estimates of consumption of electronic equipment obtained from a survey made in September and October 1975. Domestic hardware is valued at factory sales prices and imports at landed costs.

The recession that has plagued the world's economies for the past two years or so hit France so hard that even sales of champagne slumped in 1974. But now the corks are popping much more frequently than they were a year ago. A natural upturn in the business cycle, bolstered by a massive government spending package, has the French economy headed for recovery.

Prospects now are for something like a real growth of 3% in the country's output of goods and services for 1976. That pace is only about half the growth in gross national product that French businessmen got used to in the late 1960s and early 1970s, but any growth is better than 1975's "slumpflation." And, there's a chance that 1977 will be almost like the good old days.

What makes the outlook chancy, more than anything else, is inflation. Some economy watchers say that President Valéry Giscard d'Estaing's stop-go economic policy went "go" too late. They're convinced the $10 billion spending will speed the recovery so much that next year's inflation will surge past the 10% hike that the cost-of-living indexes made this year.

Electronics' annual survey puts French equipment markets for 1975 at just over $4.11 billion for a nominal rise of 11% over the 1974 figure of $3.71 billion. The forecast for 1976 reflects the expected over-all recovery, pegging French equipment markets at $4.76 billion, 16% better than the year just ending. Market values are for consumption in current prices at an exchange rate of $1 equals 4.4 francs.

Makers of communications equipment seem sure to set the pace next year. They have a lusty home market in sight—up better than 20%, according to the survey—and whopping export backlogs as well. The computer makers and the entertainment-electronics producers can count on an improvement over their lackluster 1975, too. Worst off among equipment makers will be suppliers of industrial electronics, the survey suggests. Their customers have been reluctant to invest, and sales for the sector are predicted to climb less than 9%. Worried largely by the outlook for automation equipment, CIT-Alcatel's deputy manager Louis Le Saget lamented late this fall, "We just don't know where we are going. The orders are not good at all so far."

Even less sure are the French components producers. They registered declines this year—almost 15% for semiconductors—and saw prices plummet as well. As a result, their market dwindled from last year's $1.055 billion to $1.037 billion. In late fall, some signs of a pickup started popping up here and there, and the survey points to a modest upturn for 1976 that would lift the market to $1.139 billion.

Professional performance. "Professional" electronic equipment—hardware like radars, communications equipment, guidance systems, navigation aids, and radio links—long has been a French forte.

Their worldwide reputation has stood French manufacturers of sophisticated electronics in good stead during the recession. While their domestic market dawdled, they have piled up whopping export orders. Fully half of the orders booked last year came from abroad. Judging from business logged during the first six months, the figure will go well beyond 50% this year. "France is the world's third supplier in the arms business," explains Christian Loeffler, who heads professional electronics sales at Le Matériel Téléphonique, "so we have benefitted from this booming market."

Because a lot of communications hardware goes into weapons systems tagged for export, and because the French Ministry of Posts and Telecommunications plans massive spending on stored-program-control switching, the consumption of communications equipment in France will surge next year. According to *Electronics*" survey, there's a 22% spurt in sight, to $1.31 billion from this year's $1.07 billion.

Even so, some big producers of military hardware are edgy for the long term. LMT's Loeffler predicts that military export orders will dry up before long. "We will reach the saturation point soon—maybe next year," he warns. While orders will keep production facilities going for another year or two, there's keen concern about the stagnant domestic market for military hardware.

One big project, though, will get under way next year. The RITA digital battlefield-communications system will involve most of the French telecommunications companies and LMT in particular. But "we're worried about the lack of credits for developing advanced components," says Jacques Bouyer, the managing director of the Philips' subsidiary RTC-La Radiotechnique-Compélec and president of the trade association of semiconductor and tube makers. In his view, future arms sales abroad depend on keeping ahead in technology.

The unmitigated bright spot in the outlook for telecommunications makers is the government-run phone network. France has lagged well behind the rest of the industrialized world for years now, and the telecommunications ministry plans to turn heavily to electronic switching for the catch-up effort. Along with the time-division systems it opted for in the late 1960s, the ministry has earmarked funds for a crash program of 300,000 lines worth of space-division exchanges.

At year-end, Thomson-CSF, the ITT subsidiaries LMT and CGCT, L M Ericsson, the Compagnie Générale d'Electricité, and Philips were waiting to see how the agency would split up its business. Meanwhile, CIT-Alcatel, part of the CGE group, will be looking ahead to orders for some $90 million worth of space-division exchanges for 1976—more than double its figure this year. All told *Electronics* forecasts $182 million for deliveries of electronic and semi-electronic public switching exchanges next year.

And that's just the beginning. Government planners now hope that electronic systems will take half of all new switching business by 1980 or 1981. Around then, French companies hope to be logging orders for 1 million lines a year and installing 700,000 of them. Altogether, the ministry is targeting about 19 million lines by the end of the decade, with about 2.5 million lines linked to electronic exchanges.

In addition to cutting down the waiting list for telephones, the French government hopes that a solid telecommunications market will foster home-grown advanced-components technology. They tried to do the same with computers through the Plan Calcul, which expired this year when the government let CGE take control of Honeywell-Bull and merge it with the Compagnie Internationale pour l'Informatique.

Bouncing back. Computer makers now think they are set for a rebound from a poor 1975. Computer sales did badly during the first six months of the year, logging zero growth. Not only was the economic climate too chilly for businessmen to warm up to new data-processing hardware but also the "affaire Honeywell-Bull" overhung the market, slowing orders for CII equipment.

After the Sicob computer show in September, though, the market started to perk up. According to *Electronics*' survey, the computer sector should wind up this year at $1.53 billion, up 11% over the 1974 figure of $1.38 billion. Minicomputers and microcomputer sys-

Upbeat. French electronics companies expect an improved 1975 as sales pick up. Communications equipment, such as Thomson-CSF's relay links (left) and air-traffic-control radars (far left), is the pacesetter, followed by computers.

tems paced the fall pickup to end up with a gain for the year of about 19%, the survey shows. Peripherals also ran strong. "People are much more money-conscious now," notes a Control Data marketing executive, whose big computer models nonetheless suffered relatively little during the economic downturn.

For next year, *Electronics*' consensus forecast puts the market at $1.75 billion, a gain of better than 14%. In addition to the better business outlook, the planned merger of CII and Honeywell-Bull should be finalized in the spring, bringing buyers into the market.

Consumer caution. Consumer electronics managed to register a nominal 10% rise to $976 million this year. Compared to West Germany and the United Kingdom, where the market went into reverse, that's not too bad. All the same, consumer-electronics makers in France have chalked off 1975 as a non-vintage year and count on a sprightlier brew for 1976.

France has as yet not seen the kind of color-TV buying spree that hit its northern neighbors in the early 1970s, and the French market thus is young enough to rate as robust. Led by color-TV sales, consumer electronics producers have a billion-dollar-plus year ahead. That figure, in fact, will be low if consumers decide to start spending some of the money they've been piling up as they've watched the unemployment totals get past the 1 million mark.

In the trough. Components producers, unhappily, have not been able to hold their own against the rip tide of recession. They started going into the trough some 18 months ago and can't be sure of getting back to a crest again in 1976. The survey spots French components markets next year at $1.139 billion, a rise of nearly 10%.

A major "if" is the level of parts inventories equipment makers are carrying. They have been working off inventory for more than a year and presumably are down to next-to-nothing. But no one is sure. Many market analysts, such as Raymond Genet of RTC and Michel Guerga of ITT Components, see a significant pickup starting in the second quarter of 1976.

What happens after that is a matter of debate. Some market watchers are talking of an explosion of orders from parts-short equipment makers, shortages, and double and triple ordering—a repeat of painful history. At the other extreme, some forecasters say the European economies will start slipping back into "stagflation" after a brief upturn. "In that case," Genet predicts, "the market will be flat next year."

If 1976 winds up between the extremes, the semiconductor markets almost surely will come back. They slumped around 15% in current money terms to $202 million, according to *Electronics*' survey. Next year, the forecast is for $226 million, still below the 1974 level. But until the turnaround actually comes, semiconductor suppliers will be nervously watching price levels. They have dropped between 10% and 15% this year, says Olivier Garreta, head of the Sescosem semiconductor division of Thomson-CSF. As of late fall, the price-cutting was still plaguing producers. "It's still going on," Garreta said then. □

West Germany

CCTV alarm system serves 8 cameras, responds to movement

The closed-circuit television system has become virtually standard equipment for protection against thefts in stores, banks, parking lots, and similar facilities. Unfortunately, constant observation of a flickering TV screen strains a watchman's eyes, especially at night when the monitored scene seldom changes.

This discomfort is eliminated by a monitoring unit that keeps the TV screen dark so long as no changes in the scene occur. But if the cameras pick up any movement, the picture automatically shows up on the screen, and an acoustic or optical system alerts the watchman. What's more, the picture can be recorded on video tape at the same time.

The VM 216 TV movement alarm is being offered by a small company, Reten Electronic GmbH, in Idstein, near Frankfurt, West Germany. The alarm is connected into the video line between the cameras and the monitor in existing CCTV systems. The system, which sells for $1,900 to $5,700, depending on the number of cameras it serves, can be programed for a host of other monitoring applications. Among them are industrial process control, monitoring the unintentional escape of gases from combustion plants, checking the number of people or vehicles entering or leaving a facility, and observing scientific experiments to record the movements or position changes of certain objects.

Versatile. The Idstein system can handle data from eight cameras, in contrast to competing systems in Europe and the U. S., which the company says are limited to one or two camera inputs. The VM 216 is comparable to a small process computer. By means of a multiplexer, the outputs of all cameras are scanned at a maximum rate of 20 times per second. The video information, which is digitized and stored, is then compared to the data of the previous scan.

If a change in the data causes the data to differ from the scene previously stored, the unit triggers the alarm, and the monitored scene appears on the TV screen. The video and alarm signals may be erased either manually or automatically after a change in the scene is shown.

Programing. The digital electronic circuitry allows the VM 216 to be used for a variety of monitoring tasks. It can be programed by a 16-by-16-point patch-board matrix to brighten specific areas in a display or prevent unwanted details from being processed.

The alarm can be programed by push buttons to evaluate only certain portions of a scene—say, the movement of a door, but not the changing positions of people walking in front of it. In that application, markers are used to indicate where the movement takes place.

The memory content can be refreshed at a preselectable rate between every 40 milliseconds and every 60 seconds so that both fast and slow movements in a scene can be evaluated. The VM 216 provides "extremely high resolution" and a maximum of 16 gray shades, Reten says. The video scene is divided into 1,024 individual picture segments, arranged in a square matrix. The scene is displayed and the alarm is triggered when the average gray shade is changed by 12% or more in at least 0.1% of continuous picture area. □

Japan

Differential processing squeezes TV signals onto telephone circuits

Business conferences are just one of many activities expected to benefit from a new technique for transmitting differential pulse-code modulated color-television signals over voice-grade telephone circuits. Signals are sent at 32 megabits per second, and the bandwidth is compressed by about two thirds with a resulting two-thirds decrease in the transmission rate.

Although the picture does not meet broadcast standards, its quality is said to be comparable to that normally displayed on home television receivers. The technique, developed by the Central Research Laboratory of Nippon Electric Co., is also aimed at applications in education, surveillance, and medicine. The transmitting equipment uses higher-order prediction to directly encode NTSC-standard color signals to differential pulse-code-modulated signals.

As in other differential-transmission methods, most of the bandwidth compression is achieved by transmitting only the portion of the signal that changes from scan to scan. The equipment is designed so that the amplitude of signals sampled earlier predicts the amplitude of the signals that follow. The signals that are actually transmitted are five-bit codes that represent the differences between the predicted and sampled values.

Coding. Nonlinear coding enables reproduction of 92 brightness levels on either side of a zero signal. Although a single preceding sample is adequate for black-and-white transmission, color-television signals require three previous samples. Buffer memories in identical prediction networks at the transmitting and receiving terminals make it possible to reconstitute the differential signal at the receiving terminal into a pulse train closely matching the original sample.

The rate of 32 Mb/s is used for transmission of PCM signals on commercial telephone systems. PCM color-television signal are normally transmitted at 90 to 100 Mb/s. The 32-Mb/s transmission rate for the 5-bit code pulls the sampling frequency below the standard specified by the Nyquist criterion, which requires the minimum sampling frequency to be twice the highest frequency in the sampled signal. If this rule is not followed, part of the signal can be lost, and spurious signal components can create beats between the TV signals and the sampling signals.

To increase the sampling frequency to the highest possible value, the signal is not sampled during the horizontal-retrace period, which is 10% of each horizontal line scan. At the transmitting terminal, a buffer memory enables a 35.3-Mb/s PCM pulse train to be transmitted at 31.8 Mb/s. At the receiving terminal, the PCM pulse train is speeded up to its original rate by another buffer memory. Filters and conversion circuits at both transmitter and receiver are used to limit signal degradation. □

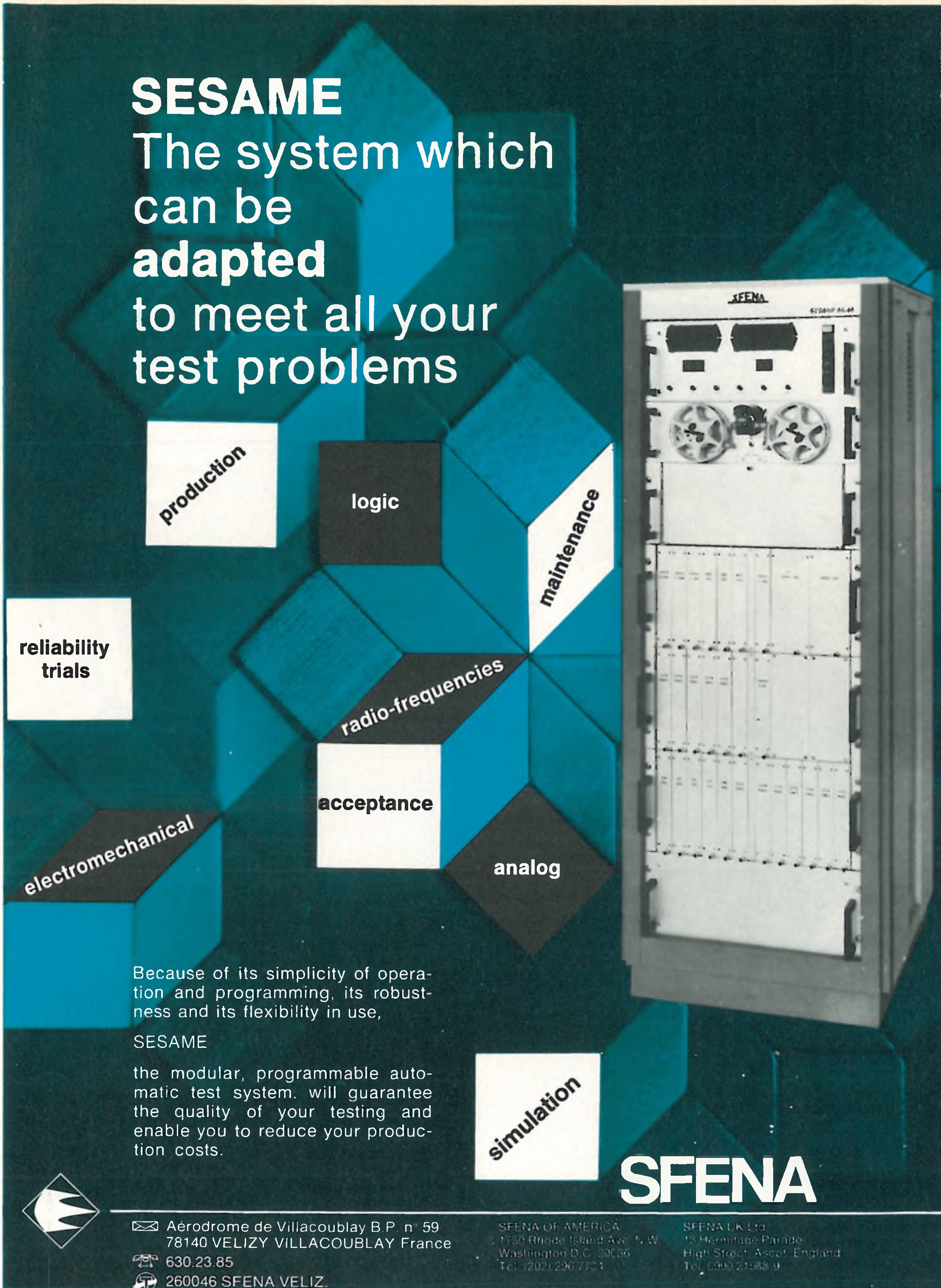
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Photo MARIN VOLK

Painless

In the medical school of the University of Utrecht dental students work on sets of teeth fixed into the mouth cavities of plastic heads. Beside each chair are a T.V.screen and earphone.
The professor - who is in what amounts to a small T.V.studio - works on an identical set of teeth. A small T.V.camera photographs him, and the picture, along with his verbal instructions, is transmitted to the T.V. screens and earphones beside the chairs. Consequently each student has a clear view of what the professor is doing and can practise it himself immediately. Since the camera has a 200 mm lens the professor can show either the whole mouth and the position of his hands, or an extreme close-up of, say, the point of the drill.

With the large classes common today, this system has the enormous advantage that any number of students can see exactly what the professor is doing. Formerly, students crowded round the professor so that only a few could get a clear view. Those who could went away and tried to remember what they had seen and do the same. Working on a plastic head, the student is free from anxiety about causing pain or doing damage and not troubled by such things as accumulation of saliva or a tongue that keeps on obscuring his view of the teeth. He can learn his technique painlessly. We designed the entire system.

1

2

3

4

1 **The PIP system** (Programmed Individual Presentation) enables a student or trainee to learn at his or her own speed. In fact a PIP teaching programme is a 30-minute sound movie viewed on a projector (Cassettescope) that any student can learn to play forward and back in a few minutes. The programmes are in cassettes so there is no threading.

2 **The diagrams in a Practonics textbook work.** The student builds up the circuits by plugging capacitors, resistors, etc. into a transparent circuit board laid over the page. A power supply and multimetre enable him to measure the parameters discussed in the text.

3 **Microwaves** To understand microwaves students must work with them. For this highly specialised teaching Philips makes two microwave measuring benches for ten basic microwave experiments. Brochures, supplied with the benches, describe the experimental setups in detail.

4 **The Video 10 system** is a two-camera mini-studio aimed primarily at schools and industrial training centres, enabling students to produce their own TV programmes.
It comprises the TV cameras with accessories, control monitors, video mixer, control unit and audio mixer, microphone and head sets as well as power supply units, tripod and cables. A video cassette recorder can also be used so that complex teaching programmes can be prepared and recorded in advance.

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PLEASE WRITE IN CAPITALS. 23–18

PHILIPS working in education

Monolithic circuit controls switched-mode power supplies

by William F. Arnold, London bureau manager

High efficiency and compactness make switched-mode power supplies attractive for many systems, but these supplies usually require a large supporting cast of components for good performance. Taking advantage of its collector-diffusion-isolation technology, Ferranti Ltd. has developed and will soon market a monolithic control circuit for switched-mode supplies. The integrated circuit typically needs fewer than 20 external components to control up to 100 watts.

Ferranti expects the versatile IC, called the ZN1066E, to open up new markets in switching supplies. It could be used, for example, to control 5-volt, 20-ampere supplies as well as 5-V, 3-A units.

Most switched-mode supplies are designed to convert an ac voltage and current to one or more dc voltages and currents. In operation, the input voltage of the ZN1066E is switched on and off at a frequency between 20 and 30 kilohertz.

Peter Krebs, new-products-definition manager at Ferranti, says the ZN1066E packs onto an 85-mil-square chip many components usually available only in discrete form for switched-mode power supplies. On the chip are a shunt regulator and a series regulator, an oscillator, a ramp generator, a comparator, steering-function circuitry, two pairs of push-pull transistor outputs, and two amplifiers.

Collector-diffusion isolation gives Ferranti several advantages for the ZN1066E because the bipolar epitaxial process gives good packing density, almost equivalent to MOS, says Krebs. The chip area is only a third as large as transistor-transistor-logic circuits. Also, linear and digital circuits can be combined on the same chip.

Typically, to get a complete circuit, Krebs says that a designer would need only to add a bridge rectifier to get the dc current into the chip, a dropper resistor and capacitor to supply the IC, a capacitor to serve as a stabilizing reference for the series regulator, a potentiometer-and-capacitor combination for generating the ramp, two switching transistors and a ferrite-core transformer.

Krebs defines the on-chip steering function as the circuitry to determine either of two modes of operation obtained by a divide-by-two gate plus five other gates. The push-pull outputs consist of a transistor and an emitter-follower, he says. And in open-loop configuration, a capacitor and a potentiometer can provide even current feed for the ramp function.

Chip needs fewer than 20 external components to handle 100 watts

"The ZN1066E can be used anywhere there are large lumps of logic," declares William Mordue, senior marketing executive. He singles out computers, photocopiers, and industrial power supplies as initial sales targets. Claimed advantages of the ZN1066E include two push-pull buffered outputs, a stable oscillator, and overlap control—all on a single chip.

Price of the IC is about $5 each in lots of 20,000 or about $10 each for 500 units. Although professional applications are the first goal, a consumer-grade version is planned. Ferranti thinks the ZN1066E is coming out in time to ride on a wave of success for switching-mode power supplies. The current European market is 1.5 million units a year and this will increase to about 20 million a year by 1980, Mordue estimates. The UK market now is 300,000 units a year, he adds.

With the chip, a designer could drive either two transistors or one Darlington configuration. Typical output in a push-pull configuration would be 60 milliamperes. The controller offers two modes of operation—either a 0-to-100% variable output or 0-to-50% alternating outputs, to switch the external transistors. The former is a "straight filtering-out," Krebs says, while the second mode is for dc-to-dc converter and inverter setups. He notes that the chip has automatic overlap protection to prevent any transistor overlap.

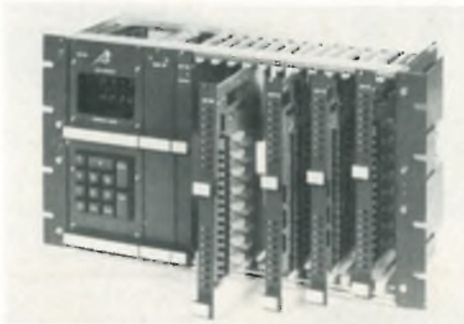
Among the chip's advantages, Krebs points out that the mark-space ratio, the fundamental parameter of switched power supplies because it determines the amount of power going through the transformer, is maintained independently of the supply voltage and the temperature.

Ferranti Ltd., Electronics Components Division, Gem Mill, Chatterton, Oldham, Lancs., England [441]

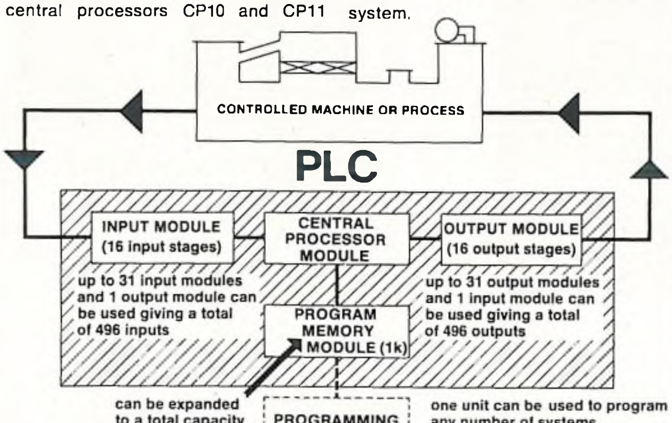
News from Philips

electronic components and materials

MODULAR APPROACH TO PLCs REDUCES COSTS



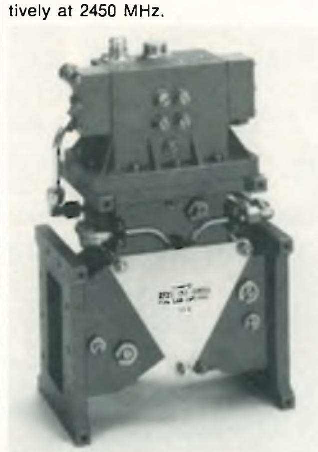
Seven different types of modules are now available for customers to build their own programmable logic controllers (PLCs) inexpensively, without redundancy. A PLC can easily be programmed and re-programmed as required at minimum cost. Our modular system allows the user or the system builder to get precisely what he wants as unwanted capability is expensive. A 5 V power supply, a rack, and interconnect wiring are the only extras. The seven modules, which are formed on Eurocards, are the input modules IM10 and IM11, output module OM10, central processors CP10 and CP11 (the latter without registers), non-volatile 1k program memory module MM10, and the programming unit PU10, which can be used to program any number of PLCs. It has also been designed to monitor the program and the status of every bit location in the central processor, and is so low priced that each PLC could use one to provide continuous signal monitoring.
Excellent noise immunity in industrial environments, internationally accepted 24 V levels of machine signals, and uncritical operating margins and thresholds are all features of the new system.



Circle 721 on reader service card

6,5 KW ISOLATOR FOR INDUSTRIAL MICROWAVE HEATING

A new 6,5 kW isolator in an aluminium die-cast housing is now available.
This isolator is of the terminated circulator type in which an integral load can withstand the full reflected power in the event of a short circuit in the microwave applicator. Isolation is better than 20 dB and the insertion loss is better than 0,3 dB, typical values being 26 dB and 0,2 dB respectively at 2450 MHz.



The isolator is water-cooled and requires about 3 litres per minute for a 20 °C water inlet temperature. It has been provided with mating flanges 154IEC-PDR26 for waveguide 153IEC-R26 and a monitoring terminal for reflection measurements. The isolator offers protection to the magnetron against too high mismatches and allows the tube to operate optimally, e.g. independent of load conditions, resulting in the highest efficiency and under the best conditions for long life.

Circle 718 on reader service card

X-BAND MINI ISOLATORS DECOUPLE LOADS

Three new miniature field displacement isolators are now available for X-Band frequencies. Covering a full range of 8,5 to 9,6 GHz between them, the new devices are only 15 mm long, 41,5 mm high and 55 mm wide.
A patented form of construction is used, consisting of a resonant array of copper conductors on ferrite. In the forward direction the ferrite is magnetically biased so that the electric field in the ferrite is very small; in the reverse direction the electric field is very large. The high magnetic fields caused by the heavy currents generated in the copper conductors are attenuated by gyromagnetic losses. An iris filter suppresses higher modes in the isolator.
The new isolators may be used with X-Band Gunn oscillators which are sensitive to frequency pulling. The latter is directly proportional to the value of reflection seen by the oscillator in its output. By inserting one of the new isolators, the reflection referred to the oscillator will be independent of the load and provide greater stability within the prescribed bandwidth.
The typical specification is: bandwidth 4% of f_c. VSWR $<$ 1,15, isolation $>$ 20 dB, insertion loss 0,35 dB, through-going power 2 W and reverse power 0,5 W. Production samples in the various communication bands and for 12,7 - 13,7 GHz frequencies are expected to be available later this year.

Circle 720 on reader service card

ECONOMY RANGE OF CERMET POTENTIOMETERS

The economy 482-series of cermet trimming potentiometers for professional use have a linear resistance law, cover the range 100Ω to 1 MΩ (E3 series), and feature high reliability and stability. Their favourable performance in severe environments makes them ideal for industrial applications. The potentiometers comprise a resistance element which is printed onto a non-conductive temperature-resistant ceramic substrate and cured to form a thin conductive glass track. They are no more than 10 mm wide and are available in two versions for either horizontal or vertical mounting. The potentiometers are adjustable from both sides and are available with, or without, dust covers.

Circle 719 on reader service card

Philips Industries
Electronic Components and Materials Division
Eindhoven - The Netherlands

PHILIPS Electronic Components and Materials

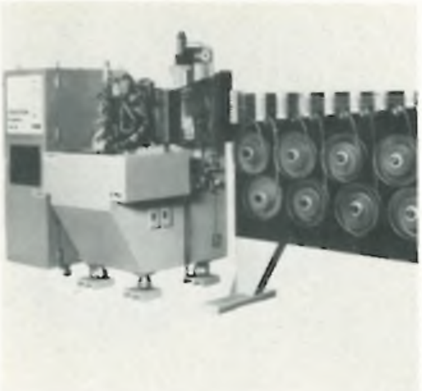
PHILIPS

New products international

A 3½-digit multimeter provides autoranging, autopolarity and autozeroing with simple one-knob operation. Full ac/dc voltage and current measurements are possible, and six resistance ranges go to 20 milliohms. Farnell Instruments Ltd., Wetherby, West Yorkshire, England [443]

Indel 85 capacitors are for applications such as smoothing of power-supply lines and general filtering. Capacitance range is 100 to 280,000 μF. The units have low leakage current and a three-year shelf life. Advance Filmcap Ltd., Wrexham, Denbighshire, England [444]

A storage tube for oscilloscopes, the E725, offers a writing speed of 100 cm/μs at a gun voltage of 2 kV when operated with zero background brightness. With low brightness, speed can be doubled or tripled. English Electric Valve Co., Chelmsford, Essex, England [445]



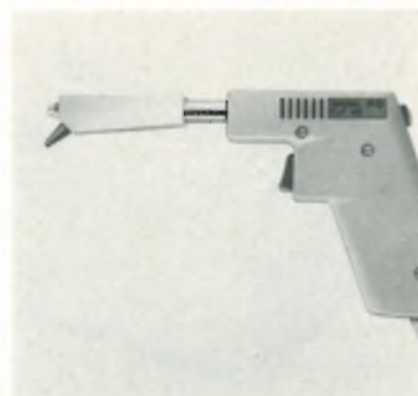
With an automatic machine called Avi-Sert, radial-lead components can be inserted into circuit boards without the need for preforming the leads, nor is a component sequencer required. Avi-Sert can handle 20 types of components. TDK Electronics Co., Chiyoda-ku, Tokyo 101, Japan [446]

Programable controller called Okipc replaces relay-logic types. Unskilled personnel can program industrial equipment while looking at the circuit diagram and using the programing panel (above). Oki Electric Industry Co., 4-10-3 Shibaura, Minato-ku, Tokyo 108, Japan [447]

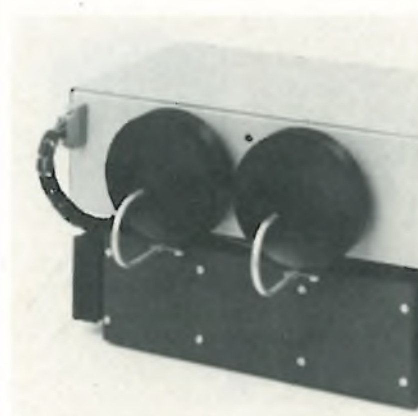
Function tracer FT-4 can be used for automatic reading and conversion of analog data into digital, as a function generator, or in program control. It reads curve information and stores the data in a semiconductor memory. Riken Denshi Co., 2-5-5 Yutenji, Meguro-ku, Tokyo 153, Japan [448]

New products international

Automatic stabilizer module for motor-driven mains transformers provides a voltage that is 5% to 115% of the input. Module is accurate to within ±0.5 V. Mains transformers, motor-drive units, and accessories are available. Philips, P. O. Box 523, Eindhoven, The Netherlands [449]



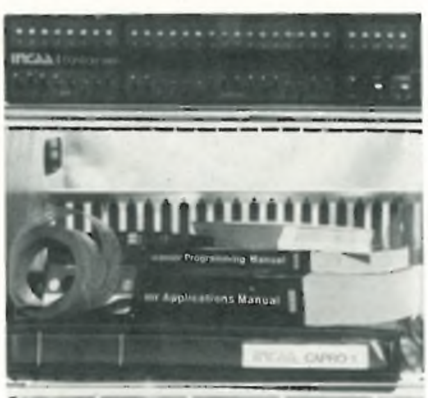
Unsoldering pistol ELP60 uses injector principles: a nozzle changes compressed air into suction. Solder is liquefied, then removed by suction. Compressed air blows out solder accumulated in pistol chamber. Ersa GmbH, 6980, Wertheim, West Germany [450]



A 60-GHz data-and-voice transmitter is intended for mobile use and for stationary applications where laying cables would be difficult. Unit, which allows duplex operation, transmits several miles. Elektro Spezial, 28 Bremen, Hans-Bredowstr. 53, West Germany [451]

The Strobo-X-pack is an X-ray flash system for analyzing rapid processes in high-speed cinematography. Picture-taking rate is 3,000 pictures per second. Flash duration is 200 nanoseconds, and frequency ranges from 1 hertz to 40 kilohertz. Impulsphysik GmbH, 2 Hamburg 56, West Germany [452]

Series P47220B turn-potentiometer (two to 10 shaft turns) is designed for the controls industry. The 25-mm length allows a long resistance element, and therefore, good resolution. Amphenol-Tuchel Electronics GmbH, Deisenhofen, Munich, West Germany [453]

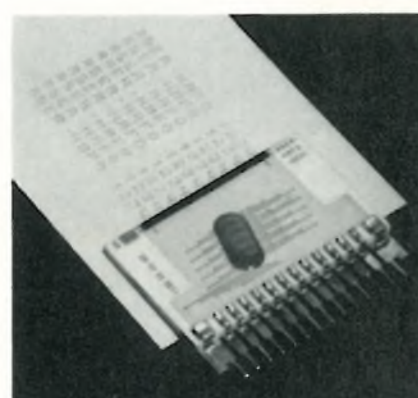


A microcomputer-based system, the Capro-1, is intended to replace the minicomputer in many process-control applications. The modular system is based on the Motorola M6800 microprocessor and includes several options. INCAA BV, Graaf van Lijndenlean 2, Apeldoorn, Holland 055-217300 [454]

New products international

Digital hand tachometers are suitable where instrument-imposed torque-loading is critical. One type uses frictional coupling and imposes fractional loading torque; the other, no-contact, no-load optical sensing. Smiths Industries Ltd., Cricklewood, London NW2 7UR, England [455]

Four operations are carried out in five minutes by a portable ultrasonic cleaner. The Ultron Microcleen, which cleans electronic and other small components, has three removable tanks and a heated centrifugal driver. Nusonics Ltd., 6 London St., London W2 1HL, England [456]



Using a nine-character printing head, characters are printed on heat-sensitive paper with a hot-spot matrix arrangement. The printing head consists of a ceramic substrate and a row of thick-film power resistors. ASEA-HAFO AB, S-162 26 Vallingby, Sweden [457]

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WIREWOUND
(TC ± 50 ppm/°C)

Type	Turns	Size	Power W	Tol. %
CT100	1	1/2"	1	± 5
CT106-4	1	1/2"	1	± 5
CT110	1	1/2"	1	± 5
CT2000	1	1/2"	1	± 5
CT2001	1	1/2"	1	± 5
CT2002	1	1/2"	1	± 5
CT205-10	25	1/2"	1	± 5
CT205-207	25	1/2"	1	± 5
CT205-208	25	1/2"	1	± 5
CT800-209	15	5/16"	0.6	± 5
CT800-20	15	5/16"	0.6	± 5
CT910-310	20	3/4"	1	± 10
CT910-20	20	3/4"	1	± 10

CERMET
(TC ± 100 ppm/°C)

Type	Turns	Size	Power W	Tol. %
CT170	1	1/4"	0.5	± 20
CT171	1	1/4"	0.5	± 20
CT172	1	1/4"	0.5	± 20
CT850-20	13	5/16"	0.3	± 10
CT960-20	20	3/4"	0.75	± 10
CT961-20	20	3/4"	0.75	± 10
CT961-20T	20	3/4"	0.75	± 10
CT989-20	20	3/4"	0.75	± 10

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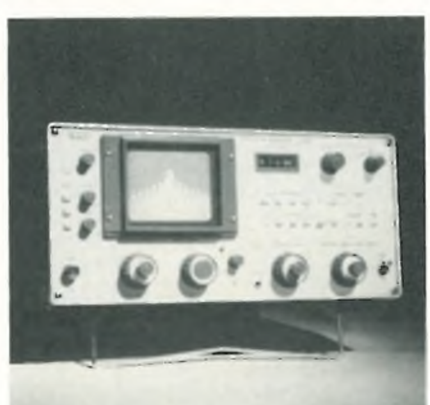
New products international

Ac weld-control model NRW-5T/U consists of a power unit and plug-in control units. Several types of welding are available by replacing the control unit for the appropriate job. Input power requirement is 200 V ac, 50/60 Hz. Nippon Aviotronics Co., Minato-ku, Tokyo 105, Japan [458]

Frequency-response tracer, type FCR-8, is a broadband dual-trace instrument for measurement of audio and other electronic signals. Ranges are 20 Hz to 20 kHz and 20 Hz to 200 kHz. Kokuyo Electric Co., 1-361-15 Ookayama Meguro-ku, Tokyo 152, Japan [459]



Spectrum analyzer called the MS62A/B measures wave forms in the range from 100 kHz to 1,700 MHz and, in conjunction with an antenna, performs measurement of field intensity. Dynamic range is more than 70 dB. Anritsu Electric Co., Minato-ku, Tokyo 106, Japan [460]

Preview of ISSCC excites designers

Devices to be described at February conference range from Intel's 16-kilobit RAM to Fairchild's 4-kilobit injection-logic RAM

by Laurence Altman, Solid State Editor

The eagerly awaited 16-kilobit random-access memory. . . . The industry's first 4-kilobit dynamic RAM made with integrated injection logic. . . . A 16-bit minicomputer controller on a single chip. . . . A 65-kilobit block-addressed charge-coupled-device memory. . . . The industry's first 4-kilobit static 5-volt RAM. . . . A 70-nanosecond, 1-kilobit static RAM. . . . A 16-kilobit MOS read-only memory built with a new V-groove technique.

A system designer's Christmas list? Perhaps. But it's also a list of 1976 development highlights that will be presented at the International Solid State Circuits Conference Feb. 18 to 20 at Philadelphia. The ISSCC is where these and other papers from semiconductor designers around the world will make their debuts. At the moment, the conference is shaping up as the best technical meeting in a decade.

Two of the developments represent the best in memory design for 1976. One is Intel Corp.'s 16-kilobit RAM. The product, which the company has just begun to deliver in sample quantities, heralds a new round of mainframe-memory penetration. The other is Fairchild Semiconductor's I^2L RAM, which breaks new ground in memory design by putting 4,096 bits of dynamic bipolar memory on a single chip. The device should have a significant impact on the next generation of add-on and buffer-memory systems.

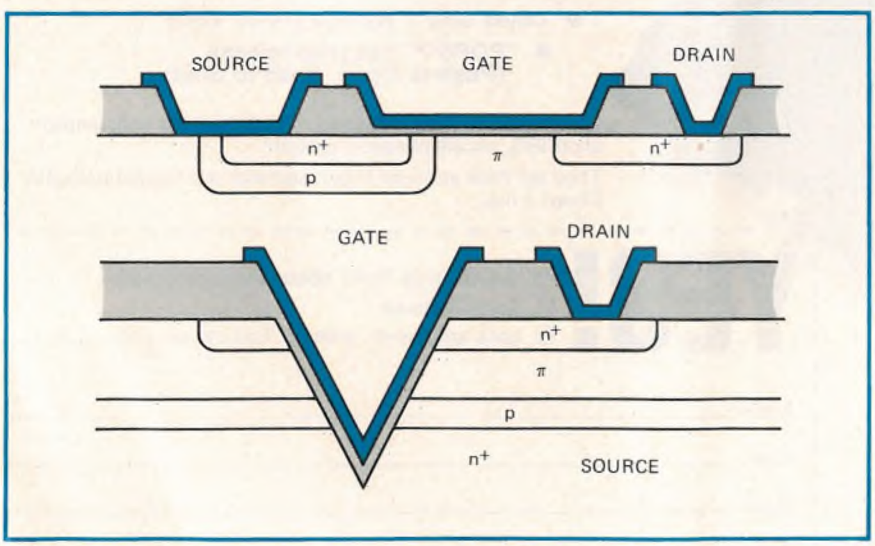
Champions. These two developments represent two competing technologies at their best: The Intel RAM is built with an enchanced n-MOS technology that uses a double-conductor level of polysilicon that shrinks RAM cell sizes in half, reduces power dissipation, and maintains good switching speed in very dense arrays. This double-poly technique (see p. 29) should be especially interesting to memory users because it's the approach being adopted almost universally by RAM suppliers for their 16-kilobit designs.

Fairchild's I^2L RAM is equally impressive—it's the first dynamic bipolar-memory design. Since dynamic designs traditionally shrink cell sizes by reducing the number of transistors needed at each bit site, Fairchild's design could signal a new trend in bipolar memories, thereby permitting denser arrays to dissipate less power. Injection logic is well suited for this circuit approach because its structure is inherently compact, anyway—a pair of complementary transistors make up an entire cell.

Although details of the paper are not being made public until the conference, Fairchild uses its Isoplanar (oxide isolation) technique to further reduce cell size and increase speed. This 4-kilobit RAM chip is estimated to be no larger than 4-kilobit MOS designs and at least twice as fast.

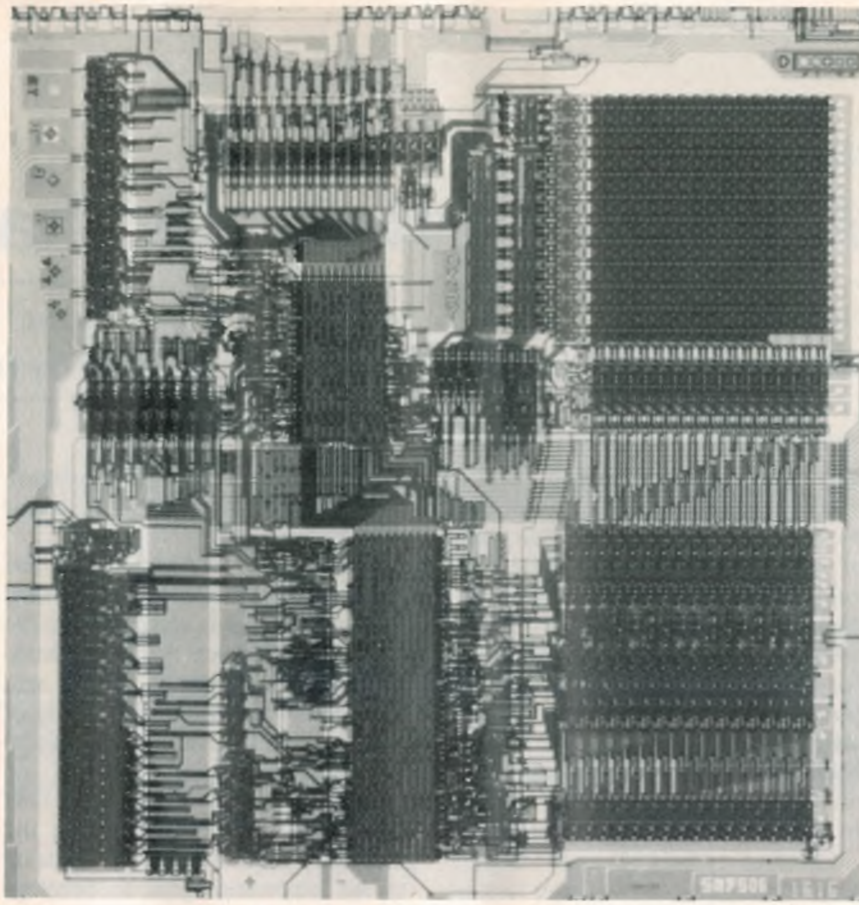
Threat? How much of a threat I^2L techniques are to enhanced-MOS technology such as double-poly or V-groove MOS also will be hotly debated at several evening panels during the conference; semiconductor-device specialists and users alike can judge for themselves how much the two technologies overlap.

For example, panelist Leslie L. Vadasz, Intel's vice president of engineering, maintains that n-MOS performance simply will continue to improve and slowly push bipolar designs into a smaller and smaller corner of the product spectrum—to be used only where all-out speed is



Which way? Of the two approaches to next-generation MOS performance—D-MOS (top) or V-MOS—companies like AMI are backing V-MOS because of its size advantage.

Mini. Toshiba's 16-bit minicomputer controller on a single chip is built with improved n-channel silicon-gate technology. Logic structures are very dense.



the principal consideration and system cost is no inhibition. On the other hand, Fairchild's Thomas Longo, vice president and general manager of the IC group, whose direction (along with research-administrator James Early) led to the 4-kilobit I²L RAM, maintains that injection logic will have a major role in computer-circuit design where it's too costly to make MOS perform—such as in sub-100-ns RAM and possibly in 100-ns-per-cycle LSI-processor families.

As for I²L competing with MOS directly, Longo foresees no profit in rebuilding today's n-MOS products with I²L—he's using MOS to do that. The trick with I²L, Longo proclaims, is to "project the moving target of MOS performance and aim injection logic at products out of that range."

Aiming. Helping to find the range of that moving target will be a half dozen MOS developments made public at ISSCC. Among those to be described are:

- A 4,096-bit static RAM from American Micro Devices—the first 5-V static to reach that density level.
- A 16-bit MOS ROM built by American Microsystems Inc. with V-groove technology that is both denser and faster than straight silicon-gate ROM designs.
- A 65-kilobit block-addressed CCD memory for replacing troublesome moving-disk systems. This design from Mnemonics, a new company in Cupertino, Calif., is four times denser than commercially available CCD memories.
- A 16-bit minicomputer controller on a single chip built with an improved n-channel silicon-gate technology. Designed by Toshiba in Japan, the logic structures are so dense that, in addition to the 16 registers, the chip contains 255 input/output ports and can address 16 kilobytes of memory.
- A continuously charge-coupled random-access-memory (C³RAM) cell designed by researchers at Siemens AG in Munich that's only one third the size of cells built with the latest two-level MOS technology. Operating with an access time of 250 ns, this design, which combines single-transistor memory cells with MOS transmission lines, may well point to the next level of memory integration—the 65-kilobit RAM chip.

Equally important is Intel's new n-MOS static RAM, which breaks the 100-ns speed barrier by harnessing depletion-load techniques to silicon-gate technology. The 1-kilobit design, which operates directly from a single 5-V supply, will surely compete directly with 1-kilobit bipolar RAMs for a piece of the buffer and add-on market. Its success will depend largely on whether a 4-kilobit I²L design, such as the one Fairchild is disclosing, will cost less per bit than fast 1-kilobit MOS static devices. Fairchild's production experiences during the next 12 months with large I²L chips will tell the story.

Groovy. A sleeper at the conference is V-MOS—a technique somewhat similar to double-diffused MOS structures (see diagram), but an insulated V-grooved notch is used to access a buried source. In essence, the technique reduces cell sizes by vertically integrating part of the MOS-circuit elements. For memory designs, this configuration reduces cell size and increases speed by reducing the device's source-to-drain capacitance.

Despite the problems V-groove isolation ran into several years ago in bipolar designs, the technology is gaining respect as a means of enhancing MOS-logic and memory designs. In the academic world, researchers at Stanford University and the University of California at Berkeley have been working on it. AMI and Electronic Arrays are committed to V-MOS technology in the next round of MOS designs—for RAMs and microprocessors, as well as ROMs. Clearly, the process, which cuts size in half and boosts speed significantly, can perform better than designs built by silicon-gate methods. AMI's ISSCC paper, presented by device specialist T. J. Rodgers, explains the process of making a fully static 16-kilobit ROM, powered by a single 5-V supply. □

Military

Are two efforts faster than one?

Navy divides All-Applications Digital Computer effort; one part has target of 1980 and the other is aimed at fourth-generation system

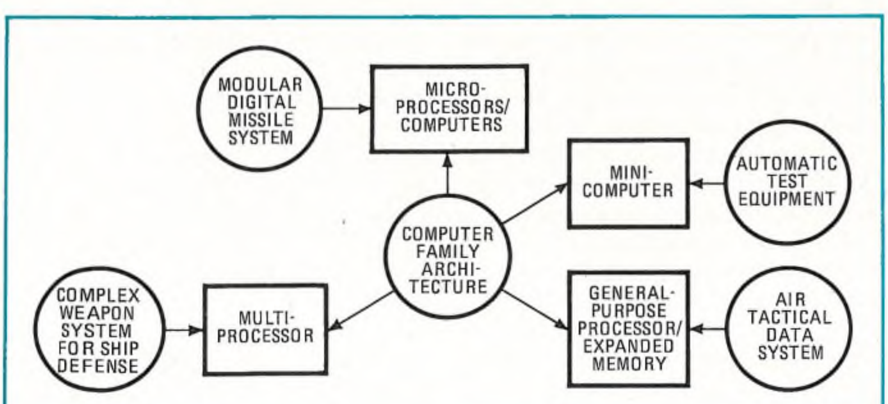
by Ray Connolly, Military Electronics Editor

The ancient Machiavellian precept of divide and rule is being employed by the Navy to overcome five years of false starts that have stalled development of a family of software-compatible computers for use in multiple weapons systems. Now, the All-Applications Digital Computer (AADC) program has been divided into two separate efforts by the Naval Air Systems Command. The original AADC program will move in January to the Naval Material Command, where it will receive greater visibility in the drive to lead a tri-service tactical-computer program that will truly serve all weapons users in the field and on ships, as well as in aircraft.

But first, for the next five years, there will be the newly named Standard Airborne Computer program and its AN/AYK-14(V) hardware package. First requests for proposals will be issued in March 1976 for 50 test systems, and selection is scheduled for August. The test computers are to be oriented for use with the new Navy F-18 air combat fighter and the Lamps (for light airborne multipurpose system) helicopter program.

Despite the name change, the goals of the AN/AYK-14(V) effort have not changed, according to the program's technical director, Ronald S. Entner. The program will push for development of a family of three minicomputers and microcomputers.

AADC's role. Where does that leave AADC? Navair officials say the plan will enable them to concentrate on the long-range goal of developing a family of fourth-generation software-compatible tactical minicomputers and microcomputers that will have even broader weapons-system applications by all military services. AADC project manager Bernard Zempolich says Navair already has an agreement to work with the Army Electronics Command's Communications/ADP Laboratory on the program. Discussions on a similar agreement are in progress with Air Force Systems Command headquarters.



One into four. Applications: microprocessors for a missile, minicomputers for automatic test gear, computers for an air tactical-data system, multiprocessors for ship defense.

The pressure for software compatibility among military computer systems to stem proliferation comes from the size of Pentagon software expenditures. Costs of software, its operation, and maintenance are now close to $6 billion annually, compared to the $1 billion to $1.5 billion spent on hardware, say defense officials.

Whereas the AN/AYK-14(V) will concentrate on standardization of relatively near-term airborne computers and begin with proven components like core memory, the AADC effort will embrace other weapons applications, such as ground-based and ship systems, as well. The computers will use large-scale integrated logic and memory circuitry. Officials in both the AYK-14(V) and AADC programs are anxious to come up with systems that will prevent the Army and Navy from becoming "locked in" with a single source of supply for tactical systems and the increased cost that such a practice implies.

If AADC does manage to pull together all three services in a unified effort over a period of five or more years, Pentagon sources envision an optimum 1980s market for 4,600 systems that breaks down this way: 1,800 aircraft, 1,500 remotely piloted vehicles, 700 automatic test systems, 500 surface ships, and more than 100 submarines. Although hardware for each application could vary, all would be software-compatible and employ the new higher-order language, tentatively called DOD-1. The new language, not yet specified, is being developed by a high-level Pentagon committee that represents all services. The choice is expected to become final by mid-1977.

The technological key to AADC's success, says program chief Zempolich, is the system's architecture. Computer architecture, he says, "includes the instruction set, registers, interrupts, and memory-address space. Architecture does not include hardware-implementation features such as cycle time, instruction look-ahead, memory interleaving, bus width, or cache memory."

Hardware-design issues need not affect the software, he points out. "A clear and clean distinction between the architecture and implementation details allows software to be transported between computers with the same architecture, even though they may have very different implementation features."

Approach. Just what does the Navy want? Even though AADC's implementation is still years away, the Navair program, which will get an Army deputy in January, proposes to use existing architecture. The threat of obsolescence is unlikely, in the military view. "Over the past decade or two, the vast majority of increases in computer performance have come about through changes in technology and hardware-design features—not through changes in architecture," Zempolich points out. "Many so-called advances in architecture—like cache memory, instruction look-ahead, and pipelining—are really advances in implementation techniques for increasing speed. Such advances are architecture-independent and can be incorporated into a computer without affecting software." As one example of this, Zempolich cites the evolution of IBM's System/360 into the software-compatible 370 series.

As for "jumping into new or radical architectures," Zempolich believes that "is a risk that the military should leave to the computer industry. Waiting for such undefined new architectures which are 'just around the corner' would only result in many years' further delay" in resolving the military's tactical-computer problems that include proliferation of more than 100 systems and expensive separate software packages. The AADC view is that tactical military computers have not kept pace with the commercial marketplace in software and hardware technology. "The least the military should do now," says Zempolich, "is take advantage of the best of what the technical marketplace has been offering."

Task. Defining the AADC architecture is assigned to the Naval Research Laboratory (NRL) and the Army's Electronics Command. Their goal is to select and validate a computer-family architecture by the end of 1976 from one of the seven existing commercial architectures. All existing proven military and commercial minicomputers and microcomputers are regarded as candidates. The Navy says it is not giving special consideration to systems it has already invested in, such as the AN/UYK-7 developed by Sperry Univac for the naval tactical data system (NTDS) or the Univac shipboard AN/UYK-20, because "the relative software investment is small, compared to the total Navy investment" in its more than 100 other processors. The Army has also invested in multiple tactical processors that are under consideration.

Other steps proposed under the Army-Navy AADC plan are tied to the following timetable, according to the interservice agreement:

- Award parallel competitive contracts by mid-1976 for highly microprogramable computers to emulate real-time third-generation tactical computers, as well as the preferred architecture candidates. Also, demonstrate software transportability between computers.
- Specify, solicit, and acquire via parallel, competitive contracts in mid-1976 plans for hardware for two computer-family concepts. Inputs for these plans would include Army-Navy user application requirements, the selected family architecture, software transportability for the third-generation tactical computers, and life-cycle cost data.
- Over-all program review at the end of September 1977 by Army-Navy management for a go/no-go decision on subsequent development. If one of the acquisition plans is approved, contract awards for advanced development models would follow in 1978 and continue for an estimated two years.

To carry out the joint effort, Pentagon officials say AADC's leaders plan "a formal methodology" dubbed ISDS—for integrated software development system—to convert tactical-user requirements into hardware, software, and firmware designs. Setting up the process will require some preliminary work in itself, including development of new, automated software tools such as a specification language/compiler, an analyzer, and an automatic documentation generator. Development of the specification language has already begun at Draper Laboratory, Cambridge, Mass., under contract to the Naval Electronics Laboratory Center in the first quarter of fiscal 1976. A static analyzer and automatic documentation generator were developed earlier at the Draper Lab.

Results of the ISDS would resemble those of the hardware-concept plan, officials explain. They include specifications for new software components as well as modification of existing software; alternate acquisition plans for new or modified software; and developing firm return-on-investment estimates for each acquisition plan. □

Licensing deals

Industry sources suspect that Sperry Univac, as supplier for the Navy's UYK-7 and UYK-20 tactical systems, may have a leg up in future AADC competitions to develop a new Army-Navy family of tactical processors. Nonetheless, the competition will be intense. Pentagon officials note that licensing arrangements developing between military and commercial computer makers—like Rolm Corp. with Data General Corp., Hughes Aircraft with Interdata, and Bunker Ramo Corp. with Digital Equipment Corp.—seem certain to provide strong competition for Univac.

Military plans to cover the costs of such licensing arrangements will be on a per-computer basis, officials report. Royalties on each computer manufactured and sold are expected to be "in the neighborhood of several hundred dollars per machine."

Companies

Broad digital-watch shakeout coming

Time Computer's Bergey says half the makers and assemblers will be out of business within a year

For all practical purposes, Time Computer Inc., the wholly owned subsidiary of HMW Industries Inc., didn't exist until 1972. It was created to develop and market one product, Pulsar, the first solid-state digital electronic watch. Today, Time Computer accounts for more than half of its parent company's income and at least one third of its sales.

No one company dominates the digital-watch market. But few would challenge Pulsar's leadership at the so-called high end of the market with prices ranging from $295 for its steel-cased models to its recently introduced solid-gold watch-calculator at $3,950.

Guiding this strategy has been John M. Bergey, president of Time Computer since its formation and a corporate vice president of HMW since last year. Before that he was director of research. What does the future hold for this still very young industry? How will Pulsar manage to compete with the new entries into the market? For the answers, *Electronics* editors interviewed Bergey. Here are excerpts from that interview.

Q. What is your short-term and long-term assessment of the digital watch market?

A. All of the figures we see suggest that there are now some 45 manufacturers and from 70 to 80 non-manufacturing marketers of digital watches. I believe we'll see this shrink to half as many by this time next year. The reason is that a lot of these people are simply taking advantage of a rapidly expanding market. They are not in it for the long haul; they're not concerned with establishing a brand name in the marketplace.

My long-term view is that by 1980 some 20% to 30% of all watches sold worldwide will be solid-state digital models. I also feel that in the early 1980s the unit and dollar volume will probably equal the conventional segment of the watch industry.

Q. Where does Pulsar fit into that picture?

A. We want to be an important and significant factor in the market, and that means we must have a brand name worldwide. This is what we are working toward. If you look at all the successful companies in the field—Rolex, Omega, Timex—you can see that they have very broad and total worldwide organizations. I think that's important to their success. Pulsar must be available just about everywhere in the world. You should be able to get the same service for a Pulsar in Madrid that you can get in New York.

Q. For some time, retailers would handle digital watches, but very few of them made an effort to promote them or push digital-watch sales over the counter. Has this changed?

A. They are promoting them, but we see this mostly in the major metropolitan areas. But some of these promotions may be misleading. Late entries into the market, because they are late entries, are playing catch-up, and one of the easiest ways to play catch-up, we're finding, is to support the dealers' promotions totally. There's nothing wrong with that, of course, except that you can't do that kind of thing forever.

Q. Where do you see the U. S. semiconductor companies who are in the digital-watch market fitting into the market?

A. I think they're using their international organizations as a mechanism to establish distribution and sales strategies. But I don't see the same kind of attention to detail throughout the world by a lot of U. S. electronics companies that I see from some of the international digital-watch companies. I don't think it will be possible for a U. S. electronics company to be a supplier alone and be successful worldwide. He will have to be a supplier and a marketer and everything that goes with that responsibility. He can forget about 30 days' price protection—that's not a worldwide concept.

Q. What is the outlook for the Swiss watch industry?

A. I think they 'll be forced to participate: I think there are signs now that their reluctance is cracking. I look for some rather significant joint ventures or buy-outs to get them into the solid-state digital-watch market. They will not depend on imported technology or imported components. The Swiss just can't import or export without adding some significant value, they must contribute something to the end product.

Q. How much time do the Swiss have?

A. If you accept as fact that some 75 million digital watches will be made in the world in 1980 and assume that this represents only 25% of the total watch production, then they have at least until 1980 because penetration of the market then will be only 25%.

But with lead times and opportunities what they are today, I think they have to be cranking out products within two years with substantial volume and guaranteed market. If they aren't, the Japanese will be right in there, filling whatever void is left by U. S. manufacturers.

Q. At what point does Japan become a factor?

A. Here we get back to the importance of a brand name. By far the largest watch manufacturer in Japan—Seiko—is not a pioneer in the digital-watch industry. Why? Because they can afford to sit back and let others plow the fields and plant the seeds. They can sit on their brand name and come in at harvest time. Pulsar didn't have that luxury. In 1971, we had to play that old game, "Bet Your Company."

Q. In the matter of technology, are you committed to light-emitting-diode displays?

A. Some of the new possibilities will not have the kind of proven reliability that I think Pulsar would need to be the first out with them. At Pulsar, we know that a lot of things are possible today. But we have to be careful not to get carried away with our own technological enthusiasm. I think liquid crystal has some future—it's not going to die. But other passive systems will have to be perfected before we seriously consider them.

Q. And integrated injection logic?

A. We're looking at I²L pretty closely, and we think it's a very strong contender for the watch business. One thing it would give us is a lot more horsepower in the same space, and that's important.

Q. So far, the Pulsar name has only shown up on digital watches. Do you plan to diversify into other products?

A. Yes—but I'm not ready to disclose what they are. □

Microprocessors

Smoke clears over 8-bit battle

Intel appears to have won the edge in mainframe peripherals, but Motorola's version has found its way into instruments

by Stephen E. Scrupski, Computers Editor

In travel, half the fun is getting there. But in 8-bit microprocessors, it appears that half the battle is getting there first. And, as Intel Corp.'s 8080 and Motorola Semiconductor's M6800 have slugged it out over the market for controllers of mainframe peripherals, it appears that Intel's first entry, the 8008, may have gained enough of a foothold to enable Intel to slip in with the improved 8080 as the standard chip for many computer companies. However, the 6800 has found applications in other areas, such as instruments. And auto makers are also looking at it.

There are several incentives for a large user of microprocessors to settle on one chip as a standard, which all its designers then will be encouraged to use. The first is keeping to a single one-time cost of characterizing the vendor's chips and approving them for use in the company's systems. This process must be repeated for every new part and, aside from the cost, it can be a rather nettlesome negotiating task and could even delay equipment design.

The second is for volume buying of just one type for lower prices. A bandwagon effect also has practical consequences—the company hopes that the device chosen will also be chosen by other users, who will also buy in volume, thus encouraging second sources to enter the expanding market and drive prices down further.

Standardizing software. And, for microprocessors, there is also the advantage of software—one part as a standard will mean that the company can afford to invest in design and application software that will be useful to many groups using the device.

"Standard" means different things at different firms. At Control Data Corp., Minneapolis, it simply indicates to a designer that all the work and the costs of selecting and qualifying the part have already been taken care of. But, if a designer can afford the time and cost of similar procedure for another part, he is free to specify it.

The NCR Corp.'s definition differs: "We do allow the use of other microprocessors where they're hidden and used only as a logic device. But we're forcing the use of the 8080 as a standard wherever the microprocessor wll end up being programed by our customer-service people or by the customer," says NCR's C. William Kessler, assistant vice president for engineering and advanced development.

Control Data started about two years ago to investigate the then-available 'microprocessor chips and "homed in on the 8008," says Harry R. Benjamin, general manager of the newly-formed small computer development division. When the 8080 came out in early 1974, it then was easy for CDC to move up to the improved chip, and the 8080 is now the standard in the company. "If the 6800 had been available when we started looking at the 8008," says Benjamin, "the decision could have gone differently." But Intel was there first." Kessler notes, "The Intel 8080 has been standard for us for quite a few applications." However, "that doesn't mean that we will continue to use it for everything. There will be future higher-speed appli-

What about 16-bit processors?

Since most original-equipment manufacturers having selected their 8-bit microprocessors, the appearance of the 16-bit versions has added a new element to the picture. The bigger processors are being made by Texas Instruments Inc., with its recently introduced 9900, National Semiconductor Corp. with its IMP-16 and Pace, and by General Instrument Corp.

The 16-bit device offers several advantages to the user. It permits greater system flexibility, increased throughput, and faster operation. But to gain these, the designer must alter his system considerably to handle the radically changed software required by the larger processors. Typically, mainframe-computer manufacturers have long lead times on planning and designing products, with equally long lifetimes for those products once they are introduced.

For example, Control Data Corp.'s Harry R. Benjamin, general manager of the Small-Computer Development division, says that the intelligent terminal his division is now producing contains Intel's 8-bit microprocessor, the 8080, which will probably be used at Control Data for at least the next two or three years.

For that reason, the consensus among mainframe houses is that it's too early in the game to predict how widespread will be the use of the new 16-bit processor chips.

cations that will require microprogramed microprocessors."

NCR presently is using the 8080 in a communications adapter, but for use between the company's model 770 automatic currency dispenser and the telephone line. In development are 8080-based controllers for flexible disks and printers.

Available. At Sperry Univac Computer Systems, Blue Bell, Pa., William F. Simon, director of product technology, says the situation with the 8080 is analogous to that with Intel's 1103 1-kilobit RAM. The 1103, which was perhaps less than optimum in performance, was available early in the game and was inexpensive, and it has gained widespread acceptance.

For current designs and near-term future designs, says Simon, "We feel that if an 8080 will do, we will use an 8080 because it's available, it's stable, it has multiple sources, and we would rather concentrate on a single type."

Timing on microprocessors can be crucial, Simon notes. Once a decision is made to use one, it's too late for others to come in. There is a "magic microsecond," he says. "Before that instant, it's too early because no one knows what to do, and one microsecond after the decision is made, we've already chosen, and you can't substitute anything."

While the 8080 seems to have captured the fancy of mainframe makers, the 6800 has made some inroads among instruments makers, such as Hewlett-Packard and Tektronix. And Chrysler Corp. is experimenting with the 6800 for auto applications.

Hewlett-Packard, which worked with Motorola during the 6800's design phase, uses the devices in its 9815A programable desktop calculator [*Electronics*, Sept. 18, p. 34]. Dougl Clifford, HP's project manager, says the Motorola part was selected because of its fairly fast operation, compatible chip set, and minimal requirements for external circuitry. "It's in complete control of the machine," he adds. And the 6800 has been designed by Tektronix into its new 4051 Graphic Computing System because, says a spokesman, "it offered better support circuitry." □

You and your career

Executive laments EEs' low status

International Rectifier's Lidow says decline in professional standards hurts industry, wants educational level raised

by Larry Waller, Los Angeles bureau manager

Crusader. Eric Lidow wants to improve EEs' status by raising standards through improved, regulated education.

"Engineers are second-class citizens in this country—they're not treated as professionals, but as skilled workers." Coming from a recently laid-off electrical engineer or a union organizer, such a statement wouldn't be surprising, but it's much more unexpected from the chief executive officer of a semiconductor firm whose stock is listed on the New York Stock Exchange.

Eric Lidow, chairman and president of International Rectifier Corp. of Los Angeles, is troubled by EEs' status because he sees its cause as basic: the decline in professional standards of the scientist-engineer. Furthermore, the effect of lowered professional standing cuts two ways, he believes, dragging down the competent engineer to the mediocrity of the mass and hurting companies that find themselves saddled with ill-prepared technical personnel who tend to make critical and damaging mistakes.

Lidow also believes he knows what's wrong: it starts with the quality of science and engineering college training. Basically, some schools do such a poor job of educating their students that all graduates become suspect. From the point of view of an electronics company, a personnel department is not prepared to evaluate candidates from schools out of their area. How can a West Coast personnel manager, for example, know whether the holder of an MSEE degree from a Southern or Midwestern university is qualified? Lidow is careful to note that the best U.S. schools produce professionals. "A degree in physics or engineering from Harvard or any top university still means the graduate knows his field."

In suggesting corrective actions, the soft-spoken executive is emphatic about where to begin. "We must clarify our academic qualifications. As they are now, degrees in themselves don't mean anything." Since it is too much to expect from schools themselves, Lidow thinks that professional engineers must undertake this on their own. A professional certifying body must examine the disorder, set educational standards that apply to every school, and see that the requirements are met. "Together with leading employers, the body could list the schools that comply."

While the IEEE would seem to be a logical organization to initiate the changes, Lidow has doubts. "It is dominated by functionaries employed by utilities, who don't understand the problems of the electronics industry."

While Lidow's firm hasn't instituted any of these changes, Lidow says he's contemplating some of them. However, he adds, one company acting alone won't have much effect on the over-all picture.

Along with maintaining technical standards, International Rectifier's chairman wants the engineer to have compulsory accounting and business courses. Without these, "he becomes boxed in with no understanding of the economic basis of business."

Lidow sees this shortcoming as a contributor to the career crisis of engineers over 40 who want to move into administrative jobs but lack the tools needed to make the transition.

Much of Lidow's criticism is shaped by his technical education in Europe at the technical university of Berlin, where he had to put in nine semesters of study and 15 months of on-the-job experience to earn his engineering degree. In Europe, he says, the scientist-engineer is still considered a top professional, enjoying a salary and social prestige equal to that of doctors and lawyers. Technical schools virtually throughout the continent offer a similar curriculum, and students receive a uniform education. Therefore, companies can be more certain about the quality of graduates they hire, he says.

Besides the bad experience of unknowingly hiring a second-rate engineer, an electronics company suffers in another way, says Lidow. It continually loses its top technical people, who leave to become entrepreneurs in order to develop their own ideas. "We have to find ways to reward them, perhaps in letting the inventor participate in the results of basic patents, as an incentive for creative thinking," he says. And certainly, in addition to money, the respect due to a recognized professional could be a big help in keeping a firm's most productive engineers content. □

What you must know about Microprocessors.

The microprocessor has permanently changed the methods of designing and building electronic equipment—from process and industrial control to computer-based designs in instruments, communication and consumer/commercial equipment.

But, getting into microprocessors is no snap. As a fundamental departure from the old familiar hard-wired logic techniques, the microprocessor technology has already produced a host of devices competing for the designer's attention, each with its own software and hardware.

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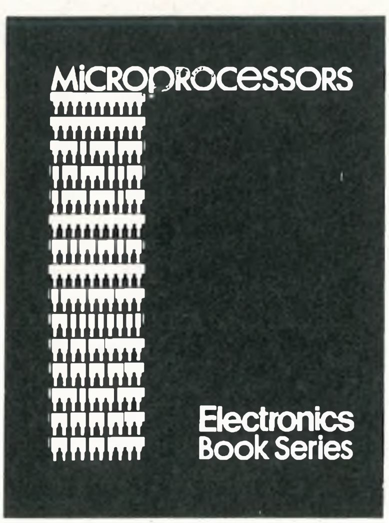

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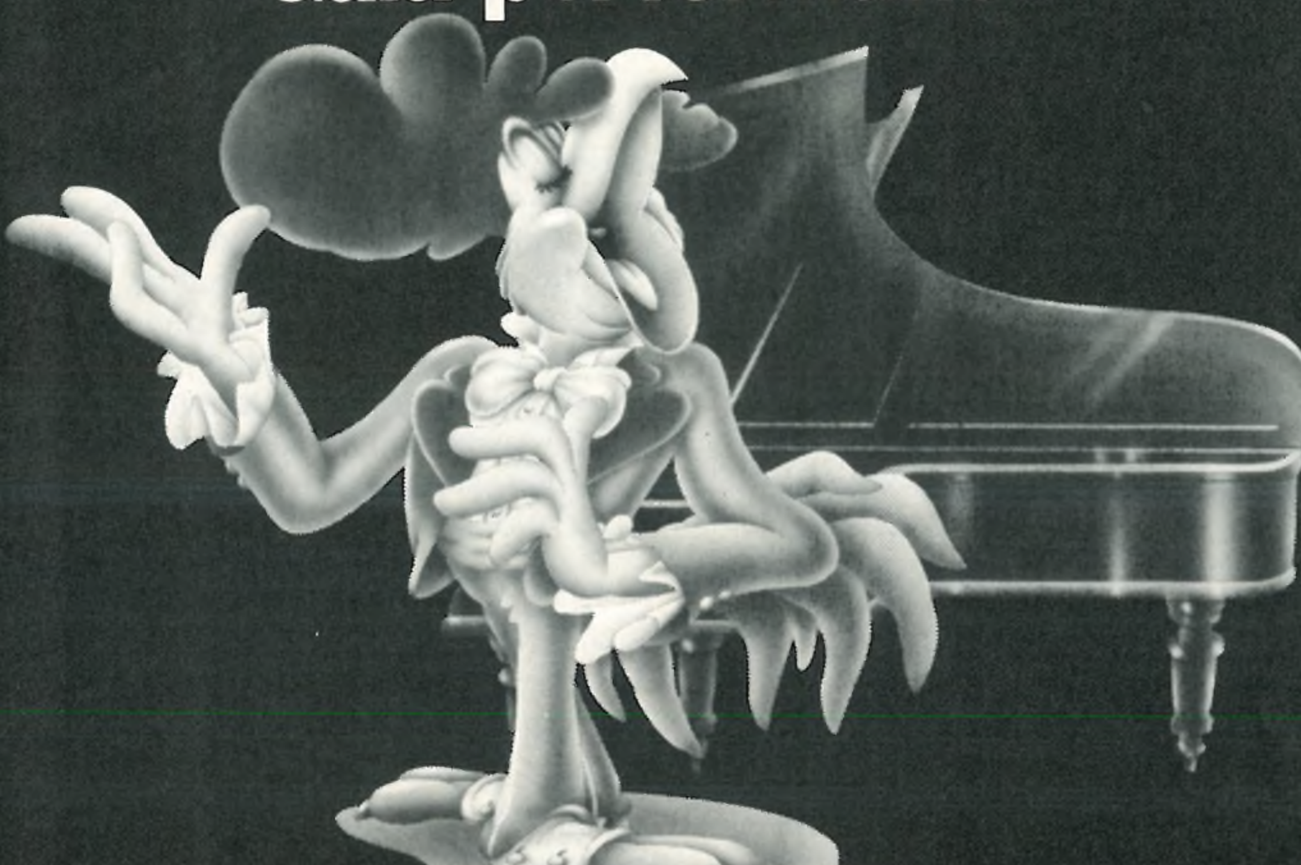

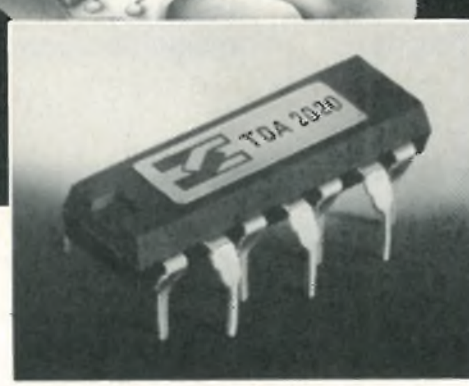

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Special report: film carriers star in high-volume IC production

by Jerry Lyman, *Packaging & Production Editor*

Automated bonding machines can package thousands of film-mounted ICs per hour with great reliability

☐ In a move that's gathering momentum around the world, more and more semiconductor manufacturers are adopting an automated film-carrier approach to assembling integrated-circuit packages. For the manufacturer, film carrier has meant lower production costs and higher profit margins on high-volume products. For the user, it means higher reliability at low prices.

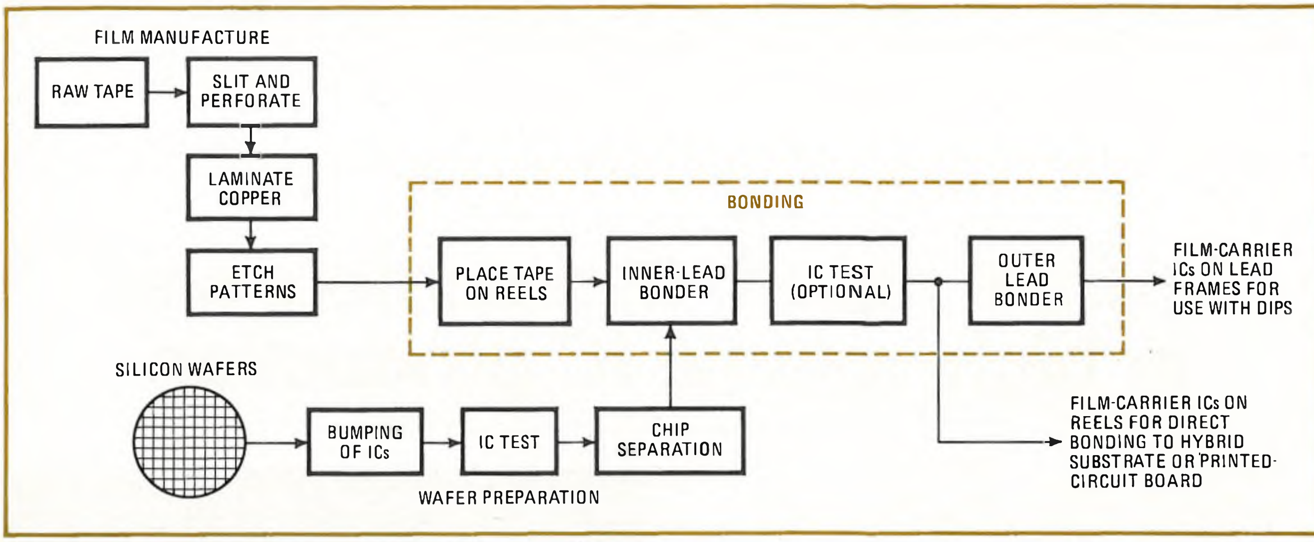
With the technique, thousands of IC packages can be produced per machine per hour. Using manual wire bonding, a single worker can process about 60 chips in the same period of time. Moreover, the wire bonds are weak, having a pull strength of only about 15 grams, and they also cause corrosion about their point of bonding, especially in plastic dual in-line packages.

The automated method derives from the Minimod film-carrier technique that General Electric developed in the 1960s [*Electronics*, Feb. 1, 1971, p. 44]. Its name comes from its dependence on a sprocketed, nonconductive film with a copper surface etched into spidery IC interconnect patterns. Reels of this film or tape are fed along with specially prepared IC chips into a bonding machine. When the tape emerges, it is studded with one chip to each interconnect pattern, ready for bonding by other machines to lead frames.

Alternative names for the process are film-carrier gang bonding, beam-tape automated assembly, and tape automated bonding. The gang bonding refers to the fact that all a chip's terminals are attached simultaneously and not serially to the copper interconnects, variously known as beams or leads.

But under whatever name, the technique lowers the cost of the IC to the user and also enhances its reliability. First, the IC terminal pads are protected against corrosion by special metallic barriers. Second, the gang bonding doubles bond pull strengths to 30 grams and more. Third, the thick copper leads, typically 3 mils wide by 1.4 mils thick, allow the chip to dissipate much more heat than it could through the 1-mil wire bonds.

In addition, the film-carrier method presents an engi-



1. ICs on film. Before the highly automated inner and outer lead bonding of ICs to film carriers begins, copper must be laminated to tape and etched into spidery interconnects, and wafers must have gold bumps added to the aluminum terminal pads of each integrated circuit.

neer with a new option. Instead of buying the film-carrier ICs already in DIPs, he can buy them on reels or strips of film to be soldered directly to rigid or flexible pc boards or hybrid substrates. In effect, the new method has produced an IC package—a frame of film—ideal for high-density packaging but with easily attachable leads.

Today, many, but not all, IC manufacturers and users in the U.S., Japan, and Europe have either adopted film-carrier assembly or are experimenting with it. In the U.S., much of the film-carrier output is small-scale transistor-transistor-logic ICs in plastic 14-pin DIPs. International companies are supplying MOS as well as bipolar ICs, both linear and digital, on reels and strips of film. Production rates worldwide range between 1,000 to 2,500 ICs per hour and are expected to rise even further soon.

Figure 1 charts the flow of a typical film-carrier or beam-tape manufacturing process. At the heart of the system is the inner lead bonder, so called because it bonds the chip terminals to the copper leads at their inner ends, round the square hole at the center of the copper interconnect pattern. Conversely, the outer lead bonder later attaches the outer ends of the leads to a metal lead frame for dual in-line packaging. Alternatively, the loaded tape is placed on a reel. Note that the nonconductive nature of the film becomes important when the ICs are to be tested on tape.

Preparing the wafer

Standard IC wafers cannot be used for the film-carrier process without modification. Normally thermocompression or alloy-type bonding is used to join the chip's terminal pads to the copper leads, and to protect the pads from collapsing under the pressure, a metal bump about half a mil high must be built up on each of them. Moreover, these bumps must include a barrier metallurgy system at their interface with the die. Otherwise, the heat will diffuse the bump metal into the die, where it will alloy harmfully with the silicon substrate or aluminum pad.

This barrier system, incidentally, also seals off the aluminum contact pads from corrosion. Thus it is one of the factors making the chips used for film-carrier work inherently more reliable than unmodified chips.

Many types and combinations of metals are used for the barrier between bump and die. They include chromium, copper, titanium, tungsten, nickel, and gold. A section of a typical gold bump is shown in Fig 2. To form the barrier in the bump illustrated, a layer of chromium is placed on top of the existing aluminum pad. Onto the chromium is evaporated a layer of copper 2,500 angstroms thick followed by a 1,000-Å layer of gold. Finally, a gold bump about 4 mils square in area and 0.5 to 1 mil high is plated on.

An alternative way to add bumps is in use at RCA's Solid State division, Somerville, N.J. There, gold bumps are built up over successive layers of silicon nitride passivation, titanium, platinum, and gold.

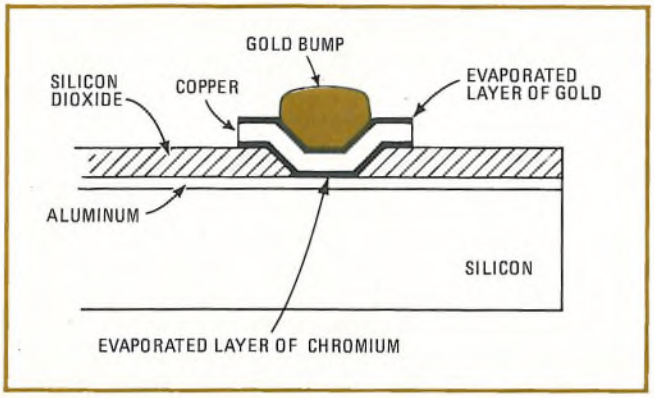
Keeping chips in their place

After construction of the bumps, the ICs in a wafer are all tested, and any rejects are marked. Next, to allow for individual chip handling, the wafer is stuck to some sort of adhesive base before being sawed apart.

At National Semiconductor Corp. of Santa Clara, Calif., for instance, the wafer is mounted on a flat substrate with a proprietary heat-released adhesive system and then sawed through just to the substrate. Other manufacturers simply attach the wafer to a plastic base by a layer of wax before cutting it apart. In both cases, the heat of the bonding process later on is enough to soften the wax or adhesive and release the chip.

To anyone contemplating going into beam-type assembly, the choice of tape or film must seem quite bewildering. There are three tape constructions (single-layer, two-layer and three-layer), at least eight tape widths (8, super 8, 9, 11, 14, 16, 35, and 70 millimeters) and four film materials (polyimide, polyester, and the as-yet developmental polyethersulfone and polyparabanic acid).

At present, the tape used in commercial applications



2. Adding height. To resist bonding pressures, chips used in the film-carrier process need special gold bumps built up on their normal aluminum pads. Metallic barrier between bump and pad protects the aluminum from alloying with the gold and also from corrosion.

is three- or two-layer in instruction. Single-layer tape is simply copper foil, and though some experimentation is going on with it, it is still in the laboratory stage (see "The film-less film carrier," p. 64).

Three-layer tapes were used on the original Minimod, and they are still the most widely used today. This type of tape consists of copper foil 1.4 mils thick that is bonded to polyimide film with a layer or barrier of polyester or epoxy base adhesive. Normally, the polyimide film is bought in large rolls, coated on one side with adhesive, and slit to the correct width. The sprocket holes and all other openings, such as the square holes for the IC chips, are punched out, and the tape is then laminated to the copper foil. Next, the foil is selectively etched into the radiating patterns that form the IC interconnects and, as a last step, the beams are plated with gold, tin, lead, or solder. The tapes come in the so-called cine widths—8, super 8, 16, 35, and 70 millimeters.

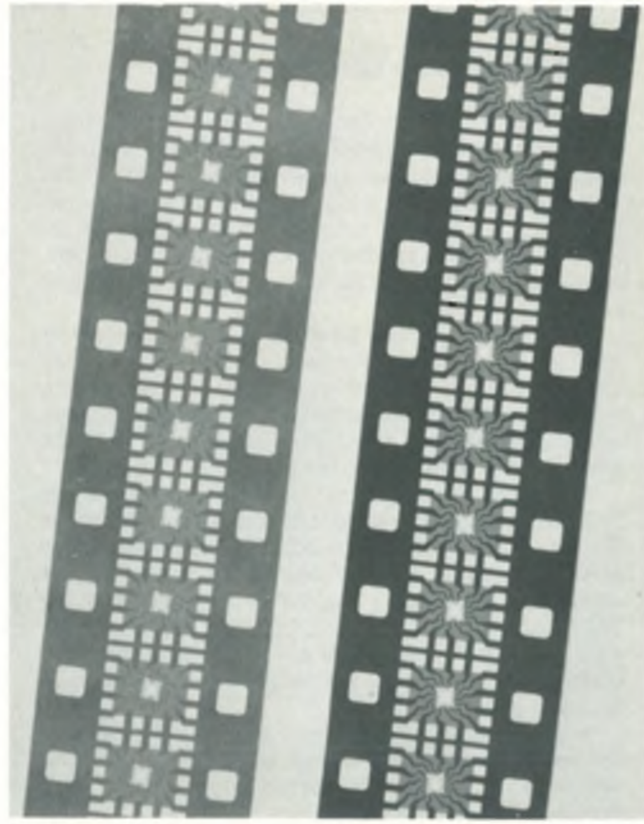
A disadvantage of this tape type is the middle layer—the adhesive, which is rated for only 20 to 30 seconds at 200° C and therefore limits the temperature at which the tape can later be processed.

Doing without the glue

The adhesive layer is eliminated in the two-layer tape originated by and still unique to the Electronic Products division of 3M Co., St. Paul, Minn. 3M developed a proprietary method of casting a layer of 0.5-mil-thick polyimide onto rolled, annealed 1-ounce copper foil. Subsequent manufacturing steps involve applying resist and developing an image of the interconnect on both sides of the tape, milling the polyimide chemically, and etching the copper.

Views of both sides of a typical 3M tape are shown in Fig. 3. It comes in 11- and 16-mm widths and will soon also be available in a 14-mm width.

The temperature limitation on the two-layer 3M tape is set only by the thermal characteristic of its cast polyimide—about 400°C. On the other hand, the thinness of the polyimide requires the copper foil to extend the full width of the tape, to strengthen the sprocket holes. This is unnecessary on three-layer tape, which is easier to manufacture in this respect.



3. Adhesiveless film. Top and bottom views of a two-layer tape, manufactured by 3M Co., show layer of copper plus a layer of polyimide film. Temperature-limiting component of this tape is the polyimide film rather than the adhesive used in three-layer tapes.

As must by now be obvious, most beam tapes currently being manufactured use as their base a polyimide film that costs about $30 per pound. The other option is polyester film, which costs only $3 or so per pound. However, a polyimide-based tape can survive 400°C for a short time, whereas polyester is limited to 160°C.

This difference is important if the film-carrier ICs are to end up in DIPs. Carmen Burns, director of National Semiconductor's automated assembly program, chose polyimide "because of the temperature bonding requirements of molding a DIP to a lead frame." Other companies prefer polyimide because it exhibits less thermal shrinkage than polyester.

Nevertheless, polyester has its uses. It can serve as a structural carrier when the IC is removed from the film, say, in a hybrid application.

Two new film materials in development are polyethersulfone (PES) from ICI United States Inc. of Wilmington, Del., and polyparabanic acid (PPA) from Exxon Corp. Each costs about half as much as polyimide and is classified as a Type H (high-temperature) film, though their maximum short-term temperatures are lower than for polyimide—the figures are 220°C for PES and 275°C for PPA.

Of the two, PPA is at the earlier stage of development, and other information on its characteristics is very sketchy. PES, on the other hand, is available in developmental quantities and is currently being evaluated for use as an IC carrier by major IC and film companies. Ac-

The film-less film carrier

The film in present film carriers preserves the configuration of the fragile copper IC interconnect or spider and acts as an insulator. But its presence adds to the final cost of the IC. In addition, many plastics contain metallic ions that could contaminate an adjacent chip. For these reasons, several companies are now experimenting with etching IC patterns on copper foil unsupported by plastic film.

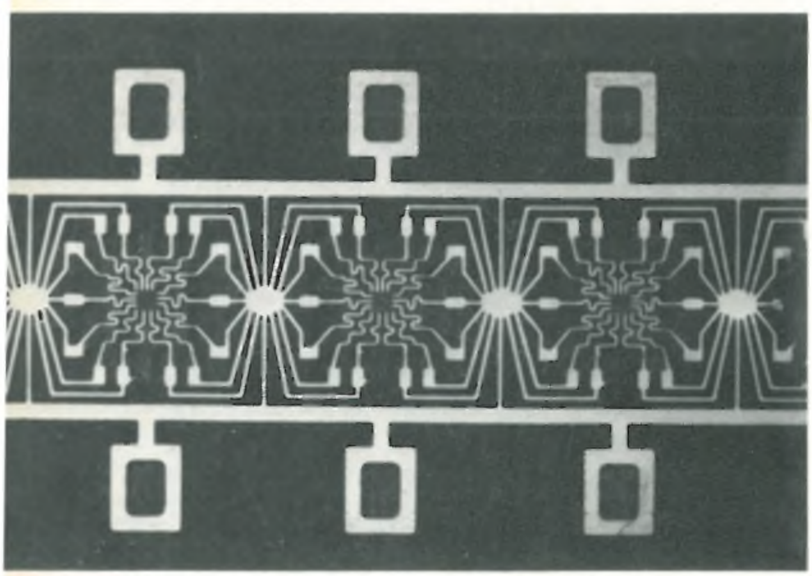
According to Dmitry Grabbe, a staff engineer at AMP Inc., all-copper automated bonding systems may be less than two to three years away. These systems will use 3-mil-thick copper foils etched from both sides and should dissipate heat better than the 1.5-mil-thick copper foil of present film carriers.

There are a couple of drawbacks, though. As Thomas Angelucci, president of International Micro Industries, points out, "An all-copper system will not be possible to test in process—say, at the point where all inner bonds are made and the semifinished ICs are reeled up. Only an insulated tape is capable of this. Also, present-day machines are designed to run with plastic films, not copper foil, so considerable machine redesign may be needed."

In any case, all-copper tapes are a good possibility for low-cost DIPs containing small-scale TTL ICs, when these need not be tested prior to outer lead bonding. However, for LSI chips that require testing, two- and three-layer tapes are a better choice.

cording to Charles Miller, manager of new products at ICI United States Inc., it has better dimensional stability than polyimide film, absorbs less moisture, and doesn't tear as easily. But it also is flammable and is attacked by some common solvents. In addition, this new material is potentially suitable for flexible printed circuits and flat cables.

Which tape type or tape width is best? The proper choice of tape width is determined by IC die size, number of leads, and the chip heat dissipation required. Sometimes users go to large tape formats simply to provide test points which are later chopped off. Figure 4, for instance, shows a tape with 14 discrete test points per frame interconnect pattern.



4. Test points on tape. A 16-mm beam tape allows on-tape testing of chips following the inner-lead-bonding step. A test point is attached to each lead, but is removed before final outer lead bonding.

As for the relative advantages of two- and three-layer tapes, both types are currently being used for bipolar, metal-oxide-semiconductor, and complementary-MOS ICs without any special problems. In fact, as Arnold Rose, manager of packaging technology for RCA's Solid State division, observes, "What really counts is the cost-effectiveness, delivery capacity, and reliability of any tape system."

Many large IC manufacturers and users in the U.S. and overseas choose to make their own tapes. They include Texas Instruments, Fairchild Semiconductor, Motorola Semiconductor, and Honeywell Bull.

Those who prefer to buy tape can obtain the three-layer type with copper patterns already etched on it from International Micro Industries, Cherry Hill, N.J., and AMP Inc., Harrisburg, Pa. Three-layer tapes with unetched copper foil and prepunched sprocket and IC holes are available from Rogers Corp., Chandler, Ariz. Only 3M Co. and AMP Inc. supply two-layer tapes.

Inner and outer lead bonding

Automation really enters the beam-tape assembly process in the action of two complex machines, the inner lead and outer lead bonders (Fig. 5). Inner lead bonding mates the IC chip to the patterned film, while outer lead bonders fasten the tape-mounted ICs to a lead frame or substrate ready for packaging.

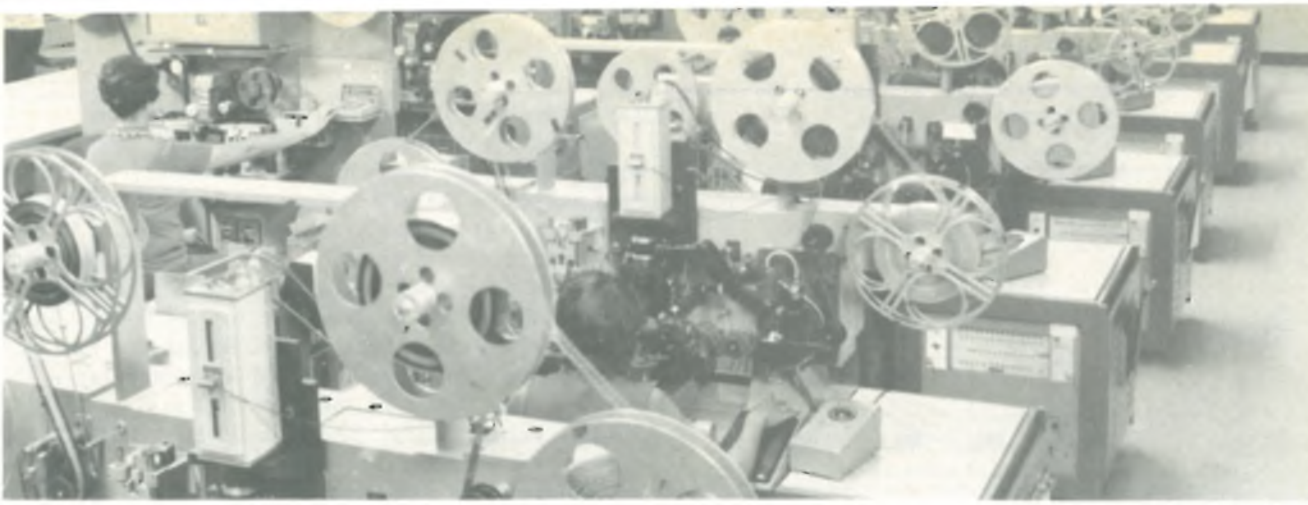
If the wafers have a high yield of good chips, all these steps can be done at extremely high speeds. The rate can range from 1,000 to 2,500 units per hour in the inner lead bonder.

The type of inner lead bonding used is determined by the metallurgy of the chip bumps and the tape beams. A popular system uses thermocompression bonding of gold to gold—gold bumps to gold-plated copper beams. Here, the heat and pressure between them force the mating parts to adhere.

Typical bond parameters for such gold-to-gold bonding of a 14-lead device, as supplied by Jade Corp. of Huntingdon Valley, Pa., are: a dwell time of 0.25 second, a bond force of 1.25 kilograms (for a 14-pin device), and a thermode or bonding tool temperature of 550°C. In this method, bonding temperature may fall anywhere between 300° and 700°C, and it is held at a constant level.

Another method, eutectic bonding or pulse soldering, is used to bond gold bumps to tin- or lead-plated copper beams. A temperature pulse is put into the thermode, producing 280°C for less than half a second and causing a gold-tin alloy to form between the bump and the plated beam.

The diagram in Fig. 6 illustrates the process of automated bonding. The first step is to align the chip's bumps to a particular beam pattern. This normally requires using a microscope, sometimes in combination with closed-circuit television. Next the bonding ther-



5. Manufacturing. Texas Instruments' large-scale film-carrier automated manufacturing facility has a production rate of 2,000 ICs per hour and, with the recent addition of improved machinery, a potential of 400 ICs per hour. Present output of this line is TTL LSI in DIPs.

mode descends and applies heat and pressure, joining all beams and bumps at the same time and also melting the adhesive or wax holding the chip in place. In the third step, the thermode rises and the array of as-yet unbonded chips is lowered, leaving the newly bonded chip stuck to the copper pattern on the tape. Finally, a new tape pattern and chip move into position for the next operation.

Outer lead bonding connects a film-carrier beam to the outside world via a DIP lead frame, hybrid substrate, or a flexible or rigid printed-circuit board. The ideal automated outer lead bonder should therefore have interchangeable heads capable of thermocompression bonding, reflow soldering, and welding. But in fact, only machines with interchangeable thermocompression-and eutectic-bonding heads are at present commercially available.

Jade Corp. has one of the few commercially available machines that thermocompression-bonds copper beams to a metal lead frame. It operates as shown in Fig. 7. The bonded chip and interconnect are removed from the tape by a punch and raised against the lead frame. A thermode forms all bonds in one stroke. Then the punch is retracted, and finally both the lead frame and tape are indexed.

Once more, many manufacturers and users make their own equipment, both inner and outer lead bonders. An example is the extremely large group of tape bonding machines, shown in Fig. 5, that are in use at a Texas Instruments manufacturing facility.

Only three U.S. machinery manufacturers currently supply commercial bonders suitable for film-carrier work. Industrial Micro Industries, Cherry Hill. N.J., has automatic, semi-automatic, and manual inner lead bonders suitable for thermocompression or eutectic bonding. Jade Corp. has manual and automatic inner and outer lead bonders that use the same two types of bonding. Kulicke and Soffa Industries Inc., Horsham, Pa., has made custom automatic outer lead bonders for welding film-carrier ICs to DIP metal lead frames. Prices of these bonders range from $11,000 to $33,000.

Most U.S. companies, particularly IC manufacturers, jealously hide almost all details of their automated tape-assembly operations. Least reticent are Texas Instruments, National Semiconductor, and RCA, while Fairchild and Motorola Semiconductor Products at least acknowledge that they have film-carrier manufacturing facilities. Bell Laboratory's facility at Allentown, Pa., and Honeywell Information Systems (HIS), Phoenix, Ariz., also maintain film-carrier manufacturing capabilities.

Behind the film curtain

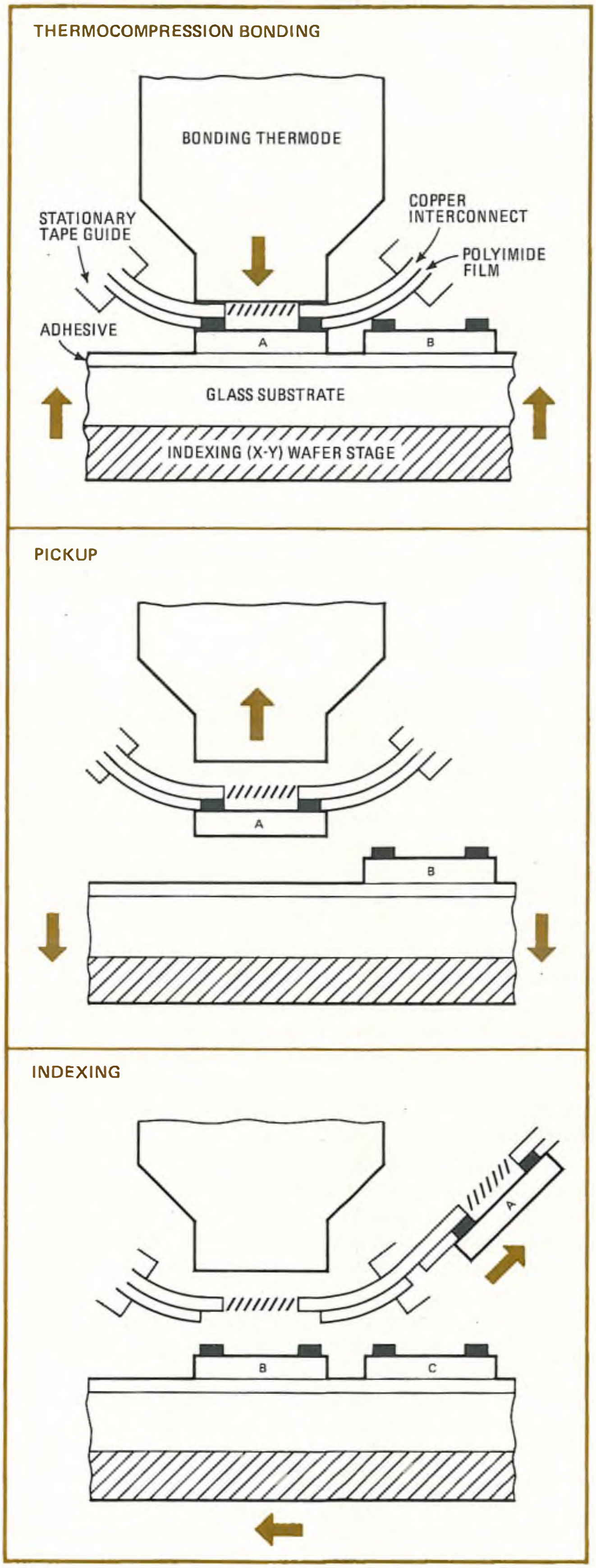
By acquiring the original Minimod from General Electric's Integrated Products department, Syracuse, N.Y., around 1971 or 1972, Texas Instruments has by now built up the most experience in the film-carrier process of any U.S. firm. Since then, the Dallas firm has invested in and modified the process extensively. Today it makes its own three-layer, 35-mm polyimide tapes and has developed its own bonders to turn out mainly TTL ICs of the 14-pin variety. Production rates of 2,000 units per hour have been achieved, and newly installed equipment is expected to increase that figure soon to 4,000 units per hour.

National Semiconductor is perhaps the second largest producer of dual in-line packages containing film-carrier TTL ICs. This firm's beam-tape operation is based on an 11-mm-wide, two-layer polyimide 3M tape, handled by Jade Corp. inner and outer lead bonders with thermocompression heads.

According to Carmen Burns, director of National's automated assembly, the Santa Clara company has been using what it refers to call its "inner lead-bond micro-interconnect system" for about two and half years. Burns has definite views on the terminology of this field.

"It is not accurate to call our system either a beam-tape system or a film-carrier system," he says. "Both designations are inaccurate both when referring to our own work and to what is going on generally. I prefer the term automated micro-interconnection technology, which involves connecting the small geometry of the die to the larger geometry of the punched lead frame or substrate with copper beams."

He explains that "the technology that National developed does not use film as a carrier. Instead the copper is used as the carrier. The film is used to support the copper structure; the small film interconnects under the copper go to individual IC DIP pads to hold them stable during bonding and perform very little function in the



6. Automated inner lead bonding. When a chip is bonded to a tape pattern, the machine aligns chip and tape, a bonding head attaches bumps to beams, and a fresh chip and tape frame are reindexed.

way of mechanical support" of the copper pattern.

For about a year now, RCA's Solid State division has been in pilot-line production of film-carrier ICs packaged in DIPs. In the RCA system, trimetalized chips with gold bumps are thermocompression-bonded to a 3-M 11-mm tape etched with RCA-specified patterns. This tape is fed to an outer lead bonder for thermocompression bonding of the interconnects to lead frames. Jade Corp. bonding machines are used. So far RCA has successfully put bipolar linear ICs and complementary-MOS chips on tape. Most of them end up in 14-pin DIPs, though experimental 32-lead patterns have been achieved on the present 11-mm tape.

Motorola Semiconductor Products Inc. in Phoenix, Ariz., and Fairchild Semiconductor in Mountain View, Calif., are both large producers of film-carrier ICs, too. But outside of the fact that each uses a 16-mm three-layer tape format, very little is known about their film-carrier operation.

Slightly more is known about Bell Laboratories' film-carrier assembly method, which it has been evaluating for about two years. Today, its Allentown, Pa., facility has a developmental operation assembling Bell's own bipolar and MOS ICs onto a two-layer, 11-mm tape and then into 16- or 18-pin plastic DIPs. Both bonding equipment and tape were purchased from makers outside the Bell System.

Outside the U.S.

In Japan, Tokyo Shibaura Electric Co. Ltd. (Toshiba) and Nippon Electric Co. Ltd. (NEC) have both been applying a modified Minimod for about 18 months.

Toshiba uses a three-layer 35-mm polyimide tape and made all its equipment in-house. ICs are inner-bonded with a gold and tin eutectic process. Outer ends of the leads are solder-plated for attachment by the customer. The final package (Fig. 8) is tape with a molded encapsulation over the chip. Note the extra points on the beam tapes, for use in testing or as interconnects.

Toshiba's various film-carrier ICs contain the circuitry for the oscillator, frequency driver and pulse motor driver of an analog electronic watch. At present, production rates are about 500 units per hour. Since demand is small, the finished tape is supplied to customers in strip form rather than reels.

NEC also employs a 35-mm three-layer polyimide format with similar inner lead bonding and solder-plating of outer lead ends. Again the chip is protected with molded resin. The finished ICs, which are bipolar linear circuits designed for cameras, are sold either in strips or as individual devices. Production rate on NEC's in-house-designed equipment is about 400 devices per hour, but is expected to rise to 1,000 in the near future.

In Europe, Siemens AG in Munich, Germany, and Honeywell Bull, Saint-Ouen, France, are engaged in work on film carriers. Philips Gloeilampenfabrieken in Eindhoven, the Netherlands, is also known to be experimenting with the technology.

For nine months Siemens has been supplying customers with sample 24-pin bipolar linear circuits on film, for use in cameras, measuring instruments and hybrid circuits. The German company uses a super-8-mm, three-layer polyimide tape carrier and has already achieved assembly rates of more than 1,000 units per hour. It's now about to transfer the technique into full production. The finished products are sold in reels containing 1000 chips.

A hybrid approach

Of all the companies in Europe, France's Honeywell Bull has had the greatest experience with the film-carrier approach. The French computer firm prefers to call it tape automated bonding (TAB) and uses it specifically to automate the bonding of ICs onto multilayer thick-film hybrids. The procedure is already in use for prototype hybrid modules.

Honeywell Bull manufactures its own 35-mm three-layer tapes, using polyester (Mylar) film as the insulating carrier and tin-plated copper beams as the IC interconnect. François Gallet, manager for advanced development at Honeywell Bull, says "Mylar costs about one tenth as much as Kapton [polyimide], and in our technique the tape does not become a part of the final package and thus doesn't need the stability of Kapton."

Strictly speaking, the film-carrier ICs at Honeywell Bull do not wind up in any kind of package. Instead, after all film has been removed, the gold-bumped mounted chips are soldered onto small alumina substrates measuring 1 by 1 or 2 by 2 inches and containing three thick-film screen-printed layers of interconnects. In essence, the substrate is a multilayer printed-circuit board for unpackaged chips.

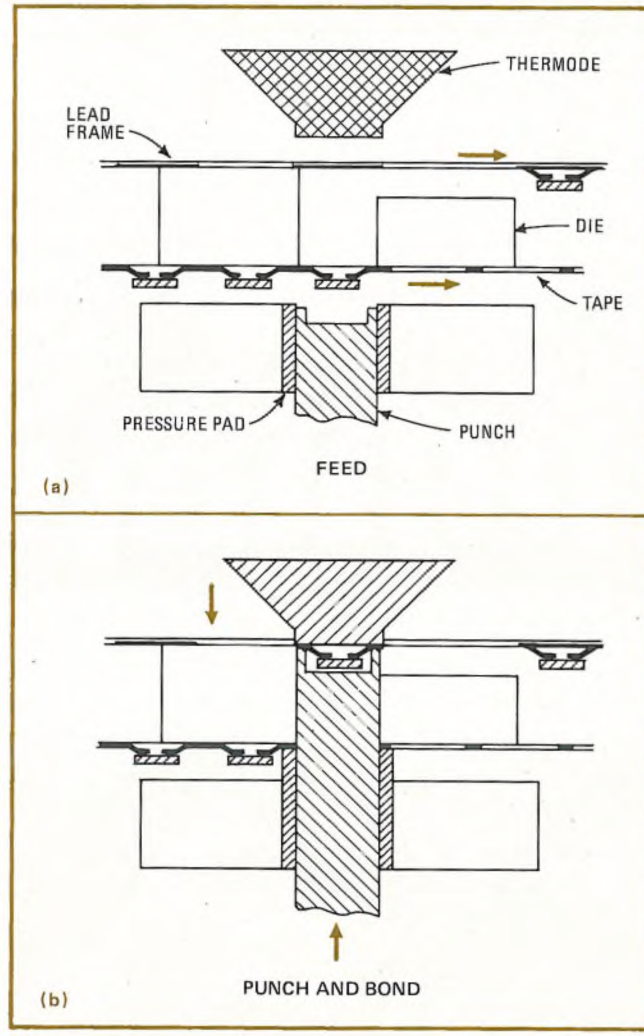
To date, the hybrid modules have carried bipolar logic chips for use in a central processor. Now the technique is being used for MOS memory chips and programable read-only memories and will be extended to C-MOS. Chips with as many as 40 to 60 connections have been mounted on substrates.

Honeywell Bull's tape has three zones: an inner zone that is bonded to the IC chip, a center zone that mates with the hybrid substrate, and an outer zone that provides connections for on-film testing of chips.

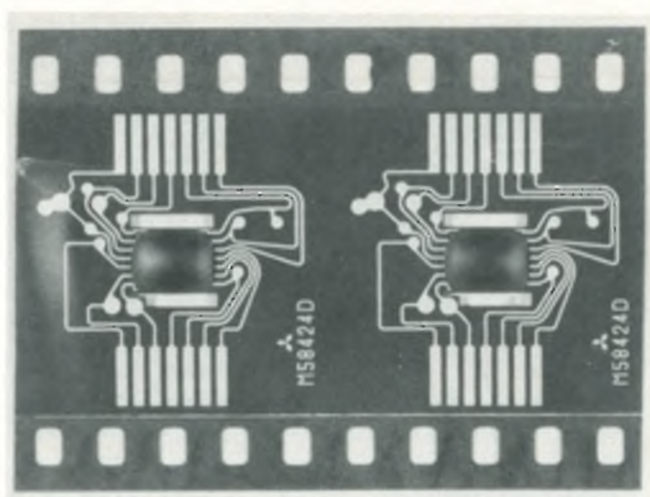
After inner lead bonding, all ICs on tapes are tested. Then an automatic machine developed by Honeywell Bull gang-bonds all the beams of the central zone of the lead frame to the hybrid's pads, and all unwanted tape is removed.

Back in the U.S., Honeywell Information Systems (HIS) of Phoenix, Ariz., is also doing prototype reliability and testing work with the tape-automated-bonding technology. But its operation differs from the French in some respects.

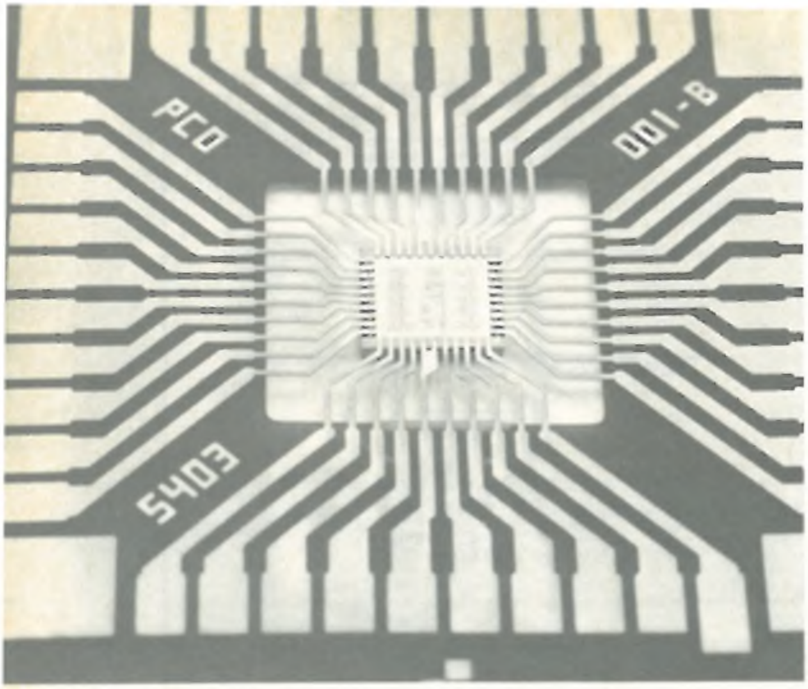
HIS uses a three-layer 35-mm polyimide rather than polyester, even though these chips, too, are excised from the film and end up in hybrid devices. Bipolar digital chips with gold bumps are gang-bonded to tin-plated copper leads (Fig. 9), and the bonded assemblies are spooled on reels and submitted to 100% electrical test. The tape from these reels then passes through equipment that excises the chip from the film, positions the device at a particular site on a pretested multichip hybrid substrate, and reflow-solders the formed leads to the substrate pads. Eventually, the hybrids end up in a large prototype computer system. A section of a HIS



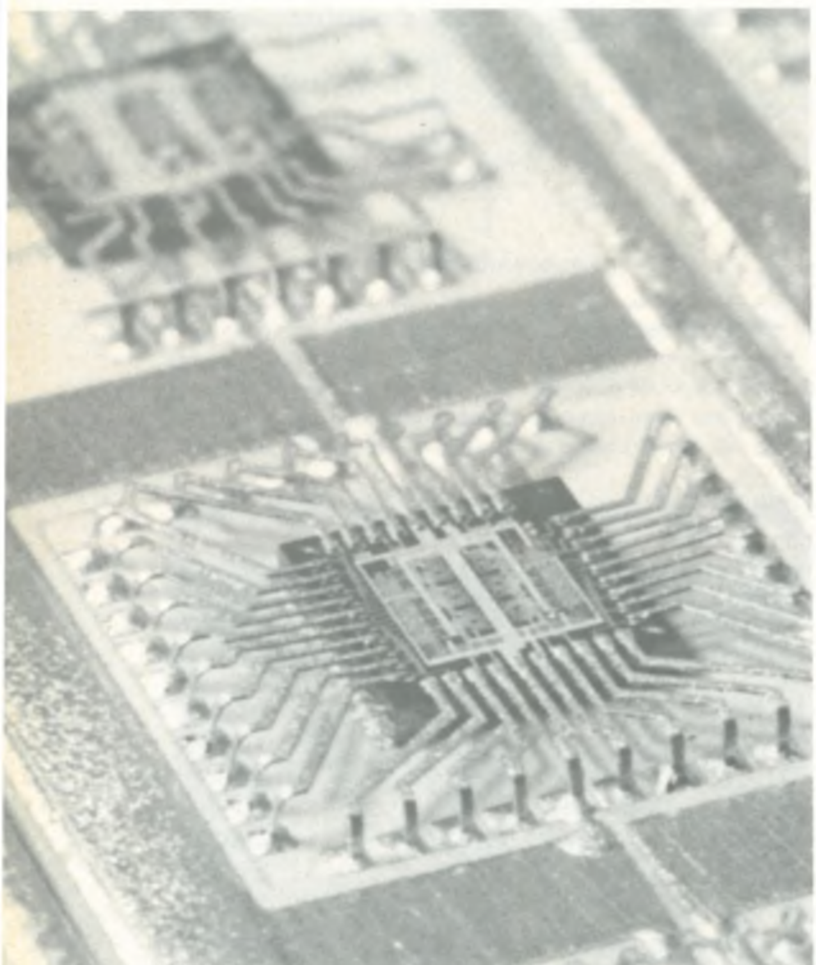
7. Beams to lead frames. Basic elements of outer lead bonding to a metal lead frame consist of: advancing both the tape-bonded chip and the lead frame, punching the device from the tape and bonding it to the lead frame, and then retracting the punch and indexing for the next IC. Welding or thermocompression bonding may be used.



8. Thirty-five mm. Toshiba film-carrier ICs, shown on a 35-mm three-layer polyimide-based tape, are sold to potential customers in film strips rather than in reels. Note the resemblance to a printed-circuit board and the molded encapsulation that protects the chip.



9. LSI on tape. This bipolar digital chip on 35-mm tape was manufactured by the tape-automated-bonding process at Honeywell Information Systems in Phoenix. After inner lead bonding, ICs are spooled onto reels and subjected to 100% electrical test.



10. A hybrid application. At HIS, Phoenix, reels of tape studded with LSI devices are sent through machinery that excises each chip from the film, forms its leads, and positions and solders it on a hybrid substrate. The hybrid is used in a prototype computer.

Phoenix multichip hybrid substrate is shown in Fig. 10.

Neither the Honeywell Bull nor the HIS Phoenix outer lead bonders are commercially available. However, such machines, and inner lead bonders, too, are needed in the potentially large military hybrid market.

The influence of the military

To quote Claire Thornton, director of semiconductor and integrated device development at the Army Electronics Command (ECOM) at Fort Monmouth, N.J.: "Fifty percent of the Army's electronics is going to be hybrid in format for a long time to come. Most of this material is now being made using conventional IC chips attached by wire bonding. The military prefers beam-leaded chips, but these have never been available in the right types and quantity. Now the Army thinks that film-carrier ICs with their substantial copper beams look like a direct reliable alternative to beam leads."

The Army Electronics Command is now evaluating bids from the hybrid industry to develop an over-all industry system for assembling film-carrier ICs into hybrids. The goal is low-cost reliable gang bonding of chips to substrates in small quantities of 100 to 1,000.

When the over-all material system and associated techniques are developed, small hybrid manufacturers will be able to put purchased chips directly on to film-carrier strips rather than reels, which in turn would be gang bonded to thick- and thin-film substrates.

The next few years

The technology of film-carrier systems still has room for improvement. Simplification of the metallurgy of the bumps and beam leads may be expected, possibly quite soon. At least one IC company has already produced an experimental copper-bump-to-copper-lead bond. Others are working on all-copper tapes (see "The film-less film carrier," p. 64).

Extensive environmental testing is also needed to fully establish the reliability of the method. Such test data is often supplied to individual customers by individual firms, but has not yet entered the public domain.

The major IC manufacturers will probably go on putting almost all their film-carrier TTL devices into DIPs. But as the technique spreads, more users will prefer to purchase film-carrier ICs on reels rather than in DIPs. Later, as low-cost manual inner and outer lead bonders become available, even quite small companies will be able to buy standard and custom chips, put them on tape, and package them just as they wish, whether in a plastic or ceramic DIP, a thick- or thin-film hybrid, or a flexible or rigid pc board.

Even now, film-carrier ICs soldered to flexible pc boards are being used in digital watches and cameras. A logical extension to this would be to eliminate the flexible board and to bond all the watch, camera or calculator ICs to specially designed copper interconnects on one or more film carriers. Indeed, several companies are currently working on such a step.

Eventually even light-emitting diode displays and their drives might also be put on film carriers. Such a method would radically cut assembly costs of consumer products like electronic watches and calculators. □

Getting the most out of C-MOS devices for analog switching jobs

by Ernie Thibodeaux, *Harris Semiconductor, Melbourne, Fla.*

☐ Although most designers appreciate the benefits of the complementary-MOS process for digital design, few realize how effective the technology can be for analog switching. C-MOS analog switches, which consume less power than bipolar devices, exhibit no dc offset voltage and can handle signals up to the supply rails. The C-MOS bilateral property furnishes input and output functions, making multiplexing and demultiplexing possible. In addition, the on-resistance of an MOS switch is as low as 30 ohms—a third as much as a bipolar device.

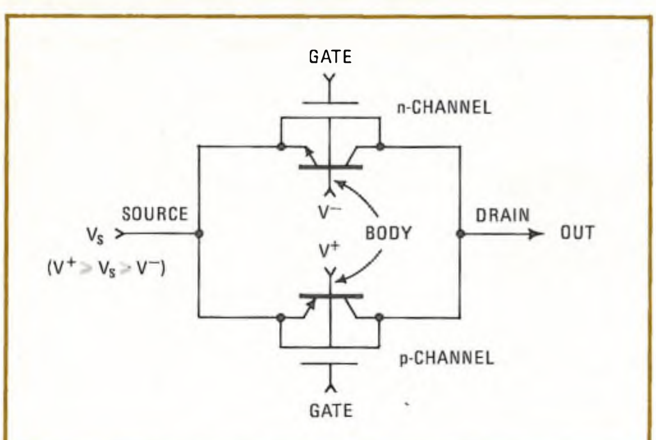
Unfortunately, C-MOS analog switches, which until recently were built with junction isolation, have been difficult to design into analog multiplexers and switches. The devices latched up easily, their C-MOS inputs were destroyed by electrostatic charges, and they literally went up in smoke when confronted with input overvoltage spikes and power-supply transients. To prevent destruction, costly external protective circuits were needed, and, even then, the devices latched up unless the power was turned on and off in a set sequence.

Because latch-up problems limited the use of analog switches so severely, device designers focused a great deal of attention on eliminating the condition. Recently, the success has been noteworthy. Indeed, three new technologies now offer latch-free analog-switch operation: latch-proof junction isolation (JI), floating-body junction isolation, and dielectric isolation (DI).

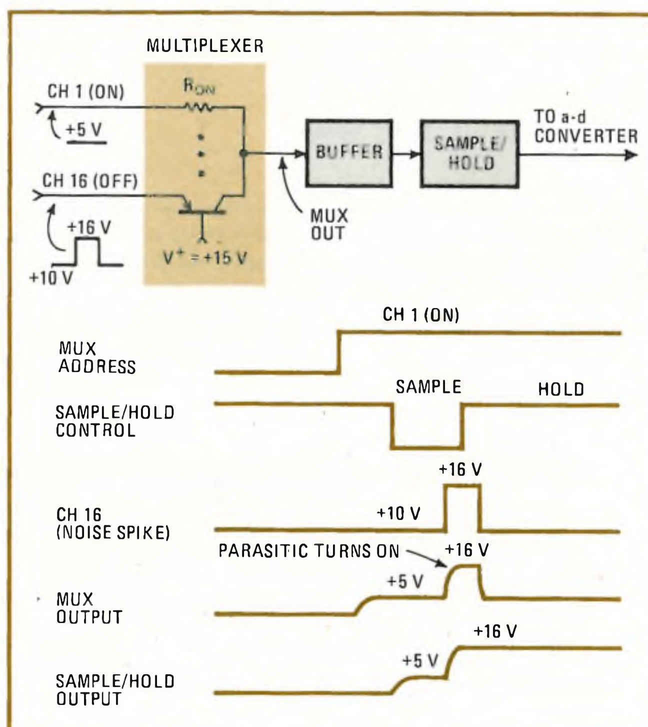
Both JI techniques are conventional processes that have been slightly modified to alleviate the old problem of latch-up. However, both of these JI technologies still require costly external protection circuits to guard against burn-out in such applications as analog-signal multiplexing that interface them with the outside world. That is why JI devices are best suited for internal-switching applications where the electrical environment can be controlled. In contrast, the inexpensive DI technology, by virtue of its construction, offers analog-switching devices suitable for many inside applications, as well as providing in-board analog protection for devices that interface with other circuits. Happily, the smaller substrate area of the DI device delivers a better speed-power product than the JI technology.

The basic C-MOS switch

The basic JI MOSFET transistor (Fig. 1) has parasitic junctions that are reverse-biased during normal operation. However, certain overvoltage conditions can forward-bias these junctions to cause high currents that could possibly destroy the devices.



1. Bad. In the basic C-MOS analog switch, the parasitic junctions are reversed-biased during normal operation. Large overvoltages, however, make them forward-biased and draw large currents.

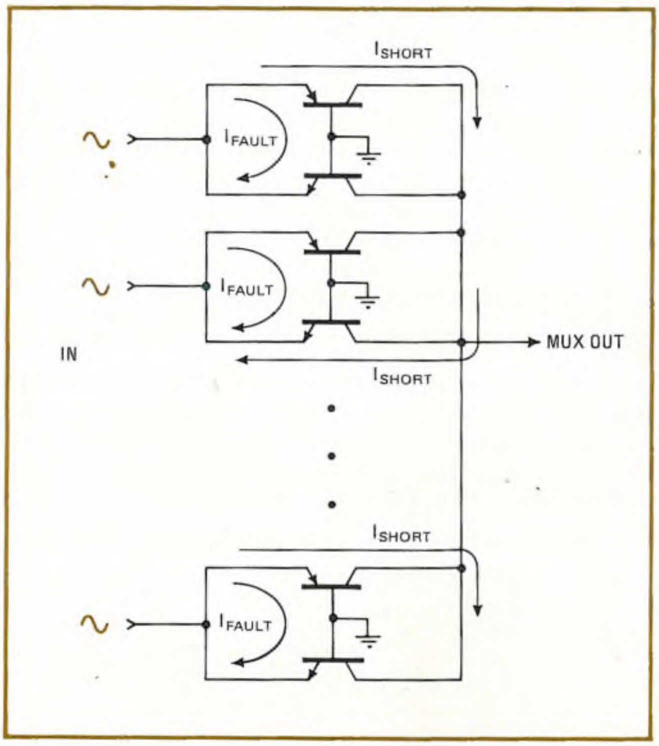


2. Worse. With JI devices, noise spikes can cause channel interaction. In this multiplexer, although channel 1 is only one selected, noise spikes cause cross talk in channel 16, which affects reading.

The parasitic junctions are actually npn and pnp transistors that are normally reverse-biased by the applied body potentials. However, because many analog switches, and especially multiplexers, are connected to their analog sources through long lines, they are highly susceptible to externally induced voltage spikes. For example, these spikes, which can often exceed the p-channel body potential, V^+, can inadvertently turn on a normally off switch through the parasitic pnp transistor (Fig. 1).

The n-channel device is similarly affected when the parasitic npn transistor is turned on by a negative overvoltage. This action, commonly known as channel interaction, causes momentary channel-to-channel shorting, which introduces significant errors in the system. This intermittent condition, which is seldom destructive, is rarely isolated because it occurs only randomly.

One of the adverse effects of channel interaction is illustrated in Fig. 2. Channel 1 of an analog multiplexer is selected when all other channels are off. Channel 16 receives an input-noise spike that momentarily exceeds the positive supply. The sequence causes channel 1 read-out to be +14 V because of interaction with channel 16 just before initiating the hold command to the sample-and-hold device. To prevent this annoyance requires additional protective circuits that clamp each channel input to a voltage below the threshold of the parasitics to ensure that the channels remain inactive under any conditions.



3. Still worse. Most serious in JI switches is losing substrate potential to ground. This condition, which happens when power is lost and the analog signal is present, causes very high currents.

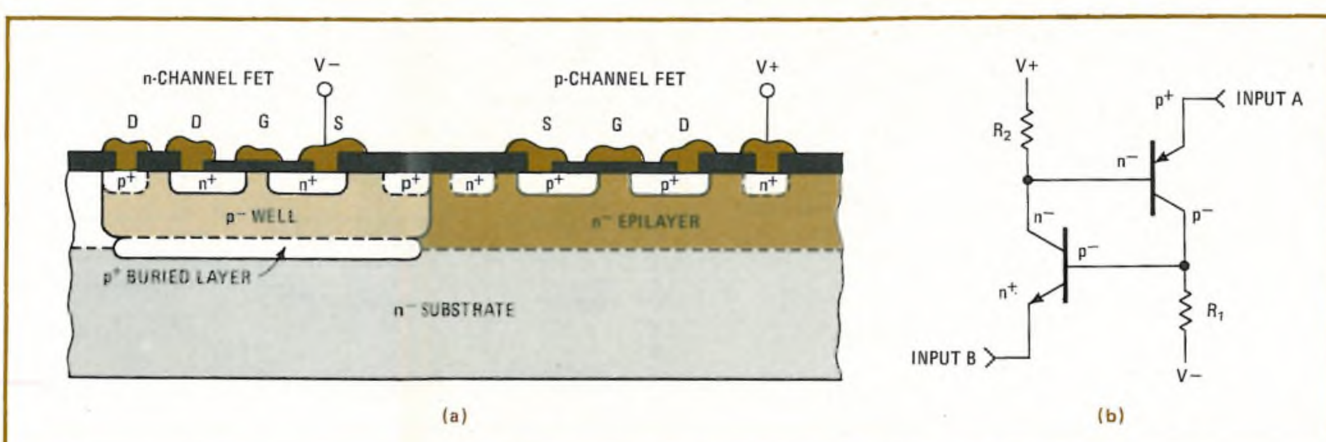
A more serious condition exists when the substrates (p^- or n^-) lose their respective potentials to ground (Fig. 3)—a condition that occurs when power to the device is turned off while the analog signals are still present. In this situation, the analog switch, which at that point represents a diode connected through the low impedance of the supply, draws high current from the analog source.

This current turns on the switch through its parasitics and shorts all channels to the output. These shorts can easily be catastrophic in multiplexer systems that have different power supplies for the analog source and the multiplexer switch. An error during troubleshooting or an inadvertent supply glitch can trigger this fault mode and destroy the whole system. Therefore, there is obviously much more to system reliability than having latch-proof C-MOS devices.

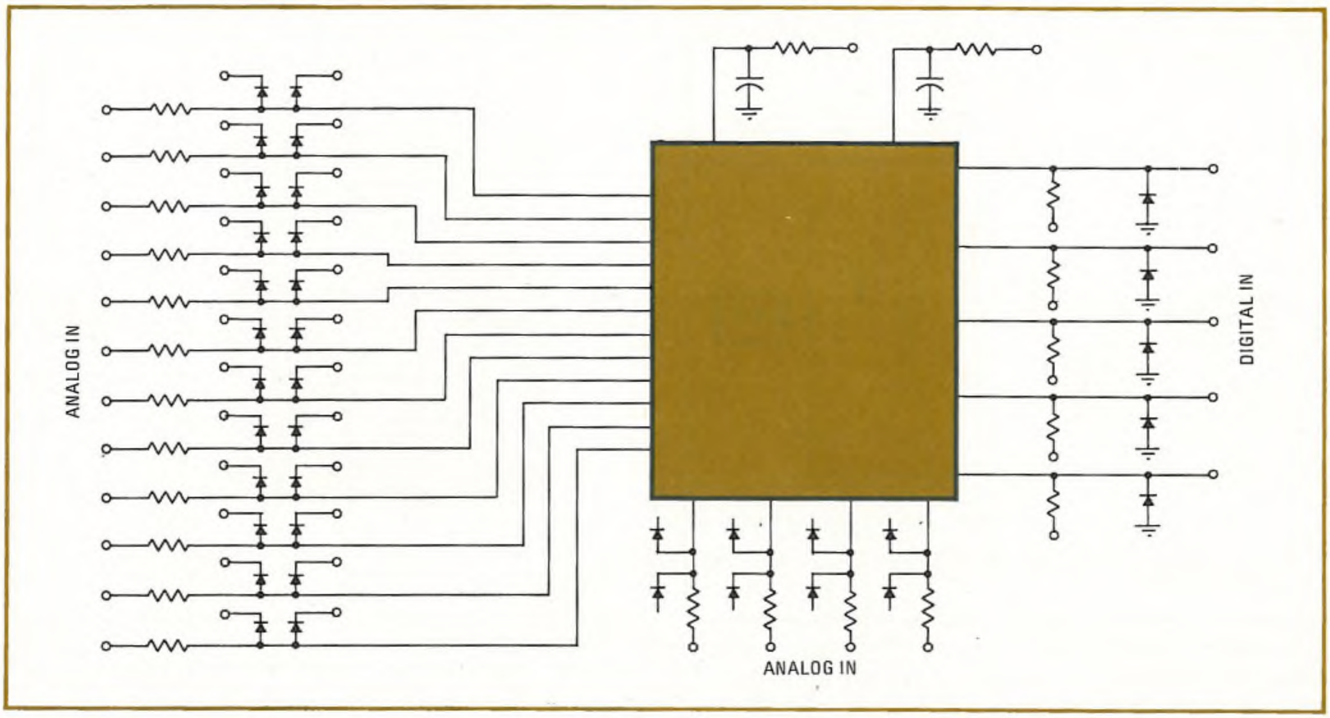
Considering latch-proof JI technology

The standard JI process has been modified by what is claimed to be latch-proof construction through control of the effective betas of the parasitic transistors. A cross section in Fig. 4(a) shows the C-MOS structure along with its parasitic transistors and the equivalent circuit in Fig. 4(b) that gives rise to the silicon-controlled-rectifier latch-up problem.

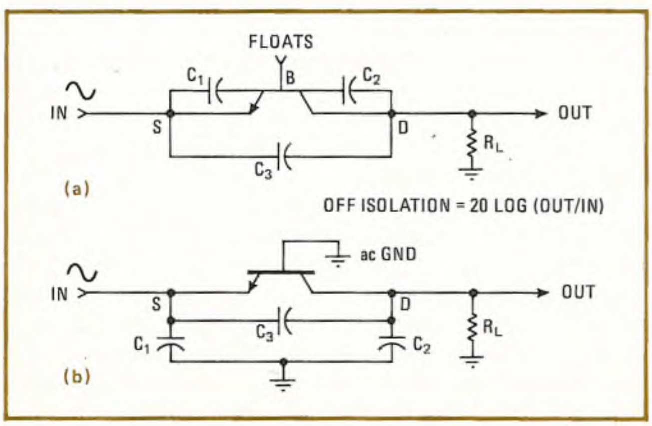
Under any of the fault conditions previously mentioned, the npn and/or pnp can trigger this quasi-dual-gate SCR into a state of high conduction. If the transistor β product is 1 or greater, this configuration is sustained



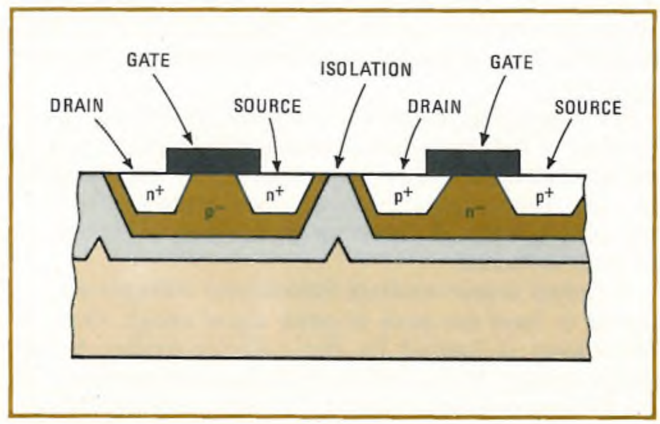
4. Latch-proof. Junction-isolated devices are now made latch-proof with a buried-layer configuration (a), which keeps beta of parasitic transistor under unity. That kills chance for latch-up (b), which plagues devices built with older junction-isolation technology.



5. Protection still needed. Although new JI devices won't latch up, they still can be destroyed by large currents. That's why typical JI switches, like the one shown here, still need to be surrounded by external protective components, which drive up system costs.



6. Floating bodies. Floating-body switches have degraded "off" impedance because total capacitance (a) combines two junction capacitances. In DI circuit (b), capacitances are shunted out.



7. How DI does it. Dielectric isolation eliminates latch-up by a silicon-dioxide isolation barrier between devices. This separates all active elements, eliminating interface junctions that cause parasitics.

until either the device burns up or all sources of power are removed. By using a buried-layer configuration, as shown in the cross section, the β product is reduced to less than 1, eliminating the latch-up conditions.

Again, especially in multiplexer applications, the latch-free devices do not guarantee against destruction, and the JI multiplexer still requires costly discrete circuits around the device, as shown in Fig. 5. If an overvoltage exists, the resistor/diode circuit at each analog input limits the input voltage to the supply-voltage range to prevent the parasitic transistor action.

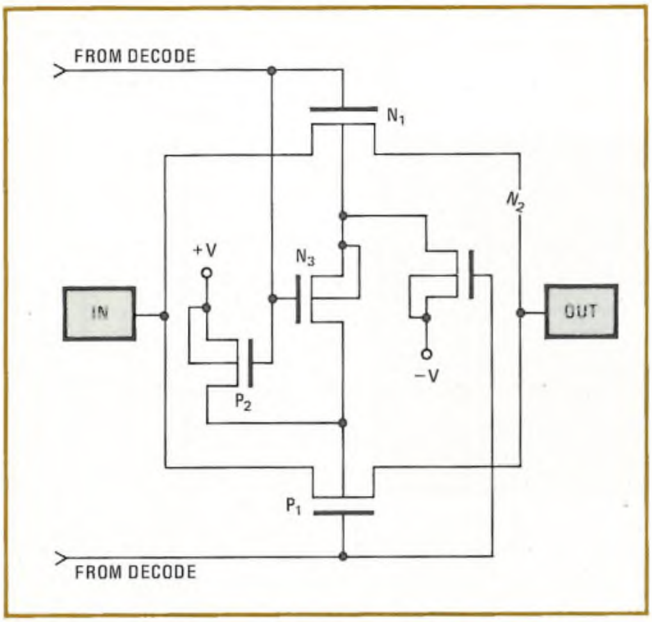
The resistors limit the overvoltage currents through the diodes. The diodes must have a low threshold voltage—much lower than the 0.6-V silicon-junction threshold of the internal parasitic diodes—to ensure that the parasitics do not turn on.

A germanium diode offers a low threshold voltage, but its high leakage current makes it impractical, especially in 0.1% systems. Therefore, in most applications, more expensive low-leakage diodes are used.

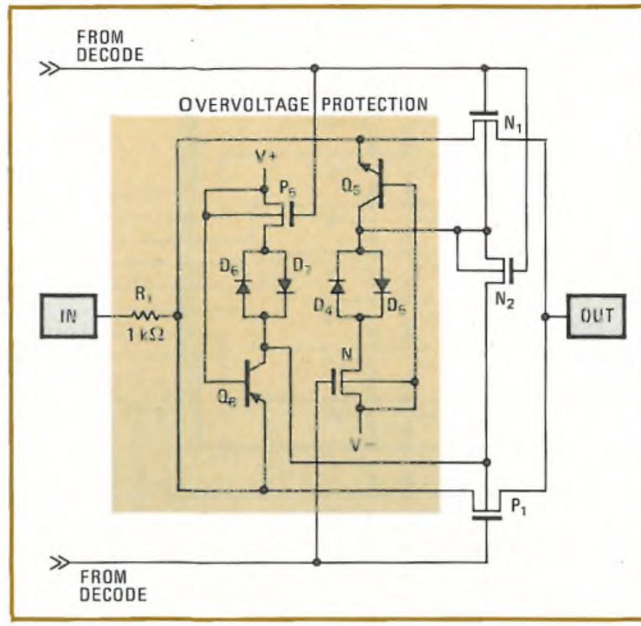
For example, Schottky diodes meet the requirements, but they cost about 50 cents each in volume, and the total cost per multiplexer, including parts and labor, for the discrete protection circuit may well be double the initial purchase price of the device. Even then, its reliability will never approach that of an IC that has this protection already built in.

The floating-body JI technology

Standard JI technology allows another approach to latch-proof device construction: a portion of the SCR continuity is broken by floating the "body" or substrate of the n-channel switching device. A cross section of this process is similar to that in Figure 4(a), excluding the



8. DI does it. In dielectrically isolated switches, on resistance increases as the analog input voltage goes up. This "modulation" of on-resistance with input voltage automatically protects the device.



9. Winning combination. Combining bipolar and MOS technologies in the same multiplexer gives built-in protection. This circuit is typical for each channel in multiplexers HI-508A and HI-509A.

buried layer and the negative supply connection to the p− substrate, so that the dual-gate SCR is changed to a single-gate device that can only be triggered by the pnp parasitic. This, of course, reduces the latch-up probability by 50%.

To completely eliminate latch-up, as before, the β product of the transistors is reduced to less than 1. This accomplishment, certainly a significant improvement over the conventional process, offers greater reliability, but certain trade-offs must be made when the body of a MOSFET is floated.

Nominal source-to-drain breakdown voltages are reduced to limit the peak-to-peak signal range. Over-all breakdown is limited by the collector-emitter breakdown voltage, BV_{CEO}, of the npn parasitic transistor of the floating n-channel MOSFET. The breakdown voltage, BV_{CEO}, increases with the degree of reverse-bias potential applied to the substrate. With a floating body, BC_{CEO} is minimum, so particular care is necessary when using these devices in configurations such as single-pole single-throw, single-pole double-throw, dpst, and dpdt, where each side of the switch connects to opposite polarities. The peak-to-peak handling capability is specified at a minimum of 22 V; therefore, 30 V pk-pk cannot be switched with ±15 V supplies, as it can with other C-MOS devices.

What's more, the leakage currents of floating-body JI devices are higher than other types have, simply because the I_{CEO} of the floating base for the npn is much greater than the I_{CBO} of other devices having fixed reversed-biased body potentials. The increased leakage currents in spst switches may not be too significant.

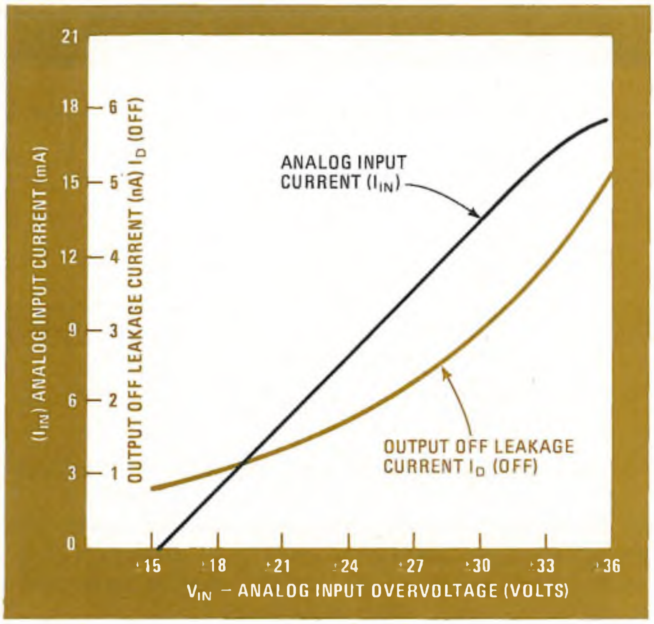
However, in multiplexers that have the outputs of as many as 16 switches tied together in one IC, the total summation of currents can significantly affect system accuracy. For example, the specification for a worst-case 16-channel floating-body multiplexer is 10 microamperes, and the channel on resistance is 550 ohms. The dc-offset error would be 5.5 millivolts, representing an accuracy to 0.55%.

Other 16-channel types specify worst-case parameters of 500 nanoamperes and channel resistance between 550 ohms and 2 kilohms. Their dc-offset error is between 0.28 mV and 1 mV, respectively, allowing accuracy to 0.01% or better.

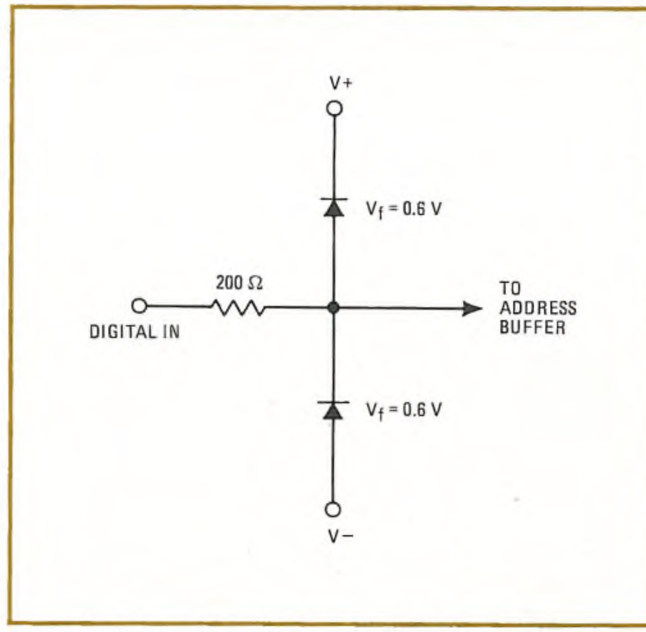
Finally, the effective off impedance of the floating-body switch is degraded by the floating-body technique. Off-isolation characteristics of a MOSFET are primarily determined by its source-to-drain capacitance. But with the base floating, the effective capacitance from emitter to collector is increased by the series combination of emitter-base and base-collector-junction capacitances (Fig. 6a). This increase degrades the over-all off-isolation characteristics. For example, the off isolation for a typical floating-body channel at 1 megahertz that has RL = 100 ohms is specified to be −54 decibels, which compares favorably with other types. However, at lower frequencies such as 1 kHz, the isolation is only −62 dB, compared to more than −110 dB for improved devices. Capacitances C_1 and C_2 for them are shunted by the low ac impedance of the supply voltage (Fig. 6b).

The linear dielectric-isolation technology

The linear dielectric-isolation process requires no modifications to guard against latch-up. Its basic construction ensures that the SCR configuration that causes latch-up can not exist. The functional cross section in Fig. 7 reveals the silicon-dioxide isolation barrier fabricated between all parasitic transistors. This isolation allows each active element to be self-contained and independent with no interface junctions. At most, only three-layer structures are permitted for each tub, so that four-layer structures, or SCRs, are impossible. Also, since the DI technology requires no guard bands, junc-



10. Blocking cross talk. DI switches have minimal cross-talk problems. An overvoltage of 33 V produces a cross-talk current of only 5 ns—an absolute error from channel interaction of only 6 μV.



11. Digital protection. DI devices also protect digital inputs. For example, the diodes in this circuit quickly discharge any static charge that may appear on an MOS input gate.

tion capacitances, leakage currents, and size are minimized. The resulting increase in packing density per wafer, together with increased yields, enables these devices to be cost-competitive with other types.

In working with DI devices, the IC designer is not burdened with the fixed substrate potentials found in JI devices. He may let the potential float, fix it to some potential, or even modulate it. Figure 8 depicts a DI circuit that increases the on resistance as analog input voltage is increased. During the off state, the substrates of both output devices, N_1, and P_1, are at the respective supply voltages through P_2 and N_2, thereby preserving high off isolation and low leakage currents. However, when the switch is turned on, P_2 and N_2 are turned off, and the substrates of N_1 and P_1 are connected together through N_3. This connection increases conductance and causes a minimum modulation of on resistance as the analog input voltage is increased.

Designing a foolproof C-MOS analog multiplexer

In dielectrically isolated multiplexer circuits, protection can be provided on the chip primarily to eliminate channel interaction. This protection prevents normally off channels from being turned on by parasitics from other channels. And because this interaction is prevented, even worst-case power-supply faults cannot destroy the device. Moreover, since DI structures have no SCR effect, protection against latch-up and power-sequencing are not necessary. In short, DI multiplexers with built-in protection can withstand virtually any conceivable fault from the outside world.

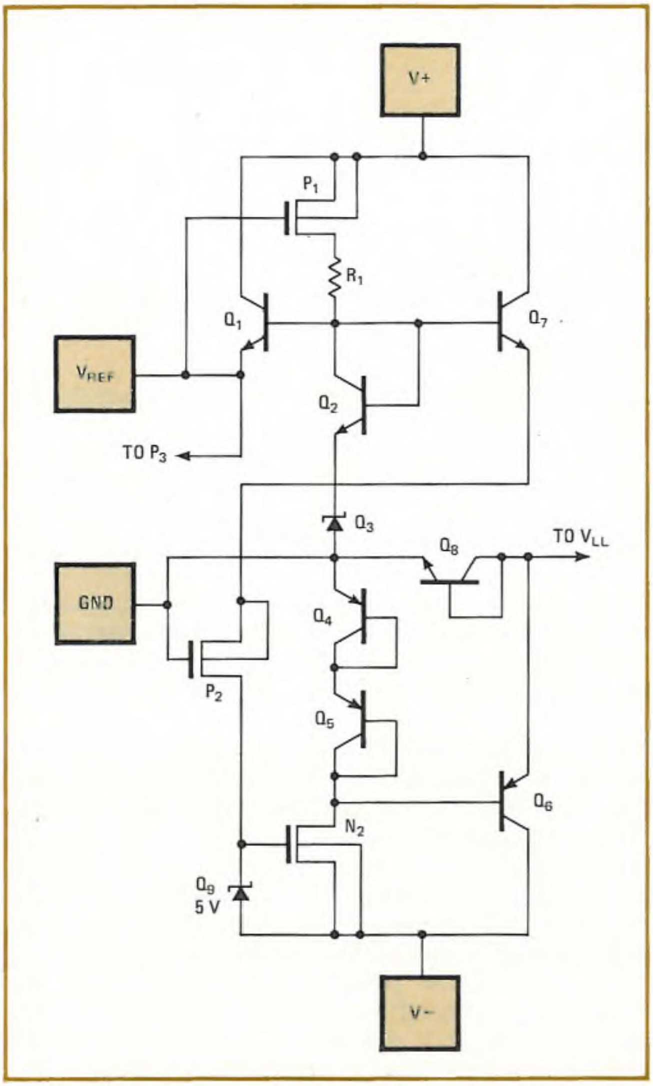
The typical protected DI multiplexer (Fig. 9) benefits from a combined bipolar/C-MOS technology. The illustrated bipolar section is used to sense an analog overvoltage condition and steer current away from the parasitic MOSFET junctions. Each of the switching devices, N_1 and P_1, has its own protection circuits. Devices P_3, D_6, D_7 and Q_6 protect P_1 while N_3, D_4, D_5, and Q_5 protect N_1. If a positive overvoltage exists, V_s is greater than $V^+ + 0.6$ V. When the switch is off, the substrate of the p-channel FET, P_1, is connected to V^+ through P_3 and diode D_7 for maximum isolation and low leakage currents in the off state. If the input voltage suddenly exceeds V^+, the source-body junction, which would normally conduct, is instead clamped by transistor Q_6.

The base-emitter junction conducts to hold the source-body diode off with a source-to-emitter saturation voltage $V_{CE(SAT)}$ of about 0.2 V. Thus clamped, the switch is protected from the effects of overvoltage.

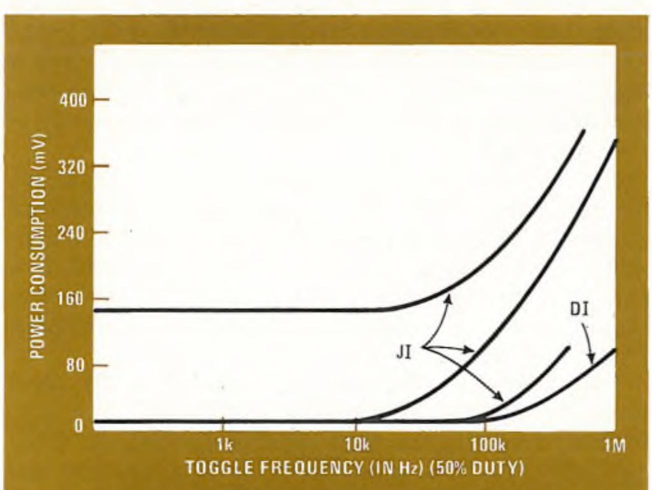
Clamp Q_6 always turns on before the forward-voltage drop of the source-body diode is exceeded because diode D_6 requires an additional forward-voltage drop for conduction through the parasitic junction. Moreover, resistor R_1 limits the current flowing through Q_6 when high overvoltages exist. Although R_1 adds to the total on-resistance of the channel, its associated error is insignificant, since most systems provide high-impedance buffering anyway. For negative overvoltages, N_1 is similarly protected.

For protection when the switch is normally turned on, the substrates of N_1 and P_1 are connected together through N_2, which, as described before, results in a constant on resistance, preventing unwanted current flow and ensuring protection. What's more, the protection circuit, rated at a nominal overvoltage of ±33 V, reveals a cross-talk current of only about 5 na (Fig. 10).

This condition represents an absolute error from channel interaction of only 6 microvolts ($R_{ON} \times 5_{NA}$)—certainly negligible in most systems. In contrast, floating-body types have guarantees only that they won't be burned up by ±25-V overvoltage. Their manufacturers do not make any claim against channel interaction. In fact, channel interaction occurs readily in these devices when the n- and p-channel thresholds are exceeded by



12. Packing it in. DI technology increases chip density of analog switch, allowing more circuit capability per package. For example, DI designs make possible this internal logic reference circuit in HI-200 and HI-201 switches.



13. DI performs. DI devices not only perform well, but do it with less power. Dynamic-power-consumption data for commercial multiplexers shows DI device consuming only 100 mW at 1 MHz.

RESULTS OF DIGITAL-INPUT PROTECTION TESTS (20 DIELECTRICALLY ISOLATED UNITS)	
STRESS STEP/VOLTS	FAILURES
500	0
1,000	0
1,500	0
2,000	1
2,500	0
3,000	3
3,500	0
4,000	3

an overvoltage. For example, the n-channel device, although floating, would be inadvertently turned on if the analog input exceeded the negative supply by its gate-to-source threshold, which is typically 1.5 V.

Adding benefits

Additional DI benefits are passed on to the user in the design of the digital input-protection circuit shown in Fig. 11. The fabrication of all components as isolated silicon islands eliminates any possibility of latch-up. The diodes switch fast and quickly discharge any static charge that may appear at the digital MOS input gates. The table gives the results of a step-stress analysis performed on 20 units. A total of 80% survived the 3.5-kilovolt level, and only one failed below 2 kV.

The DI technology enables a wide variety of active elements to be integrated on the same chip to provide maximum versatility. For example, in the transistor-transistor-logic/C-MOS reference circuit shown in Fig. 12, the bipolar technology enables realization of a simple zener reference circuit, consisting of resistor R_2 and transistors Q_1, Q_2, and Q_3.

The circuit develops a stable 5-V reference for interfacing with TTL and eliminates the need for an additional 5-V logic supply. Current for the zener is supplied through the normally on MOSFET, P_1, which can be easily turned off if not needed to minimize power consumption when interfacing with C-MOS-logic circuits. P_1 turns off when V^+ or supply voltage V_{DD} is applied to the reference terminal V_{REF} to convert the IC's power-consumption from bipolar to C-MOS level. If power is not critical, V_{REF} can be left open to speed switching.

In high-speed data-acquisition systems, the designer is concerned with both quiescent power and dynamic power consumption. If JI devices are used, the capacitance or leakage currents are so high they contribute a major portion of total power consumption. That situation is caused by the large-geometry parasitic junctions formed by the n^- junction.

In contrast, the smaller substrate area of the DI device provides much less power drain. Dynamic-power consumption as a function of frequency for several 16-channel analog multiplexers with ±15-V supplies is shown in Fig. 13. The DI device consumes only 100 mW at 1 MHz to yield the best speed-power product. □

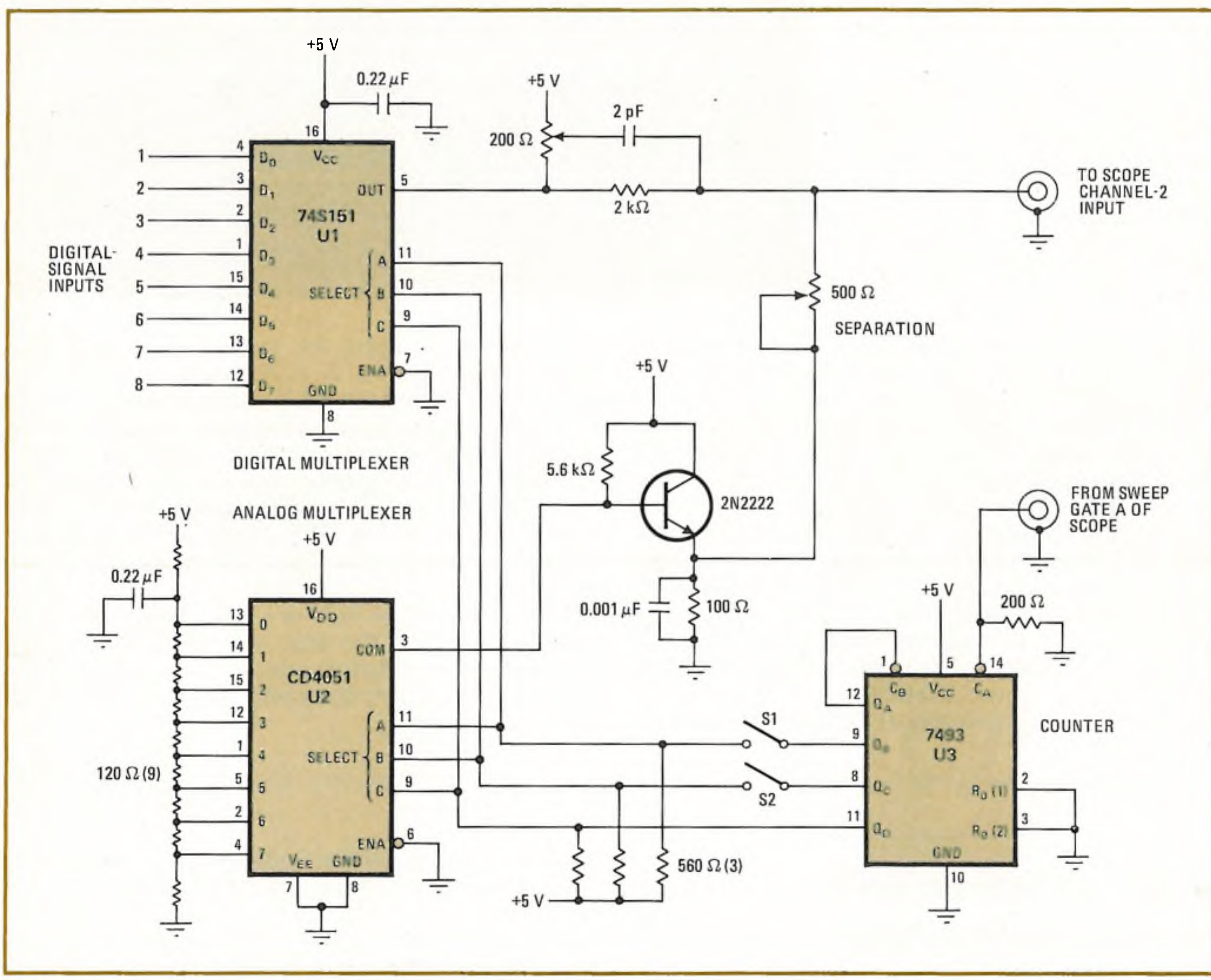
Scope display of eight signals helps debug sequential logic

by Matthew L. Fichtenbaum
General Radio Co., Concord, Mass.

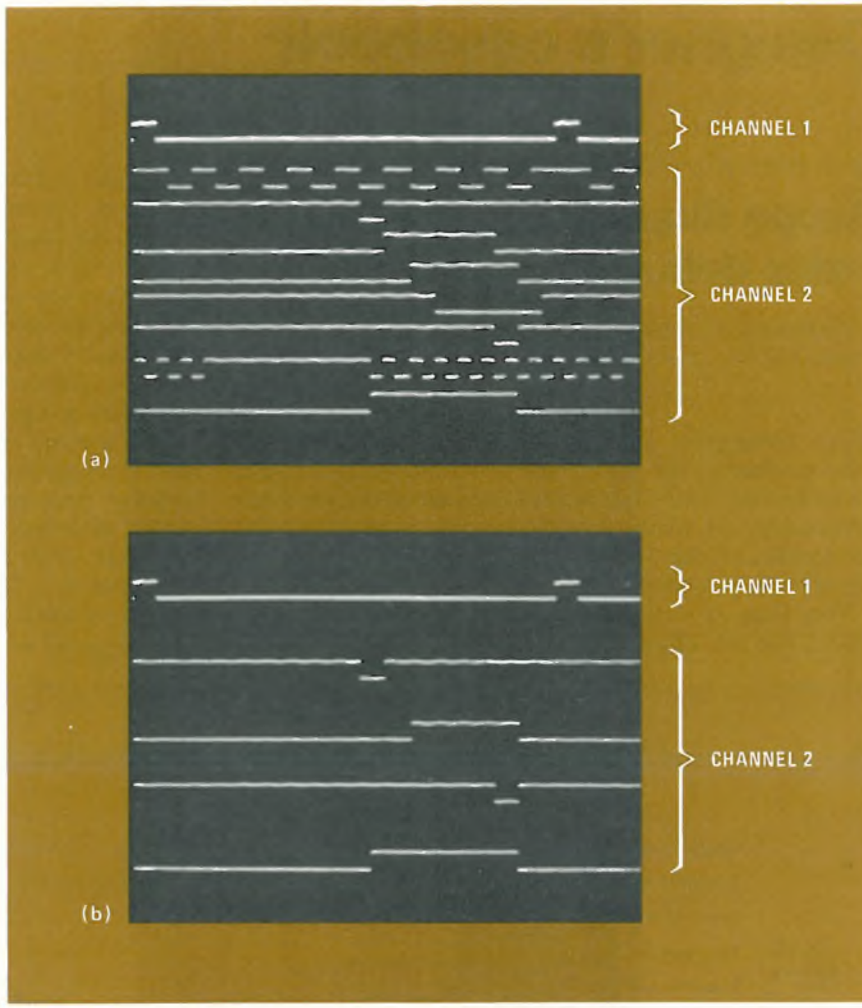
When debugging sequential logic, an engineer may have to observe several signals simultaneously. Logical states and the times that they change are of primary importance in the visual display; the exact values of voltage levels and the duration of rise times and fall times are of lesser importance.

Two, four, or eight digital signals can be displayed on one of the two channels of a Tektronix 454 or similar dual-trace oscilloscope, as demonstrated in the photographs on the next page. The other channel may then be used for triggering or for observation of a ninth signal. The eight signals are treated as logic levels and are gated by a digital multiplexer. Although this procedure does not preserve voltage levels and wave shapes, it does achieve maximum speed with simple circuitry.

The circuit for displaying the signals on the scope is illustrated in Fig. 1. The 7493 divide-by-16 counter (U3) is incremented after each scope sweep. The counter steps through the eight inputs sequentially, and the extra stage compensates for the use of every other sweep in the "alternate" display mode. The counter's highest three bits select an input signal via digital multiplexer U1, which is a 74S151 TTL Schottky type. At the same time, the CD4051 C-MOS analog multiplexer U2 picks a dc voltage off a resistor chain. This voltage is summed



1. Multi-trace adapter. Two, four, or eight digital input signals time-share the channel-2 trace of a dual-trace oscilloscope by means of this circuit. The digital multiplexer selects individual digital inputs in cyclic succession, and the analog multiplexer separates their wave forms vertically; sweep counter drives multiplexers. Switches S_1 and S_2 permit display of only two or four digital wave forms, instead of eight.



2. Signal tracing. Channel 2 of dual-trace scope is multiplexed to display eight different logic wave forms in (a) and four wave forms in (b). The channel-1 trace, used for triggering, appears at top in both photos; it is brighter than the channel-2 traces because of its higher duty ratio. This simultaneous display of several signals is convenient for logic-circuit debugging. High and low states, and the timing of their changes, are indicated accurately even though the multiplexing does not preserve voltage levels and wave shapes. The multi-trace adapter circuit is shown in Fig. 1 on the preceding page.

with the digital signal, providing a different reference level for each trace and thus separating the traces vertically from each other on the screen, as shown in Fig. 1.

The 500-ohm variable resistor adjusts the magnitude of the dc offset, varying the trace separation. The scope's variable vertical-sensitivity control may be used to adjust the over-all display amplitude. The 200-ohm potentiometer is adjusted for best transient response. Both the 500-ohm and 200-ohm pots should be cermet or other noninductive types. The three 560-ohm resistors pull up the levels of the inputs to the multiplexers.

The resistor chain could be replaced by eight potentiometers in parallel, with their wipers connected to the input terminals of the CD4051, for separate adjustments of the vertical positions of the individual traces.

If switch S_1 is open, the scope displays only four traces (digital inputs 1, 3, 5, 7). If both S_1 and S_2 are open, only two inputs (3 and 7) are displayed.

This time-division-multiplexing of channel 2 on the dual-trace scope of course makes the signal wave forms less bright than the channel-1 trace. In Fig. 2(a), the top trace is scanned eight times as often as each of the lower eight traces, and in Fig. 2(b), channel 1 is scanned four times as often as any one of the four offset wave forms that share channel 2.

The circuit may be built in a small box, with appropriate connectors to the scope and inputs. It should be used near the logic circuit under test to minimize signal-lead length and circuit-loading. Only 5 volts of dc power are required. □

Logic circuit selects most intense signal

by P. V. H. M. L. Narasimham
Indian Institute of Technology, Kanpur, India

In police wireless communications where each patrol car has its own frequency, messages from the cars are received at police headquarters via satellite receiver stations to avoid blind angles, obstacles, and dead zones. An operator at headquarters could select the best signal from these stations by manually sampling the various outputs from the HQ receiver and comparing their volumes. This method is unsatisfactory because of delays in switching and subjective evaluation of signals. Therefore, an automatic maximum-strength-signal selector is needed to select the strongest of incoming signals and connect it to the headquarters receiver. Whenever the signal level from any unselected relaying station becomes higher, the headquarters receiver must promptly select that signal.

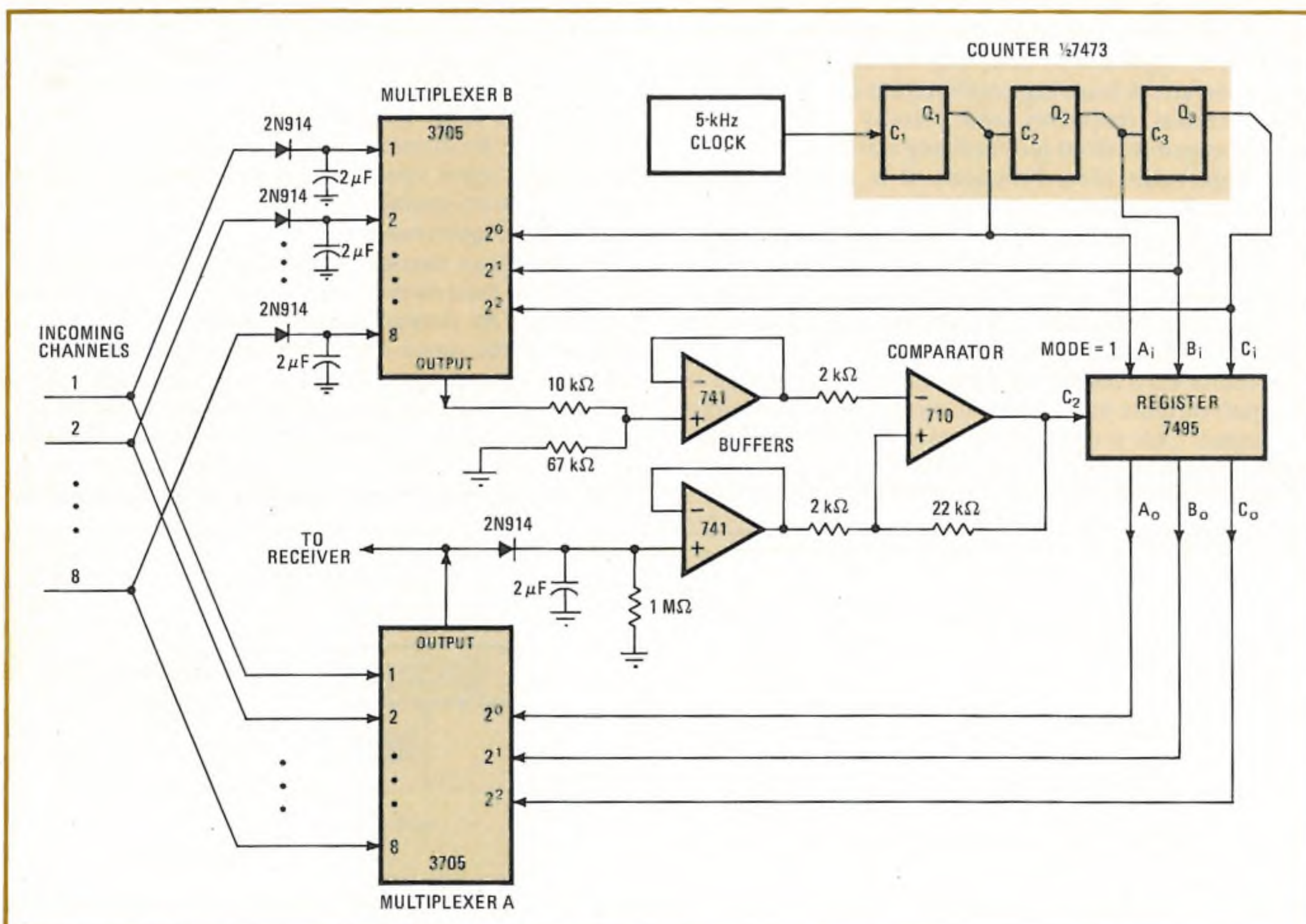
The circuit shown uses a pair of analog multiplexers to automatically connect the headquarters receiver to the strongest signal. The incoming signals from eight satellite stations, band-limited to the range from 300 to 3,000 Hz, are amplitude-limited to ±5 volts peak to peak. These signals go to multiplexer A and also go through eight level-detectors to multiplexer B. The channel-selector inputs to multiplexer B are driven by a 3-bit counter that counts 5-kHz clock pulses. Thus, the signal levels of the eight incoming channels appear, one after another, at the output of B. These levels are compared with the level-detected output from multiplexer A by a 710 comparator. The output from the comparator controls the operation of a 7495 register.

The channel-selector inputs to A come from a register that contains the code for the channel with the highest signal level, as explained below. The output from B is attenuated about 10% by the resistive voltage divider, to give the output from A an advantage in the comparator. The comparator's output is high as long as the most intense signal is selected by A.

If propagation conditions change so that the signal level on some unselected channel, say U, exceeds the level on the selected channel, then when multiplexer B is switched to channel U the output of B is higher than the output of A. Therefore the comparator's output goes low. On this trailing edge, the contents of the counter are clocked into the register so that A also selects channel U. Because of the 10% advantage given to A, the comparator's output then becomes high again. Thus the most intense signal is selected by A and connected to the receiver; all of this takes place within a fraction of a clock period.

The inputs of the comparator are buffered through the type 741 voltage followers to avoid loading on the level detectors and thus preserve the accuracy of comparison. The level detectors are simple diode peak detectors with 2-microfarad capacitors. Their performance is satisfactory, but they may be replaced by better level-detectors if necessary. □

Have you used a microprocessor to replace either hard-wired or mechanical logic in a circuit or made some other use of these versatile devices? Engineers who are just starting to design with microprocessors would be interested in learning about your experiences. We'll pay $50 for each microprocessor item published, as we do for all published Designer's Casebook ideas. Please send them to our Circuit Design Editor, summarizing the problem and how a microprocessor provides a novel solution.



Goes with strength. Most intense signal coming from relaying stations is connected to central receiver through multiplexer A. If signal from A is not the strongest, comparator goes low when counter clocks multiplexer B to the stronger signal. Register then changes input code to A so that the stronger signal is connected to receiver. System allows police cars (each with own frequency) to contact HQ via satellite stations.

Taming process-control transients with lead and lag compensation

Circuit modules adjust the time of arrival of control signals so that processing equipment can counter on-going changes in process variables

by Chun H. Cho and Kenneth P. Schwarz, *Fisher Controls Co., Marshalltown, Iowa*

☐ A process-control system can smooth out both sudden changes in stock temperature or pressure and slow alterations in viscosity by advancing or delaying the control signals it sends to processing equipment. The control circuitry essentially differentiates the input data to provide lead compensation, as it is called, or integrates it to provide lag compensation.

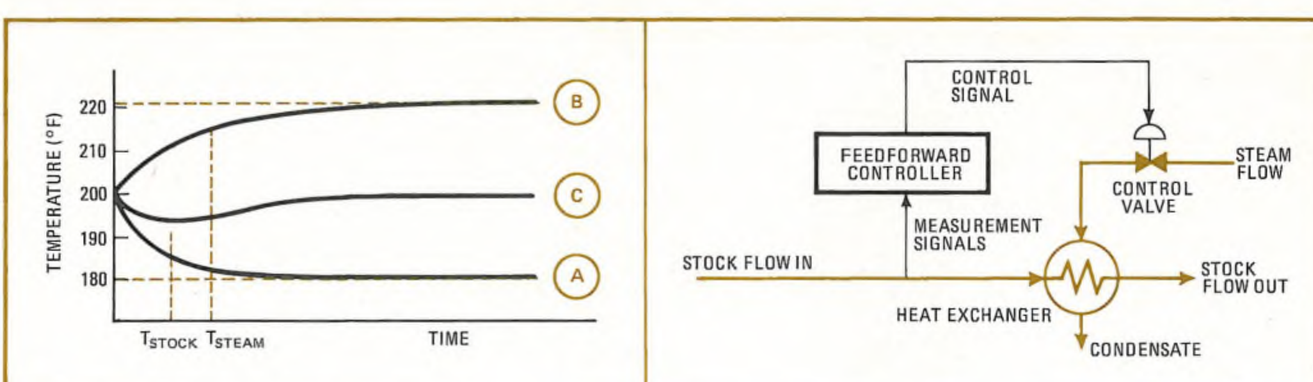
Lead and lag compensation can improve static and dynamic system performance in both the feedback and feedforward modes. Lead compensation increases the bandwidth and improves the transient response, while lag compensation enhances the steady-state response. For a given application, both may be combined for optimum control. A lead/lag combination can increase the system critical frequency and thereby permit higher open-loop gain without jeopardizing stability.

To implement these functions, it is possible to use commercially available modules—for a price. However, to buy separate lead and lag modules and then combine them would run about $1,000. A more economical and more compact unit is the compensator that is designed to incorporate both. For example, the unit discussed in this article lists for less than $600.

A feedforward control system will register a change in an input variable and cancel it out before it can affect the output. This it does by causing a corrective change in the manipulated variable. Take the case of a chemical plant where fluid stock is maintained at a constant temperature by being passed through a steam heat exchanger, as seen in Fig. 1(a). As the temperature or flow of the stock increases (or decreases) upstream, the feedforward controller adjusts the steam valve to reduce (or raise) the temperature of the heat exchanger. That is, feedforward gain is set so that the steady-state magnitudes of the two temperature changes are equal and opposite to each other.

Because of heat exchanger's construction the process temperature responds faster to changes in stock flow than to changes in steam flow. Therefore, over the short term the temperature at the outlet can vary, as Fig. 1(b) shows, even though over the longer term the system is in static balance. Whenever such a variation cannot be tolerated, the delay associated with the steam flow adjustment can be shortened by inserting a time lead into the forward signal line. This has the effect of adding a surplus of steam initially and then backing it off to the steady-state requirement.

The time lead changes the magnitude of the control signal by an increment proportional to that signal's first derivative. The change produces either an increase or decrease in the signal depending on the slope of its derivative at that instant. In effect, the circuit anticipates the future size of control signal needed based on the signal's present value and present rate of change. The output of a lead compensator will change faster than the input until the signal stops changing, at which point the



1. Blowing hot and cold. In this typical chemical processing operation, the temperature of the fluid stock is raised when the stock passes through a heat exchanger. However, in this particular example, an increase in fluid flow will create a 15° fahrenheit fall in temperature (a) faster than an increase in steam flow can raise temperature 15° F (b), causing a transient drop in fluid temperature (c). This transient could be just about eliminated if the increase in steam flow were made to precede an increase in fluid flow.

slope is zero and the values become equal.

Lead compensation can be understood by taking the example of a ramp input with a slope of m percent per second (Fig. 2). In T_1 seconds, the signal will change by mT_1 percent. Essentially, the lead compensator evaluates the first derivative of the signal, multiplies it by the desired time constant, and adds the product to the input. For the ramp, the output equals the value that the input signal will reach T_1 seconds later.

Lag occurs when the manipulated variable changes more slowly than the input variable. With a step input (Fig. 3) and a lag of T_2, the output reaches 63% of its final value T_2 seconds after the step change. The output continues approaching the input level asymptotically, but for all practical purposes the values are equal after approximately four time constants.

How to calculate lead and lag . . .

Since the same process often requires both lead and lag compensation, the equations for both are combined in the transfer function:

$$V_o = \frac{(1 + T_1 s)V_i}{(1 + T_2 s)} \qquad (1)$$

where V_o is the output voltage, V_i is the process variable input voltage, T_1 is the lead time constant, T_2 is the lag time constant, and s is the Laplace operator.

If $T_1 = 0$, the transfer function is that of a first-order lag. If $T_2 = 0$, the transfer function is that of a first-order lead. If $T_1 = T_2 = 0$, the output simply tracks the input. By adjusting the relative time constants, different combinations of lead and lag can be obtained.

For actual process control, however, a lead/lag compensator would normally include additional signal conditioning for gain and for input and output biasing. Therefore practical devices are more likely to be described by equation 2 for direct (proportional) control:

$$V_o = a\frac{(1 + T_1 s)}{(1 + T_2 s)}(V_i - B_i) + B_o \qquad (2)$$

or by equation 3 for reverse (inversely proportional) control action:

$$V_o = a\frac{(1 + T_1 s)}{(1 + T_2 s)}(B_i - V_i) + B_o \qquad (3)$$

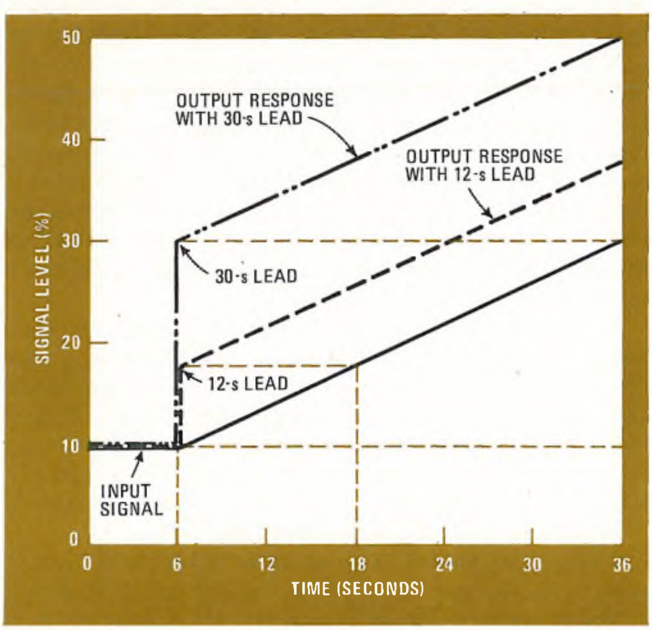
where a is the gain, B_i is the input bias voltage and B_o is the output bias voltage.

. . . and how to implement them

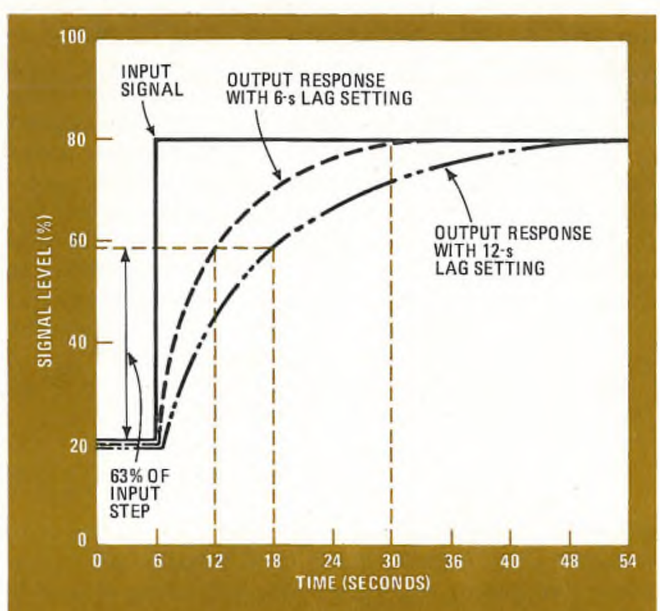
Lead/lag compensation can be built into a control system with relatively simple operational amplifier circuits, such as the series of four modules shown in simplified form in Fig. 4. Figure 5 shows the details of the lead and lag modules designed specifically for process-control applications.

Normally, the process variable is either a voltage or a current that is converted to a voltage by a resistor in the input line. The input module subtracts a bias (B_i) from this signal to cancel the live zero normally used in control systems. Live zero refers to the voltage that represents 0% of span—in process control systems conventionally 1 volt, with 5 V representing 100% of span. Subtracting a 1-V bias from this input then serves to "zero" the reading.

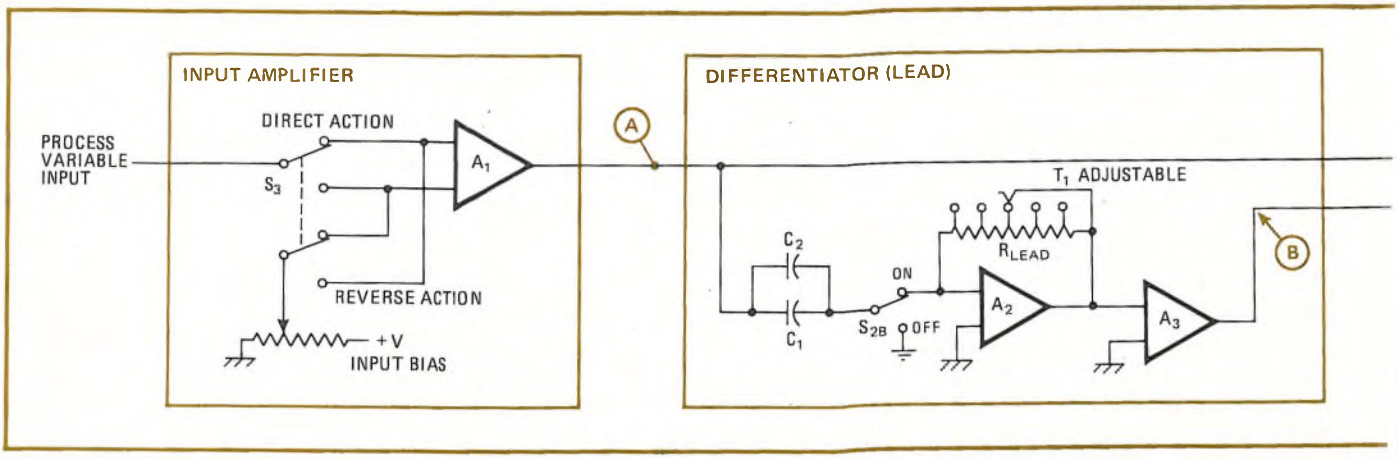
Control action switch S_3 selects the direct or reverse modes, that is, whether the system responds according to equation 2 or 3. Under direct action the output increases for an increasing process variable, while in the



2. Early warning. Lead compensation is needed when a control process needs changing ahead of a change in some process variable (heat, flow). Here, a unity-gain, direct-action compensator with a ramp input and a lead time setting of 12 seconds (30 s) produces a control signal anticipating the value of the input 12 s (30 s) later.



3. Late comer. Lag compensation is needed when a control process must be adjusted more slowly than a changing process variable. Here, with a step input and a lag setting of 6 seconds, the output of a unity-gain, direct-action compensator will reach 63% of the step change in input after 6 seconds.



4. Two in one. This four-module lead-lag compensator adds varying amounts of lead, lag, or combinations of both into the circuit, depending on the resistor values selected in the lead and lag modules. The input module zeroes the input signal and determines whether the output will be directly or inversely proportional to the input. The output module amplifies the output and acts as a current driver.

reverse mode the output decreases for an increasing process variable.

The central element of the input module is operational amplifier A_1, which produces a dc output proportional to the biased process variable. A_1 is used in a unity gain configuration. An actual module would include capacitors in the input and feedback circuits to limit frequency response and thereby filter out noise in the process variable signal. Potentiometric zero adjustment on the amplifier is also desirable to compensate for voltage offsets.

The next two modules introduce lead and lag into the signal. When S_{2B} is closed (on), the derivative function is activated, and when S_{1B} is closed, the integrator is added to the circuit. The time constant is the product of a fixed capacitance and an adjustable resistance. The range of 6 to 3,000 seconds (lead or lag) has been found to cover most process-control applications.

The derivative function is generated by operational amplifier A_2 with input capacitor C_1 and C_2 and feedback resistor R_{lead}. R_{lead} represents the resistance value selected by a rotary switch from the resistance bank shown in Fig. 5. Dual field-effect transistors, also shown in Fig. 5, are inserted in front of A_2 to increase input impedance without contributing voltage or phase inversion. More capacitance, C_3 and C_4, is added across the feedback resistors to limit derivative gain and make the circuit less susceptible to noise. When there is no lag in the circuit this additional capacitance is particularly important since it protects the circuit against unwanted output peaks. A_3 is needed in the module for gain.

When the lead/lag compensator of Fig. 5 is set to include lead only, the transfer function becomes:

$$V_D = \frac{K\,R_{lead}(C_1 + C_2)sV_c}{[R_{lead}(C_3 + C_4)s + 1][R_2(C_1 + C_2)s + 1]} \quad (4)$$

where V_D represents the voltage at point D—in this case, essentially the output of the differentiator—V_C is the voltage at point C, the input to the differentiator, and K is the derivative gain.

On the basis of the values shown in Fig. 5, equation 4 becomes:

$$V_D = \frac{-T_1sV_c}{[(T_1s/22)+1][0.3s + 1]} \quad (5)$$

In the process-control applications, it is best to limit derivative gain to less than 25 decibels. Without this limitation, minor changes in input, particularly those induced by noise, will substantially change the output of the derivative circuit. Process-control system response will not be affected by this rolloff, which is generally well above the frequency range of interest. Rolloff is obtained through R_{lead}, C_3, and C_4, which are connected into the network when switch S_{1A} is off (position shown).

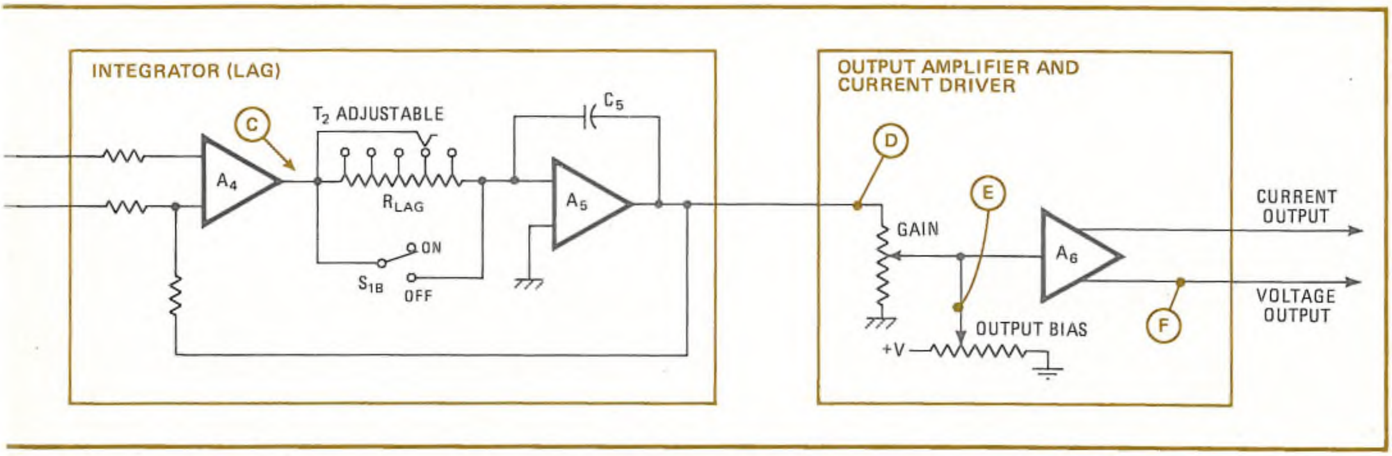
This applies only to lead compensation, however. When lead-lag is implemented, the limit on derivative gain is no longer necessary, and switch S_{1A} selects only C_4 in parallel with R_{lead}. The derivative transfer function then becomes:

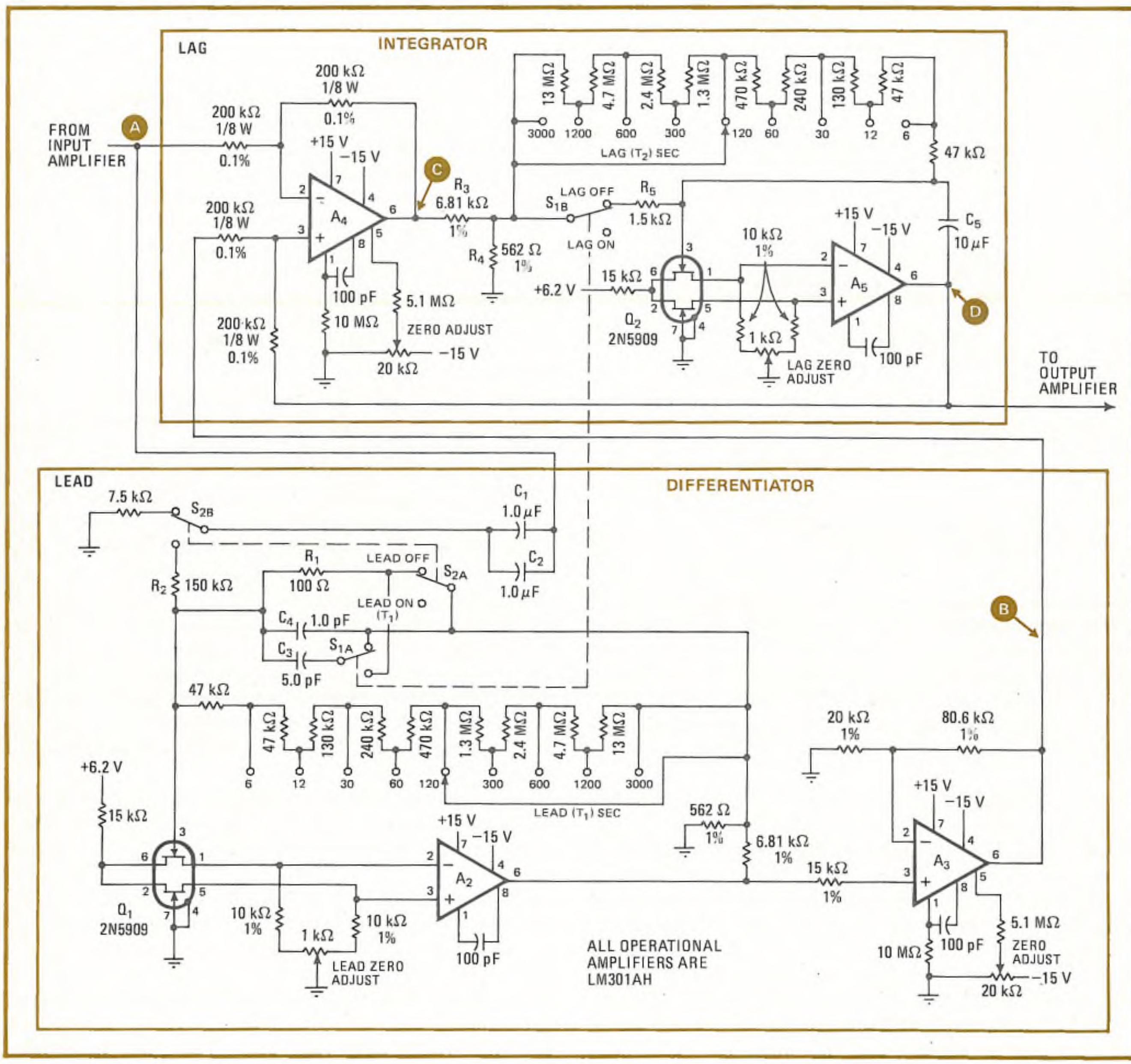
$$V_D = \frac{-T_1sV_c}{[(T_1s/130)+1][0.3s + 1]} \quad (6)$$

A derivative circuit with time constants as large as 3,000 seconds is sensitive and demands premium-quality components. To illustrate, an input changing as slowly as 1 millivolt per second will result in a 3-V output when T_1 is set at 3,000 seconds. To limit error, therefore, the operational amplifier should have a high input impedance and low bias current. In Fig. 5, for instance, dual FET Q_1 is used in conjunction with A_2 to achieve a bias current of less than 1 picoampere. (Though some FET-input operational amplifiers perform just as well as the A_2 and Q_1 combination, they cost more than six times the $3.50 of the A_2 and Q_1.)

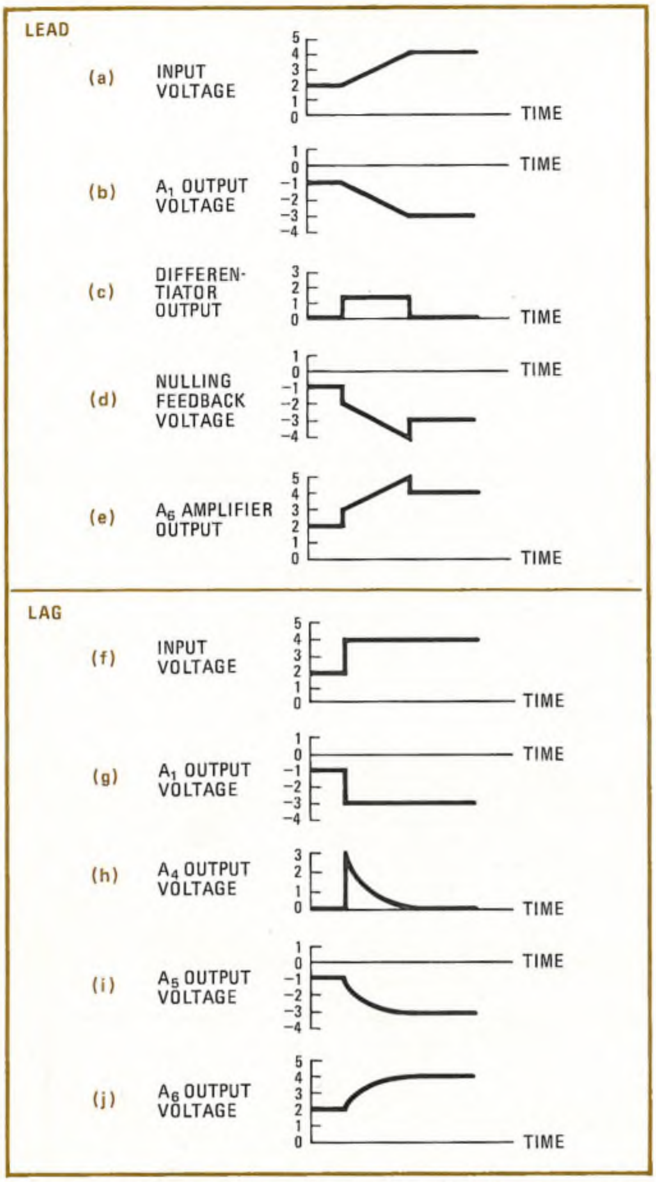
In the lag module, integration is carried out by operational amplifier A_5 with input resistance R_{lag}—the value selected from the lag resistor bank—and feedback capacitor C_5. Dual FET Q_2 is used as a source follower in the input circuit of A_5 to increase input impedance without contributing voltage or phase inversion to the signal. A_4 is included in the module to add the signals needed to produce the first-order effects.

The output module acts as an amplifier and current driver. The output voltage and current are determined by the amplifier gain and bias settings. Output bias B_o is





5. Inside the lead and lag modules. This circuit, designed for process control applications, realizes the lead and lag portions of Fig. 4. A rotary switch on each resistor bank dials in the lead and lag time constants to values between 6 and 3,000 seconds. In the lead-only mode, C_3 and C_4 limit derivative gain to 25 dB to reduce circuit susceptibility to noise. When both lead and lag are used, A_4 adds the lead module output into the lag circuit. Output of the lag module is delivered to an amplifier and current driver, which sends input to the control circuitry.



6. Sequence of events. In the lead-only mode, the system functions as in (a) through (e). A ramp in the process variable (a) produces a ramp change in the output, but the output slope is proportional to the input rate of change. When lag only is added, wave forms (f) to (j) occur: output approaches input asymptotically and reaches 63% of the input value one time constant later.

set by a voltage divider; over-all gain is set with a potentiometer. The current driver is constructed from two transistors in a Darlington configuration connected to the output of A_6. To protect instruments connected to the module from possible excessive input, a zener diode could be placed across the downstream terminals of A_6. A diode is also needed on the line between the collector of the current driver and the external power supply to protect the transistors from accidental polarity reversal.

Output voltage at point D V_D, based on values in Fig. 5, is approximately equal to:

$$\frac{(1 + T_1 s)}{(1 + T_2 s)} V_A \tag{7}$$

In this example the transfer function for the integrator only (with feedback loop from A_4 to A_5 open) is:

$$V_D = -\frac{R_4}{R_3 + R_4}\,\frac{V_C}{R_{lag}\,C_5 s}$$

$$V_D = -\frac{V_C}{T_2 s}$$

$$\text{where } T_2 = R_{lag} C_5 s \frac{R_3 + R_4}{R_4} \tag{8}$$

The voltage divider action of R_3 and R_4 in the lag module supplies a multiplier of about 13 to the RC time constant of R_{lag} and C_5. Because of this multiplier, a relatively small resistor will produce the equivalent of a 300-megohm input resistance. A dual-FET source follower identical to the configuration used in the differentiator provides the required low bias current and high input impedance.

From input to output

How the circuit operates as a lead compensator can be understood from the waveforms shown in Fig. 6 (a) through (e). These assume that the input amplifier is on direct action, switch S_{1B} is off to bypass the lag circuit, and output gain is set to unity. If the process variable input ramps up (a) and input bias is held constant at 1 V, amplifier A_1 produces an offset inverted ramp (b). This is applied to the inverting input of differentiator A_2, which responds with a step that's amplified by A_3 (c). The amplitude of this step is proportional to the slope of the ramp and to the resistance R_1 in the feedback branch of A_2.

Since the lag switch is off, the input resistance to integrator A_5 is essentially zero, and the integral time constant is very small. The loop around A_4 and A_5 acts as a null servo and drives the output of A_4 to 0 V, regardless of the signal applied from upstream. The output of A_4 without the component fed back from A_5 would be the waveform shown in (c) minus the one shown in (b). Therefore, the nulling feedback signal must be the negative of this combination (d). For an output bias of 1 V and a unity gain, amplifier A_6 inverts the waveform in (d) and adds 1 V to the result (e).

Operation of the circuit as a lag compensator can be understood by reference to Fig. 6 (f) through (j). The waveforms illustrate operation when the input is set to direct action, the differentiator is bypassed, and the output gain is set to unity.

If the process variable increases in a 2-V step (f) and the input bias is 1 V, amplifier A_1 produces an inverted offset step (g). The lead circuit is bypassed, so the input of A_3 is 0 V.

The inverted offset step is applied to the inverting input of A_4, where it is subtracted from the output of integrator A_5 by a null servo feedback loop. As a result, the leading edge of the waveform in (g) produces a step at the output of A_4 (h), but the amplitude of this output decreases because of the subtraction of the integrated signal (i). As the output of A_4 decays to zero in (h), the output of integrator A_5 approaches a constant (i). With the output bias set to 1 V and the output gain equal to unity, amplifier A_6 inverts the waveform in (i) to produce the final output signal (j). □

Reliability revisited: failure-rate comparisons are given a second look

by Lucinda Mattera, *Components Editor*

☐ Failure data does indeed bear watching, as a number of readers of part 1 of our special report on component reliability ["Failure data bears watching," Oct. 2, p. 91] pointed out. There were some distorted—although still valid—comparisons in the article, owing to an effort to sort out and collate varying masses of statistical data. The problem arose when we attempted to "normalize" the data with respect to certain base groups of components. As it turned out, the normalization procedure was based on an assumption that failure percentages were dependent on lot size. That is the rub, because failure rates remain the same regardless of lot size. The contrary assumption led to distortions of some of the graphic material in the report. This article should rectify these distortions and clarify a few other ambiguities that seem to have puzzled our readers.

First, our attempt at normalization affected the bar charts for relative component failure rates (Graph 3), relative failure rates for logic ICs (Graph 10), and failure rates for shift registers and memories (Graph 12). With one exception, the absolute comparisons themselves do not change, but the relative differences among various failure rates change considerably.

Comparing components again

Graphs 3, 10, and 12 are reproduced here, corrected and slightly modified. In Graph 3, for instance, only the total number of devices tested, plus the over-all failure percentage, is given for each type of component, and the failure rate relative to that of resistors (without correction for lot size) is plotted. As can be seen, transistors would appear to be the component most prone to failure, but the transistor population used for these tests consists mostly of general-purpose and fast-switching types. Interestingly, the percent failure for ICs is quite high, especially as simple gates make up close to 70% of the IC test sample. Actually all of the failure percentages are rather high because the data happens to reflect the intensive screening done for a satellite program.

The revised bar chart for logic ICs (Graph 10) indicates that C-MOS can fail almost five times more often than standard TTL, while ECL is less likely to fail than TTL. (The failure data here is normalized to the percentage given for TTL.) A word of caution, though—the populations for TTL and C-MOS are reasonably large and represent a substantial mix of vendors and device types, whereas the ECL population is comparatively small and is made up of only about a dozen different device types. From this data alone, then, it is unwise to assume that ECL is always less likely to fail than standard TTL.

Looking at memories and registers

In the revised Graph 12 for shift registers and memories, the failure percentages themselves are plotted for both bipolar and MOS technologies. Because the complexity of these devices ranges from a few bits to well over 500 bits, it is not meaningful to normalize the data with respect to any single type of device. Comparisons can be made, however, between bipolar and MOS devices of the same order of complexity.

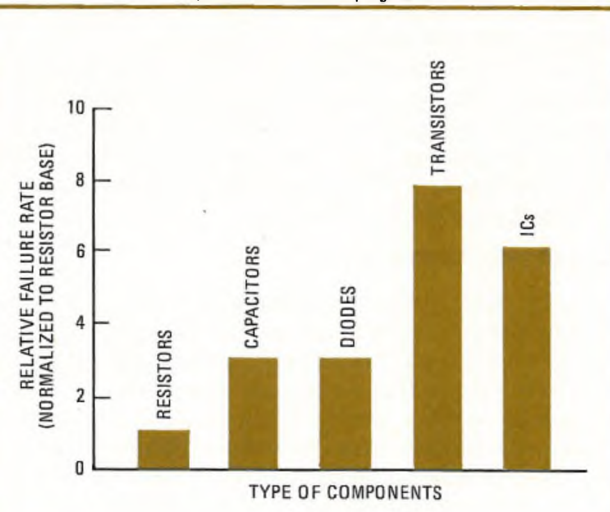
For example, for shift registers, small-scale (up to 20 bits) MOS units appear to fail nearly five times more often than small-scale bipolar units, while MOS large-scale

GRAPH 3: RELATIVE COMPONENT FAILURE RATES

SCREENING SUMMARY

Component	Number Tested	% Failure
Resistors	46,688	3.2
Capacitors	13,965	10.0
Diodes	3,861	10.0
Transistors	4,739	24.9
ICs	7,030	19.2

Data from NASA/Ames Research Center, Mountain View, Calif., for Jupiter/Saturn Satellite program

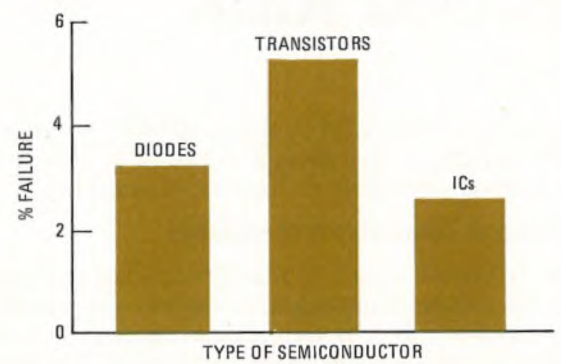


GRAPH 9: SEMICONDUCTOR FAILURE ANALYSIS

SCREENING SUMMARY

Type of Semiconductor	Number Tested	% Failure
Diodes	1,008,262	3.22
Transistors	785,807	5.26
ICs	3,015,544	2.57

Screens per MIL-STD-883, class B, or MIL-STD-750/MIL-S-19500
Based on data from Continental Testing Laboratories over one-year period

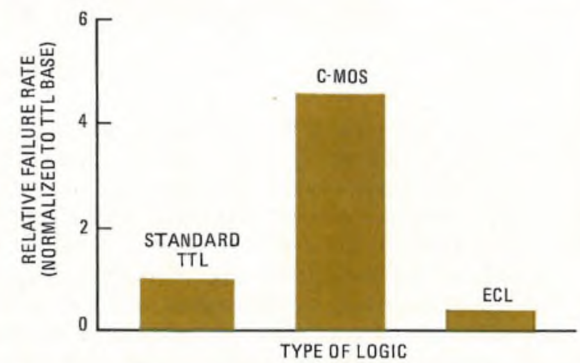


GRAPH 10: RELATIVE FAILURE RATES FOR LOGIC ICs

SCREENING SUMMARY

Type of Logic	Number Tested	% Failure
Standard TTL	282,238	1.4
C-MOS	107,005	6.6
ECL	10,859	0.4

Screens per MIL-STD-883, class B.
Based on data form Continental Testing Laboratories



registers are more than twice as likely to fail as medium-scale MOS registers. The situation is somewhat reversed for memories—the percent failure for medium-scale bipolar RAMs is approximately 2.5 times higher than that for comparable MOS RAMs. In contrast, bipolar and MOS large-scale RAMs seem to have about the same reliability.

Although the populations here are not all that large, they do represent a mix of devices and vendors. As with all data, though, there are differences in the population sizes, and the number of over-all failures is affected by the types of devices making up a group's population. In this case, the data for medium-scale MOS registers is heavily skewed by 100-bit devices, while the data for large-scale MOS RAMs is heavily skewed by 4-kilobit devices. The group of large-scale MOS registers consists of both static and dynamic units having densities of up to 1 k. However, the population of the large-scale bipolar RAMs is small and contains only 1-k units.

Graph 9, a semiconductor failure analysis, is also republished here, in revised form, showing only the numbers needed for the bar chart. The bar chart of the original version contains a drawing error—the percent failure for ICs should be 2.57%, as indicated above the original chart in the screening summary.

A word about some data

Caution also is required when interpreting the data in the original screening summary for Graph 9. The figures given for each screen represent the number of devices subjected to that screen and how many failed as a direct result of that screen (not necessarily an electrical test). Some devices may have been subjected to only one screen, while others may have gone through several. Because of this the figures that indicate the number of devices tested will not add up to the figures given for the grand totals. The grand totals reflect the total number of devices tested and the resulting number of rejects found over a fairly recent one-year period.

It is interesting to note that these failure percentages in Graph 9 are considerably lower than the ones given in Graph 3. This is because the screening was not as intensive. Although every semiconductor here was subjected to one or more standard military screens, only a small number were put through the full sequence of screens required for military applications.

Two other illustrations, Graphs 6 and 7, are not affected by failure rates being made sensitive to lot size, but some of the labels should be changed to avoid confusion. In Graph 6, the vertical axis should be called "board failure percentage," and the curves should be labeled "device failure percentage." Similarly, in Graph 7, the vertical axis represents "device failure percentage," and the curves "gate failure percentage."

Not true averages

Another clarification is needed regarding the way the failure percentages are computed throughout the report. Except for the two time plots (Graphs 4 and 5), which show mean percent failures, all other graphs are based on failure percentages that represent the total number of rejects divided by the total number of devices tested. In other words, the percent failures do not reflect true averages, which would be determined by averaging the failure percentages of individual lots of devices.

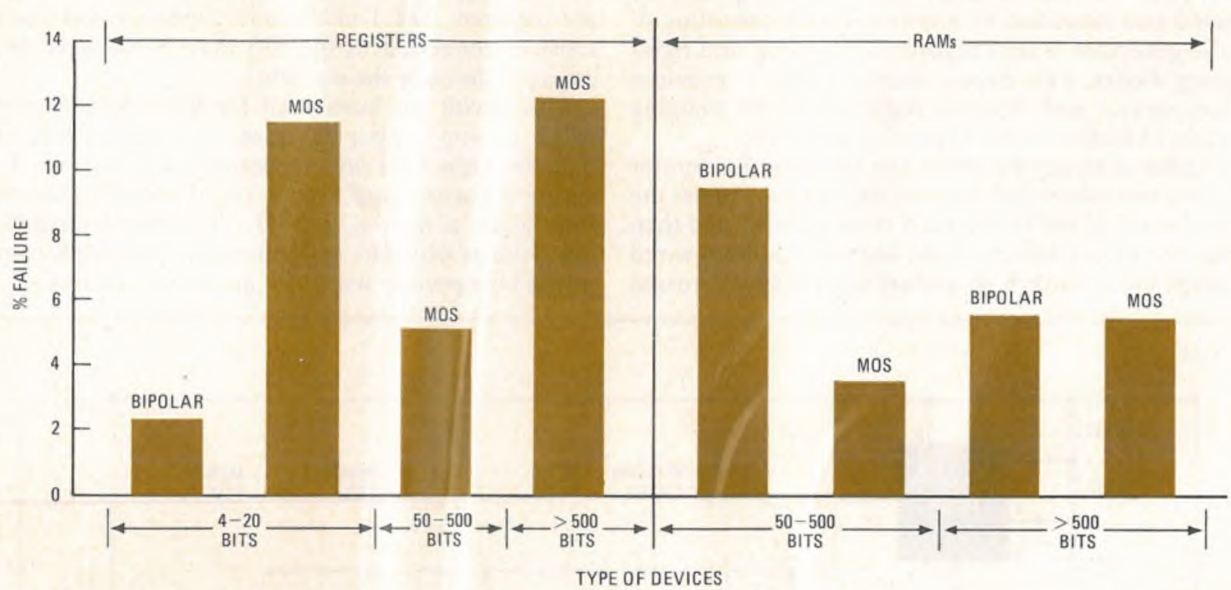
The bulk of the data in the report is based on screening done by independent test laboratories for component users. The devices tested, then, were those that manufacturers shipped as "good" units. So the devices that later failed at the test labs did so due to time-related causes that made them unable to meet their data-

GRAPH 12: SHIFT REGISTERS AND MEMORIES

SCREENING SUMMARY

Type of Device	Complexity	Technology	Number Tested	% Failure
Shift Registers	4–20 bits	bipolar	36,674	2.4
		MOS	24,078	11.5
	50–500 bits	MOS	30,301	5.1
	> 500 bits	MOS	9,756	12.2
Random-Access Memories	50–500 bits	bipolar	3,070	9.5
		MOS	3,643	3.6
	> 500 bits	bipolar	1,239	5.6
		MOS	14,641	5.4

Screens per MIL-STD-883, class B. Based on data from DCA Reliability Laboratory and Continental Testing Laboratories



sheet specifications. Such failures were due to functional inadequacies and/or excessive parametric shifts, or catastrophic faults.

Any reliability data is always a mixed bag. Doubtless a number of the devices counted here as "reliability failures" were marginal parts that could have been screened out by tighter control at the manufacturers' plants. But they weren't—they were shipped by the manufacturers as "good." Also, with any kind of testing—particularly a stress screen—there are going to be devices that are overstressed, damaged, or even destroyed through human error. However, such mistakes generally account for a minimal number of failures if the test laboratory is a reputable one.

Data sources must be sound

A far greater possible source of error is the rejection of devices that actually are good. This is why *Electronics* carefully researched its sources of reliability data, choosing only those whose reputations are exceptional. Granted, chances are that a few of the failures reported on were actually good devices. But these instances are so few that they are not skewing the data at all. Furthermore, a number of readers have indicated finding similar results—or worse.

One final point should be re-emphasized. Tables 2 and 3 in the original report, which show the cost-effectiveness of a variety of screening programs (Table 2) and single screening tests (Table 3), are greatly influenced by prevalent failure modes, and these can vary from manufacturer to manufacturer and lot to lot. The data in these tables reflects a population in which many failures were due to a lack of hermeticity. As a result, the large number of hermetic failures is skewing the data, and hermeticity testing seems to be a very cost-effective screening measure indeed. However, at another time, another failure mode may predominate, and hermeticity tests then would be less effective. Finally, the test costs per part shown in these tables are average ones and do not reflect testing costs for the actual number of parts tested. These average costs are for small lots of devices containing from 1,000 to 5,000 pieces. □

Logic circuit tests wiring assemblies

by Steven Graham
Parsippany, N. J.

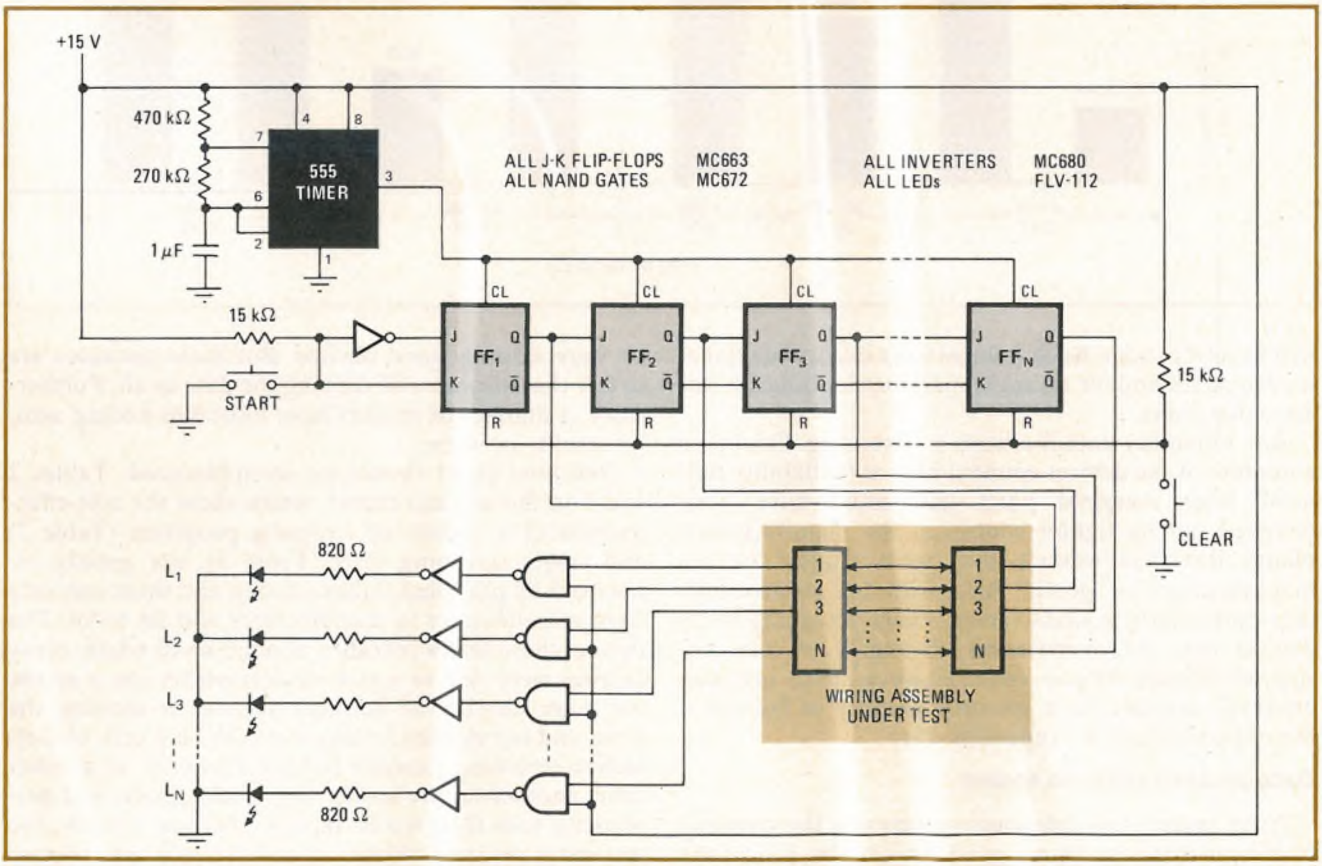
Before shipment or installation of wiring harnesses, the completed assemblies must be checked to verify that each pin of the connector at one end is wired to the corresponding pin of the connector at the other end. Open circuits, short circuits, and crossed wires can quickly be detected and identified by a testing circuit consisting of a pulse generator, a shift register, some gates, and light-emitting diodes. This circuit, shown in Fig. 1, provides an inexpensive and effective replacement for stepping switches, ohmmeters, and expensive analyzers.

To check a wiring assembly, the test-station operator plugs the two connectors into the test fixture, presses the CLEAR button if any of the LEDs is on initially, and then presses the START button. If the harness has been wired correctly, the LEDs turn on and off sequentially. Crossed wires are indicated when the LEDs come on out of sequence. A short circuit causes two LEDs to light simultaneously. An open circuit turns the LED on as soon as the harness is connected.

The circuit diagram shows that the 555 timer is connected as a free-running multivibrator with a frequency of a few hertz. The pulse train from the 555 clocks the flip-flops to shift the high starting pulse down the line, feeding a high input to each NAND gate sequentially.

If a wire in the harness is not connected, so that the input to a NAND gate is not connected to its flip-flop, that gate stays high all the time (even when the CLEAR button is pushed), and the LED stays on. If the wire bundle contains N wires, then N flip-flops and N LEDs are required. The 1-microfarad capacitor and the two resistors connected to the 555 may be changed to increase or decrease the test rate.

This circuit has been used for more than a year to check 12-wire jumper harnesses. It could be refined so that the LEDs turn on sequentially and stay on if the wiring is correct, and a latch could halt the sequential shift when a fault is located. The operator could do other things while the test proceeded; this improvement would be especially useful for many-wire harnesses. □



Flashing the word. Test arrangement checks feed-through wiring between two connectors on harness of N wires. Correct continuity is indicated by LEDs flashing on and off sequentially. Crossed wires cause LEDs to flash out of sequence, a short circuit makes two LEDs flash simultaneously, and an open causes a LED to glow continuously. Although high-threshold-logic elements are shown, TTL is satisfactory.

2½-digit DVM uses quad Norton op amp

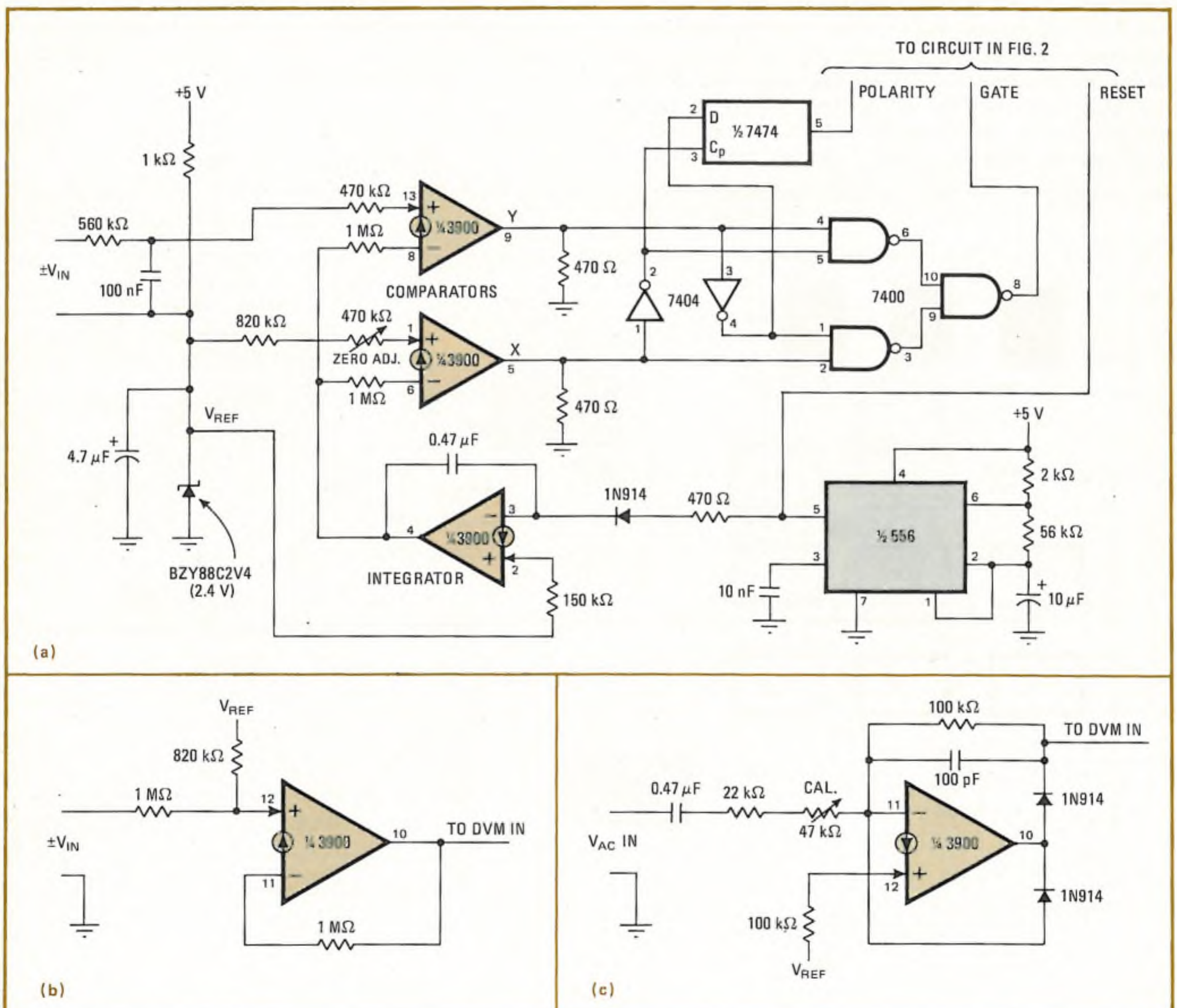
by Erdal Musoglu
Medical Computing Center, Free University of Brussels, Belgium

A compact digital voltmeter can be built inexpensively around a quad Norton operational amplifier (LM3900). It has a 2½-digit display with polarity indication and a 1-megohm input impedance, is accurate to within 1%, and is powered by a single 5-volt supply. The basic scale is chosen as ±1.99 V.

The voltage to be measured determines how long a counting circuit stays on. The display shows how many clock pulses were counted during that period. The measurement is repeated two and one-half times per second.

The measuring circuit for the DVM is shown in Fig. 1(a). One half of a 556 dual timer, used as a reset flip-flop, generates a 2.5-hertz square wave that drives the ¼ LM3900 connected as an integrator. (This is why the DVM makes a measurement every 400 milliseconds.) When the output of the reset flip-flop is $+V_{CC}$, the integrator is reset. But when the output goes to 0, a positive ramp is generated by integration of current entering the integrator's noninverting terminal. This current is driven through the 150-kilohm resistor by the 2.4-v reference voltage V_{ref} across the zener diode. Each positive ramp at the output of the integrator has an amplitude of more than 4 v and lasts 200 ms.

Two other Norton op amps are used as comparators. The dc input voltage to be measured is applied between V_{ref} and the noninverting terminal of one of the comparators after filtering. The noninverting terminal of the other comparator is connected to the reference point via a variable resistor that is adjusted so that there is no



1. Measurement. Basic circuit for digital voltmeter (a) uses 2.5-Hz reset flip-flop to cycle integrator and comparators to generate gate pulse with duration proportional to voltage being measured. Gate pulse, polarity signal, and reset output are fed to counter and display portions of DVM in Fig. 2. If input voltage is referenced to ground, input stage (b) is used. For ac voltage measurement, converter (c) is added to circuit.

output gate pulse when $V_{in} = 0$. The inverting terminals of the comparators are driven by the integrator.

The outputs from the two comparators, X and Y, are applied to an exclusive-OR circuit. The XOR output is used to gate on the counter in the counting and display circuit, as shown in Fig. 2(a). The time that the gate is on is directly proportional to the amplitude of V_{in}. The XOR circuit is realized here using three NANDs and two inverters, for reasons of economy. Polarity information for the display circuit requires only one half of a 7474 dual D-type flip-flop.

The arrangement in Fig. 2(a) optimizes the package count for the counter, display, and clock of the complete DVM. Here the other half of the 556 timer is used as the clock generator. The nominal clock frequency is 2 kilohertz, and the meter can be calibrated with the 22-kΩ variable resistor that modifies this frequency.

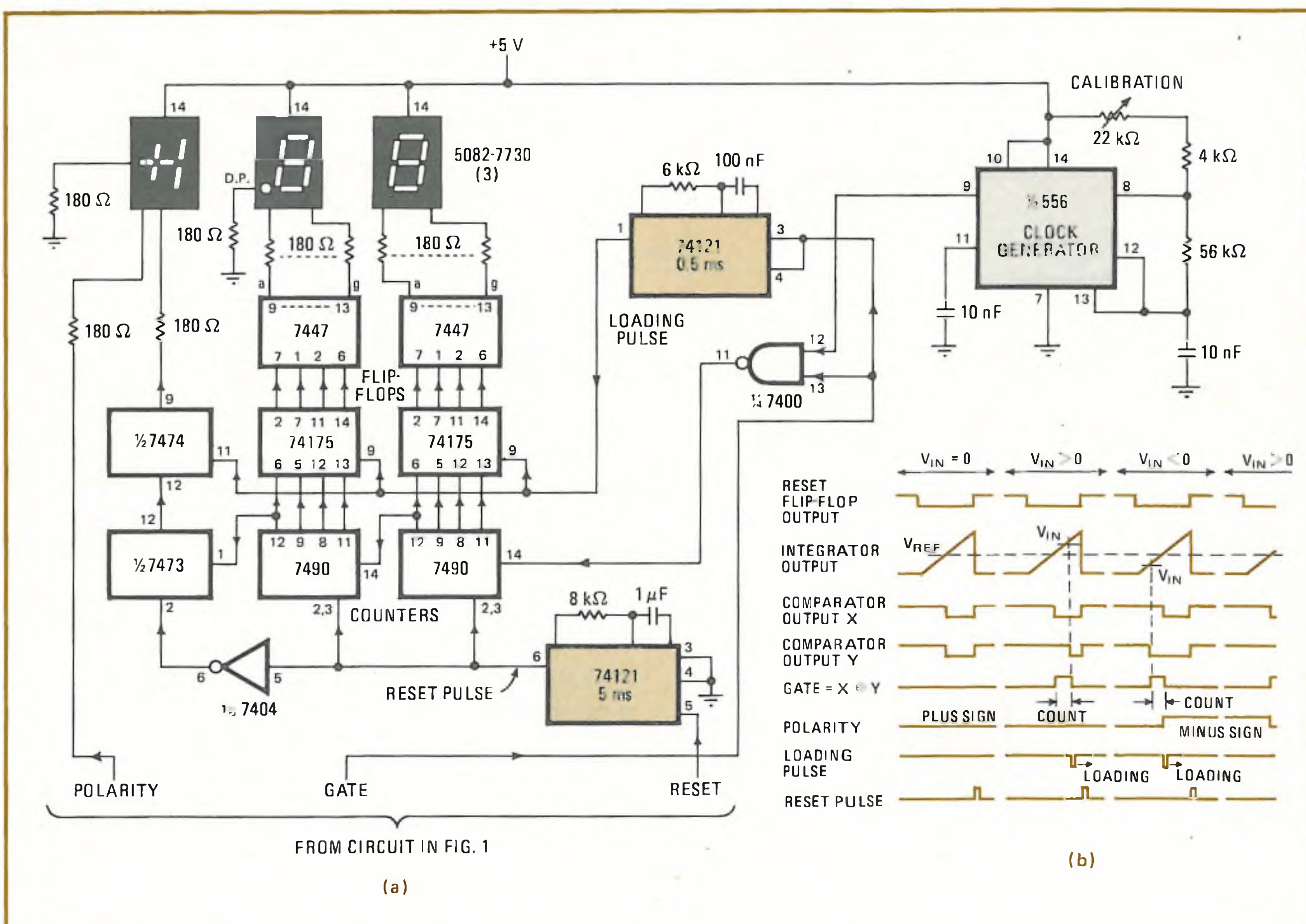
Two one-shots, which have output pulses lasting 0.5 ms and 5 ms, respectively, are used for loading from and resetting the counters. The reset one-shot is activated by the leading edge of the reset flip-flop output that comes in from the circuit of Fig. 1(a), so the counters are reset immediately after the ramp ends. Because the reset time is quite long (5 ms), any spurious gate outputs that occur during the fall of the ramp are ignored by the counter circuits; the fall time of the integrator is less than 2 ms for the circuit of Fig. 1(a).

The total accuracy and stability of the DVM depend on the frequency stability of the clock generator and on the stability of the ramp's slope. If stable external components (e.g. polycarbonate capacitors and metal-film resistors) are used in these circuits, the least significant digit is in error by only ±1, so accuracy within 1% is obtained. Note that the frequency stability of the reset generator does not affect the accuracy or the stability of the DVM. To avoid error due to the bias current of the Norton amplifier, the source impedance must be less than 20 kΩ even though the input impedance of the DVM is 1 MΩ.

If ground-referenced signals are to be measured, the fourth Norton amplifier of the LM3900 package can be used as shown in Fig. 1(b). In this case, however, it is advisable to divide the input voltage by two—for example, by using a 2-MΩ resistor at the input of the circuit of Fig. 1(b) instead of 1 MΩ—and to have a nominal clock frequency of 4 kHz for better linearity.

The fourth amplifier of the package can also be connected as an ac-to-dc converter, as shown in Fig. 1(c), for measurement of ac voltages. □

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.



2. **Display.** In counter and display portion of digital-voltmeter circuit (a), clock pulses are counted by decade counters during gate pulse. After gate pulse, total count is loaded into D-type flip-flops that drive seven-segment displays via decoder-drivers. Counters are reset by 5-ms pulse from one-shot every 2.5 seconds for new measurement. Timing diagram (b) summarizes operation of DVM.

Engineer's newsletter

A week in Washington on solid-state imaging

If you're into solid-state imaging devices and systems, look into **a one-week course that has some of the top people in the field in its staff of lecturers.** The course is a repeat of one given in September at Université Louvain la Neuve, Belgium, under the aegis of NATO. This time it will be at American University, Washington, D.C., during the week of June 28 to July 2, 1976 (you might also want to stay for the Bicentennial weekend—the on-campus accommodations can be extended).

Course organizers are M.H. White of the Westinghouse Advanced Technology Laboratory in Baltimore and D.F. Barbe of the Naval Research Lab. Contact Ms. Jennifer Murphy at American University, Massachusetts and Nebraska Ave., N.W., Washington, D.C. 20016.

Lasers make light of transmitting data amid noise

With the cost of **cable skyrocketing to around $1,000 per 100 feet, perhaps you should consider a laser for data links spanning several hundred feet** or more. Laser links cost $5,000 to $10,000 and are particularly useful in industrial environments where other forms of data transmission may be affected by arc welders, radio interference, and the starting and stopping of large motors. In one application, a laser data link supplied by International Laser Systems Inc., Orlando, Fla., picks up information from a scanner traveling on an overhead crane and transmits it to a receiver 600 feet away.

And you needn't worry about anyone getting zapped. The lasers operate well below the level that is even minimally dangerous to users.

More on $X^2 + Y^2 = Z^2$

In our Nov. 13 Engineer's newsletter, a typographical error slipped into the scheme for finding the resultant of two measured orthogonal components. We said the multiplier-divider should provide the function (YZ/Z). But when Dan Sheingold of Analog Devices, Norwood, Mass., sent us his idea, it of course read (YZ/X).

And one other note on the Sept. 18 newsletter item that started it all—Timothy J. Kriewall's suggestion for finding the resultant of two orthogonal components by modulating them with quadrature carriers, summing the two, and demodulating the summed signal. Steve M. Gehlbach, digital systems engineer at the University of Texas' Health Science Center at Houston, points out that **by comparing the phase of the resultant carrier with the phase of one of the quadrature carriers, you can find the phase angle arctan Y/X.** Gehlbach says he has used this technique to determine reflection coefficient magnitude and phase from a four-probe detector on a microwave transmission line.

A stopwatch for a penny (plus an HP-45)

Our Nov. 27 newsletter item on using the HP-45 calculator as a stopwatch brought a flood of responses from readers with similar ideas. We're now putting them together for an upcoming Electronics Notebook, but we thought one neat little trick deserved mention now.

Remember that the way to get the calculator into the stopwatch mode was to hit three buttons absolutely simultaneously? Mansoor Ahmed, of the University of Pittsburgh's EE department, points out that the **simultaneity is easily obtained by pressing on a penny placed over the three buttons.**

—Stephen E. Scrupski

1-k C-MOS RAMs flock to market

Activity quickens as more than a half-dozen companies design units to compete with n-channel in point-of-sale, communications, auto jobs

by Bernard Cole, San Francisco bureau manager

When complementary-MOS random-access memories contained only 256 bits and offered access times of about 1 microsecond, their main attraction was low-power operation in nonvolatile applications. But now that they have moved to the 1,024-bit level of complexity and their speed range is 250 to 800 nanoseconds, their near-zero quiescent power dissipation makes them strong contenders with static n-channel MOS RAMs for small static-memory systems in point-of-sale terminals, telecommunication equipment, data processing, and automotive functions.

That's why more than a half dozen semiconductor companies are going to market with C-MOS RAMs of various designs and configurations. Until recently, only two companies were widely known for their 1-kilobit C-MOS RAMs: Intel Corp. for its static 650-ns, 256-word-by-4-bit model 5101, and Intersil Inc. for its IM6508/18, a 1,024-by-1-bit, 350-ns static device. Competition is now being offered by Harris Semiconductor, National Semiconductor, American Microsystems Inc., RCA, and Solid State Scientific, among others.

In addition, Intersil is adding several new 256-by-4-bit designs to its C-MOS RAM family, both to support its 12-bit C-MOS microcomputer system, the IM6100, and as support for other systems. Intersil is also introducing a 1,024-word-by-12-bit masked C-MOS read-only memory.

However, that is only the beginning of C-MOS-memory activity. In the works are other C-MOS ROMs, first-in/first-out memories, and shift registers. And several manufacturers indicate that 4-kilobit static C-MOS RAMs are but a few years away.

In the opening round of C-MOS memories, however, Harris Semiconductor's first entry, for example, is the IM8508/18 pair of 1,024-by-1-bit devices. The 8508 version will have the same pinout as the 16-pin, 1,024-bit bipolar RAMs now offered by several companies. The 8518 is an 18-pin version aimed at designs requiring latched output control or minimum support logic. Specifications on the self-aligned silicon-gate devices are 50 nanowatts per bit in the standby mode and 15 microwatts per bit during operation. Prices of the two parts in quantities of 100 to 999 are $8.95 for the industrial range and $22.40 for the military range. These will be followed in February by a 256-by-4-bit version, part of the IM6100 family that Harris is second-sourcing from Intersil.

Intersil's 256-by-4-bit C-MOS RAMs—the IM6551 and IM6561—will be available in January. At 5 volts and 25°C, parts specified at 350 ns use standby power of 500 μW and operating power of 13 mW. The 6551 is pin-compatible but not functionally compatible with Intel's 5101, and the 6561 has the same pinout as Intel's 256-by-4-bit n-MOS RAM, the 2111. In quantities of 100 to 999, price of the 6551 is $10.75 each and $9.85 for the 6561.

National Semiconductor Corp.'s entry into the field in January will be a 256-by-4-bit C-MOS RAM, the MM54C920/74C920, a silicon-gate device that will be available in speeds ranging from 250 to 600 ns. Parts specified at 500-ns worst-case access consume 75 microwatts on standby and 30 milliwatts in operation. Another device, the 54C933/74C933, with a 1,024-by-1-bit array, is in the design stage.

American Microsystems Inc.'s first 1-kilobit C-MOS memory, the S5101, is organized as a 256-by-4-bit array and is a second source for Intel's 5101. It is immediately available in three speed ranges: 450 ns, 650 ns, and 800 ns. At 5 V and 650 ns, standby power is 90 μW, and operating power is 80 mW. Depending on speed and power consumption, prices of 1 to 24 units range from $9.30 to $14.25 each. A 1,024-by-1-

bit array will soon be introduced.

Intersil's 1,024-by-12-bit masked ROM, the IM6312, was designed for use with the 12-bit IM6100 C-MOS microprocessor family, but it has several features that make it useful in the implementation of RAMs and ROMs in other systems. In 10-bit word systems, two extra bits are left, allowing the use of two additional pins to select up to four other ROMs directly and eliminating a lot of peripheral addressing circuitry. Alternatively, the extra bits can be used to select a bank of RAMs for every ROM they address, thereby eliminating other components. The IM6312 is priced at $36 each in 100 to 999 quantities, plus a $1,000 one-time mask charge.

The major thrust at RCA is in C-MOS-on-sapphire. Currently available is the NWS5001, a 1-k-by-1-bit, 150-ns, 5-V device in a 16-pin package. Henry Miiller, director of memory products, says the Solid State division will also have available in the first quarter the NWS5040, a 256-by-4-bit, 120-ns RAM. Also, Miiller says, RCA will begin sampling an 80-ns version of the 5001. Two 10-V C-MOS-on-sapphire parts will also be available in the first quarter, and the division will begin sampling a 512-by-8-bit ROM by the end of the period.

Solid State Scientific Inc. also plans to introduce several C-MOS-on-sapphire memory products early this year. "They'll come in fairly rapid succession," says Walter F. Kalin, C-MOS marketing manager, "and will include several configurations up to 1-k."

Harris Semiconductor, Box 883, Melbourne, Fla. 32901 [401]

Intersil Inc., 10090 N. Tantau Ave., Cupertino, Calif. 94014 [402]

Intel Corp., 3065 Bowers Ave., Santa Clara, Calif. 95051 [403]

National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, Calif. 95051 [404]

American Microsystems Inc., 3800 Homestead Rd., Santa Clara, Calif. 95051 [405]

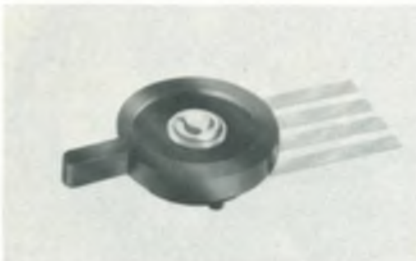
RCA Solid State Division, Rte. 202, Somerville, N.J. 08807 [406]

Solid State Scientific Inc., Commerce Dr., Montgomeryville, Pa. 18936 [407]

Circle 91 on reader service card

Components

Tiny switch handles 500 mA



Measuring only 0.28 inch in diameter with a volume of less than 0.02 cubic inch, the model 283 rotary selector switch can handle up to 500 milliamperes. Encased in a hard-epoxy housing, the switch has four gold-over-silver-plated beryllium-copper terminals for a life of at least 20,000 operations. It is offered with two- or three-position switching and in either black or beige. A single 000–120 fastening screw is the only hardware needed to mount it.

Wilbrecht Electronics, 240 Plato Blvd., St. Paul, Minn. 55107. John Judge (612 222-2791 [343]

Solid-state relay has $6.90 unit price

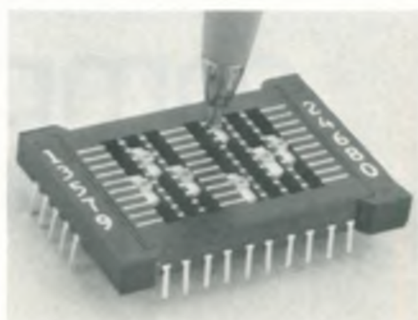
Selling for only $6.90 each and dropping to $3.80 in lots of 1,000, the model 226 solid-state relay can switch 1.5 amperes ac. The addition of an external heat sink raises its rating to 7 A. Connections to the unit can be made by means of standard push-on connectors, or the unit can be inverted and wave-soldered

onto a pc board. An isolation-voltage rating of 2,500 V rms and an isolation resistance of 10^{12} ohms suit the 226 for the interfacing of low-level logic circuitry with line-voltage loads.

Sigma Instruments Inc., 170 Pearl St., Braintree, Mass. 02184. Robert E. Cullen (617) 843-5000 Ext. 344 [344]

Matrix contains 10 slide switches

A matrix of 10 interconnected slide switches that measures only 1 by 1.38 by 0.165 inches is intended for the crosspoint switching of logic signals. The device's gold-plated crosspoints are rated to switch 100 milliamperes at 12 volts dc and to handle 50 V ac, nonswitching. Each of the 10 10-position slide switches

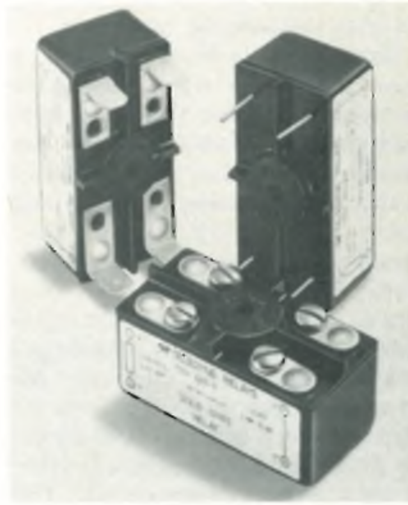


uses stainless-steel springs and gold-plated copper-alloy buses. Dry-circuit contact resistance is less than 1 ohm. The matrix's plastic housing, made of glass-filled thermoplastic, has an insulation resistance at 100 V dc of 10^{10} ohms.

AMP Inc., Harrisburg, Pa. 17105. Phone (717) 564-0101 [345]

Solid-state relay handles 5 A at 250 V dc

Capable of handling loads of up to 5 amperes at 250 volts dc, the model 603 solid-state relay is offered with two control-voltage ranges. The 603-3 has a TTL-compatible 3-to-10-V dc input, and the 603-4 is meant to work with inputs from 10 to 32 V dc.



Transformer-coupling gives the relays an input/output isolation-voltage rating of 1,500 V. Three connection options are available: screw terminals, solder pins for mounting on pc boards, and quick-disconnect terminals. The relays sell for $20.95 each in lots of 1,000.

Teledyne Relays, 3155 W. El Segundo Blvd., Hawthorne, Calif. 90250. Phone (213) 973-4545 [346]

Tiny relay can switch 1 ampere at 24 V dc

Although it measures only 0.4 by 0.39 by 0.59 inches—about 3/32 of a cubic inch—the G2E mechanical relay can switch up to 1 ampere at 24 V dc, with a resistive load, for half a million operations. The relay's annealed-steel frame, isolated from other components by a polyester-film bottom plate, is enclosed in a transparent polycarbonate cover. The device can carry a continuous current of 2 A and can handle an inrush of 8 A. Its small size makes it fast: switching time is only 5 milli-

seconds. Required input power is 450 milliwatts. The G2E is offered with nominal coil-voltage ratings of 1.5, 3, 5, 6, 9, 12, and 24 v dc. The price is less than $1 each in lots of 1,000.

Omron Corp. of America, Sales and Service, 1051 State Parkway, Schaumburg, Ill. 60172 [347]

240-V solid-state relay occupies only 1.6 in.^{3}

Capable of handling sustained loads at 240 volts ac and housed in a package measuring 1 by 1 by 1.6 inches, the models 1002 and 1003 solid-state relays are 3-ampere single-pole single-throw devices with built-in snubbers to prevent false triggering from transients. The normally open devices have control-voltage ratings of 3.5 to 15 v (model 1002) and 9 to 32 v (1003). Price is $10.87 each in lots of 100, and delivery time is three weeks.

Electronic Instrument & Specialty Corp., 42 Pleasant St., Stoneham, Mass. 02180. Phone (617) 438-5300 [348]

Hybrid potentiometers have low nonlinearity, long life

Utilizing an integral conductive-plastic tracking area and a precision wire-wound mandrel, the Plast-O-Wire potentiometer combines the infinite resolution and long life (10 million cycles) of conductive plastics with the low temperature coefficient (-20 to -60 ppm/°C) and low nonlinearity of metals. Nonlinearity ratings from 0.5% to 0.025% are offered. The potentiometer elements are available in lengths from 0.5 to 25 inches with resistances of from 10 to 10,000 ohms per inch. Power dissipation is 0.75 watt per inch up to a maximum of 5 W. Standard resistance tolerance is ±5%, and ±2% is the best practical tolerance that can be offered.

Electronic Controls Inc., 1900 Tyler Ave., S. El Monte, Calif. 91733. Phone (213) 444-9277 [349]

TOPICS

Components

The series TXR time-delay relays by **Syracuse Electronics Corp., Syracuse N.Y.** are the first octal plug-in units to be covered by the Underwriters' Laboratories Recognized Component Program. . . . Two lines of nonpolar electrolytic capacitors—one with radial leads, the other with axial leads—have been introduced by **Illinois Capacitor Sales Co., Morton Grove, Ill.** . . . A standard line of center-tapped thin-film chip resistors has been unveiled by **LRC Inc., Hudson, N. H.** The chips are passivated with glass for mechanical and chemical protection. . . . **Power Conversion Inc., Mt. Vernon, N.Y.,** has announced a lithium battery that can sustain a drain of 1 ampere for 25 hours. The model 660-5 has an energy density of 135 watt-hours per pound. . . . The type F69 is the first in a series of flameproof metal-film power resistors now being produced by **Dale Electronics Inc., Columbus, Neb.** The units are rated at 3 watts at 25°C and can be derated for use up to 235°C. . . . **APM-Hexseal Corp., Englewood, N. J.,** has applied for a patent on a new type of keyboard architecture in which all of the keys or buttons on an existing keyboard are replaced by other keys or buttons that are molded as part of a continuous silicone-rubber membrane. Capable of being fitted onto nearly all existing keyboards, the new keyboard/seal provides protection against hostile environments.

Semiconductors

IC references are adjustable

10-volt precision sources can be varied by ±3% with negligible degradation

Just a few months ago, monolithic sources of a regulated voltage were strictly fixed-output devices—but not any longer. Three-terminal IC regulators can now have a variable output [*Electronics*, Nov. 27, 1975,

p. 133], and newly developed precision references from Precision Monolithics are also adjustable. The output of these IC voltage sources, the REF-01 series, can be varied by ±3% over their full operating temperature range, with negligible change in their nominal 10-volt output level.

Since the units use the energy bandgap of silicon as their reference, rather than the breakdown of a zener diode, they provide a stable reference voltage within a few microseconds of the application of supply voltage. Their output remains stable to within 5 ppm/°C, and their minimum input-voltage range is 12 to 40 V. Power dissipation is nominally 20 milliwatts.

All the units are designed to compensate even for second- and third-order error terms, so that their temperature coefficient remains low over their operating temperature extremes. Each chip is built with compatible thin-film resistors and active bipolar devices that have special geometries for optimum component-matching. Both temperature coefficient and reference voltage are calibrated simultaneously at the wafer-test stage by means of zener-zap trimming, so as to avoid the surface damage that typically occurs with laser trimming.

Five models are available—two (the REF-01AJ and the REF-01J) are military devices for operating at −55°C to +125°C, and three (the REF-01EJ, the REF-01HJ, and the REF-01CJ) are commercial devices for operation at 0°C to 70°C. For the REF-01CJ, line regulation is 0.015%/V, and supply current is 1.6 milliamperes. All the other units have a line regulation of 0.01%/V and a supply current of 1.4 mA.

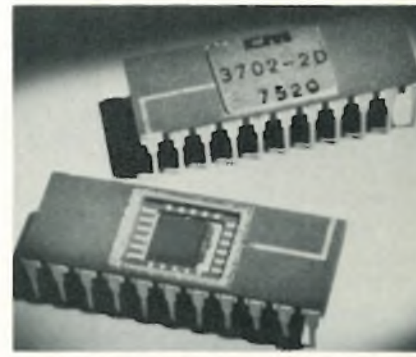
Output voltage remains accurate to within ±0.3% for the REF-01AJ and the REF-01EJ, ±0.5% for the REF-01J and the REF-01HJ, and ±1% for the REF-01CJ. Similarly, load regulation is 0.008%/mA for the REF-01AJ and the REF-01EJ, 0.01%/mA for the REF-01J and the REF-01HJ, and 0.015%/mA for the REF-01CJ. Over the full operating temperature range, the maximum change in output voltage is 0.06% for the REF-01EJ, 0.15% for the REF-01AJ, 0.17% for the REF-01HJ, and 0.45% for the REF-01J and the REF-01CJ.

All the devices are available now. For quantities of 100 and up, price is $22 each for the REF-01AJ, $10.50 each for the REF-01J, $7.95 each for the REF-01EJ, $4.95 each for the REF01HJ, and $1.90 each for the REF-01CJ.

Precision Monolithics Inc., 1500 Space Park Drive, Santa Clara, Calif. 95050 [411]

90-ns n-MOS 2-k static RAM is priced below $20

The 3702 family of 2,048-bit n-channel MOS static random-access memories consists of two models: the 3702-1, with a worst-case access time of 90 nanoseconds and a small-quantity price of $19.85 (dropping



to $13.25 in hundreds), and the 3702-2, which is rated at 70 ns and has corresponding prices of $21 and $14. Both devices are organized as 2,048 words by 1 bit and employ a fully static memory cell which requires no refresh or charge-pump circuitry. Like the manufacturer's earlier 1-k RAMs, the new memories are being used mainly in high-performance add-on memory systems for IBM System/370 computers. The devices are available from stock.

Cambridge Memories Inc., 12 Crosby Dr., Bedford, Mass. 01730. Al Bargoot (617) 271-6355 [413]

Fast-recovery rectifier is rated at 650 amperes

Rated at 650 amperes, continuous, 8,000-A surge, the 651 PDL series of rectifiers has units with maximum reverse recovery times of 1.5 microseconds at 500 to 800 volts, 2.0 μs at 500 to 1,200 V, and 2.5 μs at 1,000 to 1,200 V. Housed in Hockey Puk packages, the rectifiers are well suited for use as bypass (free-wheeling) diodes and in inverter systems. They are priced at about $50 in quantities of 10.

Semiconductor Division, International Rectifier Corp., 233 Kansas St., El Segundo, Calif. 90245. Phone (213) 678-6281 [414]

ICs control triacs in ac power circuits

Containing a limiter/power-supply circuit, a differential on/off sensing amplifier, a zero-crossing detector, and a triac triggering circuit, each of three ICs is intended to control a triac in an ac power circuit. Two of the ICs—the SG3058 and SG3059—also include provision to inhibit the zero-crossing detector and a protection circuit that removes the triac drive in the event of sensor failure. The basic circuit, designated the SG3079, is housed in a 14-pin plastic DIP and sells for $1.65 in singles. The added-capability 3059 is also packaged in plastic and is priced at $3.20. The 3058, supplied in a ceramic DIP, goes for $5.80. All are available from stock.

Silicon General Inc., 7382 Bolsa Ave., Westminster, Calif. 92683. Dick Seinfeld (714) 892-5531 [416]

Reference diodes are extremely stable

A series of temperature-compensated reference diodes includes units with maximum temperature coefficients as low as 5 ppm/°C and operating currents as low as 100 microamperes. The C8000 series devices are offered with three operating currents: 100 μA, 250 μA, and 500 μA—each with a range of ±50%. The 6.5-volt diodes will maintain their specifications from -50°C to 100°C, and can be operated from -65°C to 175°C. Hermetically sealed in DO7 glass packages, the diodes are available with long-term stabilities as tight as 10 ppm/year.

Codi Corp., Pollitt Dr., Fair Lawn, N. J. 07410. William C. Henderson (201) 797-3900 [417]

Monolithic a-d converters resolve up to 12 bits

A line of monolithic analog-to-digital converters consists of C-MOS devices that can resolve 8, 10, and 12 bits. All three converters dissipate no more than 20 milliwatts and require only a few resistors and capacitors and a voltage reference to form complete converters. The integrating-type converters require 1.25

milliseconds to perform an 8-bit conversion, 5 ms for 10 bits, and 20 ms for 12 bits. Housed in 24-pin dual in-line packages, the series includes the model 8700 (8 bits) at $16, the 8701 (12 bits) at $22.50, and the 8702 at $29.50. All prices are for quantities in the hundreds.

Teledyne Semiconductor, 1300 Terra Bella Ave., Mountain View, Calif. 94041. Phone Allan Colby (415) 968-9241 [415]

500-ns n-MOS static RAM is priced below $10

Aimed at microprocessor and peripheral-equipment applications, a 2,048-bit random-access memory is organized as 256 words of 8 bits. The n-MOS static RAM has a maximum access time of 500 nanoseconds and a 100-piece price of $9 each. Inputs and outputs of the 3539-2 are compatible with standard TTL circuitry. A slightly slower version, the 650-ns model 3539, is priced at $8.50 in hundreds. Both of the units are housed in 22-pin dual in-line packages. The RAMs are available from stock.

MOS Products Division, Fairchild Camera & Instrument Corp., 464 Ellis St., Mountain View, Calif. 94042. Phone (415) 962-3816 [418]

Array of eight SCRs minimizes crosstalk

An array of silicon controlled rectifiers from Texas Instruments Incorporated is designed for use in LED- or display-latching, analog switching, or crosspoint-switching. The array, called the TCP2410, uses dielectrically isolated material to minimize crosstalk between the SCRs.

The array has eight SCRs and eight holding-current resistors on the same monolithic chip, reducing the number of external components required for latching applications. It is packaged in an 18-pin dual in-line plastic module and is offered with diode protection from the cathode to the gate. For applications where on/off control is required, the device is available without diode protection, in a version designated the TCP2411. The maximum absolute rating for applied voltage is 50 V, with operating voltage of 20 V. The holding current is typically 350 microamperes with maximum rating of 100 milliamperes.

The units are available in sample quantities. Delivery time for both versions, which are priced at $2.95 each in quantities of 100 to 999 pieces, is two weeks after receipt of order, the company says.

Texas Instruments Incorporated, Inquiry Answering Service, P.O. Box 5012, Mail Station 308, Dallas, Texas 75222 [419]

TOPICS

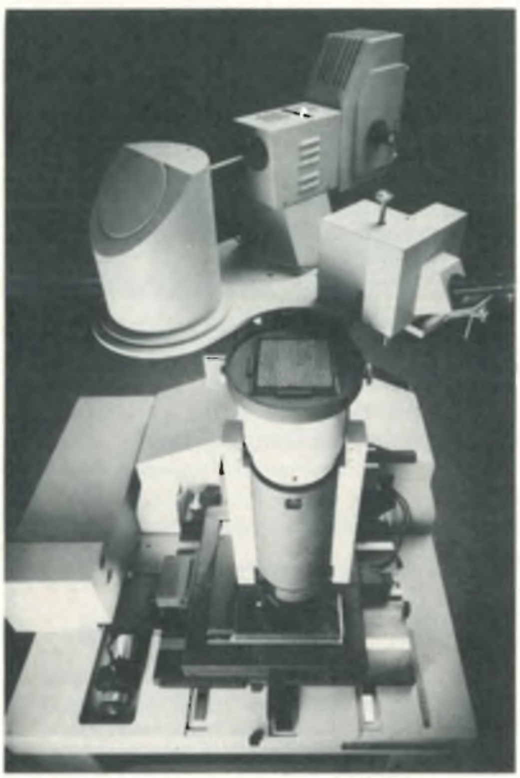
Semiconductors

A 2-kilobit read-only memory that can be erased and programed electrically has been introduced by **NEC Microcomputers Inc., Lexington, Mass.** The device, called the μPD454D, is an n-channel silicon-gate device with a maximum access time of 800 nanoseconds. . . . The industry-standard 8080A 8-bit, fixed-instruction-set microprocessor is available from **Advanced Micro Devices, Sunnyvale, Calif.,** for $29.95 in 100-piece quantities. Called the Am9080A, the device is a plug-in replacement for both Intel's 8080A and 8080 as well as the version made by Texas Instruments. . . . Royalty rates on its microcomputer software have been reduced 50% by **Intel Corp., Santa Clara, Calif.** Affected are the company's PL/M compilers, macro assemblers, and simulator packages.

Packaging & production

System defines lines 1 μm wide

Laser-based photorepeater for IC masks can handle wafers 6 inches square



A crucial step in microelectronics production is the precise manufacture of chromium photomasks. In this process, a 10× reticle is generated—by either photolithography or optical pattern generation—and then further reduced to 1× on step-and-repeat equipment known as photorepeaters. The resulting chromium mask has multiple integrated-circuit patterns exposed on its emulsion.

To produce higher resolution and accuracy in larger wafers, the D.W. Mann division of GCA Corp. has developed the Mann Type 3696 photorepeater. It can handle wafers up to 6 inches square and uses a laser-metered stage-positioning technique that provides linewidths down to 1 micrometer.

To gain this resolution, the 3696 uses a closed-loop system of measuring and positioning, based on a laser interferometer. A servomotor provides coarse positioning of the stage on which the wafer is mounted—to within 25 μm of the desired position, after which fine positioning is done—to within 0.08 μm—with linear motors. The interferometer has a servo-feedback loop to correct the position.

In the laser-metering system, the reference for X and Y positions is the optical axis of the lens rather than a fixed position. So when the stage moves, it moves relative to the optical axis, and the relative position of stage and axis are taken into account at all times. GCA says this method gives a greater probability of accuracy in positioning. The laser interferometer also automatically corrects for atmospheric changes in pressure, humidity and temperature, adjusting itself every 0.5 second. The laser is a Hewlett-Packard model 5501 helium-neon type.

The 3696 also includes an automatic photoelectric focusing system. A stream of photons coming from a source mounted on one side of the lens system is bounced off the mask to a sensor mounted on the other side. If the wafer moves up or down, the sensor will detect the change, and the whole system will move with it. Focus can be maintained to within ±0.5 μm.

The exposable area of the system is 6 by 6 inches (150 by 150 millimeters), and maximum image size is 10 by 10 mm at 10× reduction. GCA says the resolution of 1 μm, high stepping accuracy, and large image size or field of view open up the possibility of using a photorepeater in fabricating surface-wave devices, that need high resolution. The system will also allow the fabrication of bubble memories and charge-coupled devices without photocomposition. Most photorepeater systems use a lens with an 8-mm circular field, but the 3696 has a 10-mm lens that allows it to get good size control at the edge of a 250-mil chip.

The 3696's light source for exposing mask emulsions is a mercury vapor lamp. Power requirement is 110 volts at 130 amperes. Maximum speed of the positioning stage is 2 inches per second. The unit operates at 68°F and is vibration-isolated.

The 3696, controlled by a PDP-11/05 minicomputer and including an environmental control chamber and installation, will cost $237,000. The first units will be available about April 1976, and delivery time will be five months.

GCA Corp., Burlington Rd., Bedford, Mass. 01730. Phone A.C. Tobey at (617) 272-5600 [391]

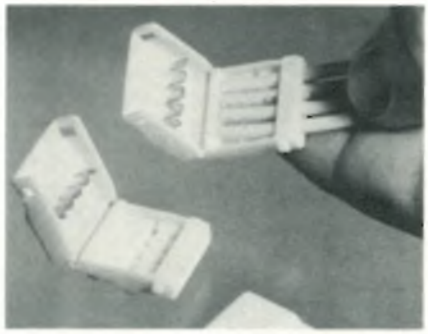
Logic-board testers start at $2,795

A line of low-cost digital logic board testers is available in portable and bench-top models. Both versions are self-contained and perform complete semi-automatic board test and fault diagnostics using the transition-count method. Test capabilities include all types of digital circuits with certain models designed for DTL/TTL testing only, and other versions for MOS, C-MOS, ECL, and other logic types. Requiring minimal program development because of its internal test-pattern generator, the Datatester 1500 series starts at $2,795. Delivery time is 30 days.

Data Test Corp., 2450 Whitman Rd., Concord, Calif. 94518. Phone (415) 689-3583 [393]

U-contact connectors can carry high currents

Designed to connect two, three, or four insulated copper wires, two self-stripping pressure connectors are rated up to 20 amperes and 600 volts. Called the Scotchlok 552 (two-wire) and 554 (three- or four-wire), the connectors use 3M's patented U-shaped contact for both cutting through insulation and establishing a mechanical and electrical connection. The U-contact principle was developed by 3M for telephone hook-up work some 15 years ago; the new connectors are an advance in the technology from low currents to high. Listed by Underwriters' Laboratories and approved by CSA, the connectors are applied in a single operation that simultaneously pierces the insulation on the wires, establishes electrical contact, and encloses the splice in a tough protective housing. The connectors can accommodate wire sizes from 16 to 20 gage. The contacts are made of tin-plated, spring-tempered brass, and the bodies are made of high-impact polypropylene. The connectors are available from stock.



Industrial Electrical Products Division, 3M Co., St. Paul, Minn. 55101 [394]

Tool cuts and bends leads after insertion into board

The model TP-6 Nipper is a hand tool that cuts and bends component leads after they have been inserted through a circuit board. Using no air or electrical power, the tool is claimed to be very easy to use and to be able to stand up to rigorous industrial use. It enables the user to cut and bend leads securely to the board in a single operation. A tension regulator allows the selection of a suitable force to minimize the risk of damage to delicate components.

Hampton Mfg., Box 10, Southampton, Pa. 18966. Sally Pelletier (800) 523-1960 [396]

Data handling

Redundancy is built in

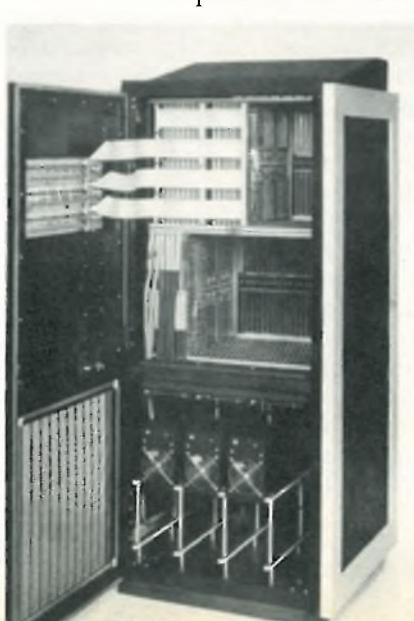
Multiprocessor system designed for businesses that can't afford downtime

Most minicomputer systems are designed to operate singly. When a customer demands a fail-safe system, therefore, specialized operating software is needed to stitch two or more computers together into a redundant system.

It's much better to design a redundant system from the ground up and develop standard operating-system software, claims James Treybig, president of the fledgling Tandem Computers Inc., Santa Clara, Calif. And he's pinning his hopes on that concept with the company's first product, the Tandem-16 Nonstop system, which can contain two to 16 interconnected 16-bit processors.

Such fail-safe systems are aimed at transaction-oriented businesses that can't afford downtime, and the market amounts to about $250 million a year, says Treybig. And, by 1980, the needs of such businesses as banks, airlines, retail and wholesale outlets, insurance companies, and hotel/motel chains could balloon this multiprocessor market to about $800 million a year, Treybig adds.

The minimum Tandem-16 system, designated the Nonstop 204, consists of two Schottky bipolar processors with 32,768 words of core memory each, a 10-megabyte disk drive, a magnetic-tape unit, an operator console, and 16 terminal lines—all for about $65,000. That system is expandable to 16 processors with 512 kilobytes of memory and up to 32 peripheral-device controllers per processor. The processors are connected by a Dynabus, a redundant independent-bus structure with a 20-megabyte-per-second transfer rate and built-in bus control for automatic switch-over or disconnect in the event of a processor or bus failure.



Each processor also contains a microprocessor dedicated to input/output functions. In addition, all I/O-device controllers have dual ports for access to two processors. Even power supplies are redundant.

The Tandem system comes with standard semiconductor main memory that can support up to 512 kilobytes arranged as 22-bit words (16 data bits plus 6 error-correction bits for simultaneous correction of 1-bit errors and detection of 2-bit errors). Cycle time is 500 nanoseconds. With core memory instead of semiconductor, the system can support up to 256 kilobytes arranged as 17-bit words (16 data bits and one parity bit). Cycle time is 800 nanoseconds.

Tandem Computers Inc., 2909 Stender Way, Santa Clara, Calif. 95051. Phone (408) 984-1800 [361]

Conversational CRT terminal has three operating modes

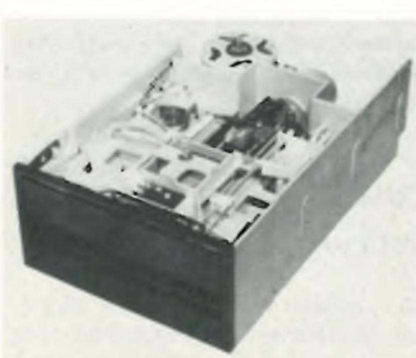
The model NCR 796-401 block/conversational CRT terminal is a multi-speed device with three oper-

ating modes: conversational, page, and message. In these modes, transmissions from the terminal take place a character, a line, or a full screen at a time. The terminal provides upper- and lower-case characters, graphics, and local editing. It can run at 110, 300, 1,200, 2,400, and 9,600 baud. A total of 1,920 characters, arranged as 24 lines of 80 characters each, can be displayed on the terminal's 12-inch screen. The terminal sells for $3,100, and it rents for $130 a month. Availability is immediate.

NCR Corp., Dayton, Ohio 45479. Phone (513) 449-2150 [363]

Universal drive handles hard- and soft-sectored disks

Able to accept IBM-formatted soft-sectored diskettes and 32-hole hard-sectored disks in the same unit, a "universal" drive from Remex allows the user to expand from basic IBM compatibility to enhanced performance without changing drives. The model RFD 7400E includes its own unit-select decoding circuitry allowing four drives to be controlled



by one set of drivers and receivers in the host system. An optional sector generator permits the user to define his own hard-sectored format with storage capacities from 1.9 to 3.2 megabits. The unit contains its own negative-voltage supply. Price is $650 in small quantities; delivery time is 60 days.

Remex, a division of Ex-Cell-O Corp., 1733 Alton St., Santa Ana, Calif. 92705. Phone (714) 557-6860 [364]

Latest Conographic terminal offers selective erase

The latest addition to Hughes Aircraft's line of Conographic graphic-display terminals is a high-resolution unit with selective erase, built-in serial interface, and a base price of only $9,750. Like the rest of the

line, the Conographic-9 displays curvilinear information by conic curve generation rather than by X-Y plotting. As a result much less data is required, speeding image transmission, cutting communications costs between the terminal and the host computer, and reducing storage requirements at the host computer. Also, the curves displayed are smoother.

The fully interactive Conographic-9 has a 17-inch 1,029-line video monitor, built-in zoom/pan capability, a joystick for graphics interaction, and a hardware graphics processor for scaling graphics and numerics. Options include hardware for rotations, reflections, line-texturing, and gray levels. A wide range of software is available in Fortran IV, including a set of Tektronix-compatible subroutines. The basic Cono-Pac software package is offered at no extra cost. Delivery time is 120 days.

Hughes Industrial Products Division, 6855 El Camino Real, Carlsbad, Calif. 92008. Phone (714) 438-9191 [366]

Software system supports 6800 microprocessor

Consisting of a cross assembler, a simulator, and a Fortran IV compiler, the Wintek 6800 software support system can be purchased for as little as $2,000. The compiler, called Wintek PL/M, is largely compatible with Intel PL/M. Both it and the assembler produce relocatable code which can be combined with previously assembled or compiled programs with the Wintek linking loader and can be fed to the simulator, read by a 6800 system, or used to program a read-only memory. The cross assembler and simulator sell for $600 each, or both for $1,000. The compiler is $1,000.

Wintek Corp., 902 N. Ninth St., Lafayette, Ind. 47904. Phone (317) 742-6802 [367]

TOPICS

Data Handling

A hardware/software system to support users of the Intel 8080, the μPro 80, from **μPro Associates, Cupertino, Calif.,** is a convenient debugging and field-service tool. . . . A rugged "intelligent" printer from **Dataroyal Inc., Nashua, N.H.,** is designed for continuous use in extreme environments. . . . The model 7835/7330-12 disk-storage subsystem from **Itel Corp., San Francisco, Calif.,** is designed to provide added memory capacity to IBM System/370 model 135 (and larger) computers. . . . **Pro-Log Corp., Monterey, Calif.,** is now delivering its MPS 8611 microcomputer card which is based on the 8-bit **Motorola** 6800 microprocessor.

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December 25, 1975

■ For more information on complete product line see advertisement in the latest Electronics Buyers' Guide
* Advertisers in Electronics International
‡ Advertisers in Electronics domestic edition

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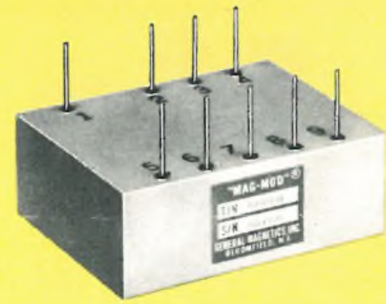
SOLID STATE SINE-COSINE SYNCHRO CONVERTER

This new encapsulated circuit converts a 3-wire synchro input to a pair of d-c outputs proportional to the sine and cosine of the synchro angle.

- Complete solid state construction.
- Operates over a wide temperature range.



UNIT	DMD 1436-1	DMD 1430-1	DMD 1403-2	DMD 1361-6	DMD 1361-4	DMD 1193-4	DMD 1361-8	DMD 1446-1	DMD 1193-5	DMD 1193-6	DMD 1361-10	DMD 1472-2
L - L SYNCHRO INPUT (VRMS)	11.8	90	95	90	11.8	11.8	11.8	11.8	11.8	11.8	11.8	90
FREQUENCY (Hz)	400	400	60	400	400	400	400	400	400	400	400	60
FULL SCALE OUTPUT (VDC)	± 10	± 10	± 3	± 3	± 3	± 10	± 10	± 10	± 10	± 10	± 10	± 10
OUTPUT IMPEDANCE	<1Ω	<1Ω	<1Ω	<1Ω	<1Ω	<1Ω	<1Ω	<10Ω	<1Ω	<1Ω	<1Ω	<1Ω
L - L INPUT IMPEDANCE	>10K	>30K	>5K	>30K	>5K	>5K	>5K	>5K	>5K	>5K	>5K	>5K
REFERENCE VOLTAGE (VRMS)	26	115	115	115	26	115	26	115	115	115	26	115
ACCURACY SIN/COS (+25°C)	± 6MIN	± 6MIN	± 6MIN	± 6MIN	± 6MIN	± 6MIN	± 6MIN	± 0.5%	± 6MIN	± 6MIN	± 6MIN	± 6MIN
FULL TEMPERATURE RANGE ACCURACY SIN/COS	± 15MIN	± 15MIN	± 15MIN	± 15MIN	± 15MIN	± 15MIN	± 15MIN	± 0.5%	± 15MIN	± 15MIN	± 15MIN	± 15MIN
D.C. SUPPLY (VDC)	± 15	± 15	± 15	± 15	± 15	± 15	± 15	± 15	± 15	± 15	± 15	± 15
D.C. SUPPLY CURRENT	<30MA	<30MA	<30MA	<30MA	<30MA	<30MA	<30MA	<30MA	<30MA	<30MA	<30MA	<30MA
BANDWIDTH	>10Hz	>10Hz	external set	>20Hz	>5Hz	>10Hz	>10Hz	>10Hz	>2Hz	>40Hz	>5Hz	external set
SIZE	1.1x3.0 x1.1	2.0x2.25 x1.4	1.1x3.0 x1.1	1.5x1.5 x0.6	1.85x0.85 x0.5	2.01x2.25 x1.4	0.85x1.85 x0.5	2x2.25 x1.4	2x2.25 x1.4	2x2.25 x1.4	2.15x1.25 x0.5	1.1x3.0 x1.1
NOTES	–	dual channel unit	–	–	–	dual channel unit	–	dual sine output	dual channel unit	dual channel unit	–	–
TEMPERATURE RANGE	–40°C to +100°C	–40°C to +100°C	–40°C to +100°C	–40°C to +100°C	–40°C to +100°C	–40°C to +100°C	–40°C to +100°C	–40°C to +100°C	–40°C to +100°C	–40°C to +100°C	–40°C to +100°C	–40°C to +100°C

4 QUADRANT ANALOG MULTIPLIER DC x DC = DC OUTPUT

Model MCM 1478-1

Product Accuracy is ± ½% of all theoretical product output readings over Full Temperature Range of –55°C to +125°C.

Maximum Output Error for Either
X = 0, Y = 10V
Y = 0, X = 10V
X = 0, Y = 0
would be ±2 MV over Entire Temperature Range.

Specifications: Model MCM 1478-1
Transfer Equation: E = XY/10
X & Y Input Signal Ranges: 0 to ± 10V peak
Maximum Static and Dynamic Product Error: ½% of point or 2MV, whichever is greater, over entire temperature range
Input Impedance: X = 10K, Y = 10K
Full Scale Output: ± 10V peak
Minimum Load for Full Scale Output: 2000 ohms
Output Impedance: Less than 10 ohms
Bandwidth: 1000Hz
DC Power: ± 15V, unless otherwise required, at 20ma
Size: 1.3" x 1.8" x 0.5"
Output is short circuit protected

4 QUADRANT SINE FUNCTION GENERATOR

Model MSFG 1489-1
Model MSFG 1489-2
Model MSFG 1489-3
Model MSFG 1489-4

FEATURES:

- Provides a sine function with ½% accruacy over a -180° to $+180^\circ$ range
- Excellent temperature stability
- Full scale output of ± 10V DC
- Scale factor adjusted by a DC signal
- Hermetically sealed package

Specifications:
DC accuracy: ± 30 min of ARC or 0.5% whichever is greater
DC accuracy over operating temperature range:
± 30 min of ARC or 0.75% whichever is greater
Transfer equation: $Eo = -E \sin\theta$
E represents an external DC voltage in the range of + 2V to + 10V
Input resistance: θ input (pin 6) - 100K ± 10%
Input resistance: E input (pin 4) –47K ± 10%
Rated output voltage: ± 10V max at 5ma
Output impedance: < 1Ω
Frequency response:* 400HZ
Power requirements: ±15V DC ±1% at ± 40ma
Operating temperature range:

MSFG 1489-1	– 40°C to + 100°C
MSFG 1489-2	– 25°C to + 85°C
MSFG 1489-3	0°C to + 70°C
MSFG 1489-4	25°C ± 10°C

*Frequency response is specified for a ± 5V triangular input waveform.

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And they're all hermetically sealed to work longer in the toughest environments. Maximum dark currents are only 100 na at 10 volts.

You can choose from six standard Clairex photodarlingtons. Or we'll build custom designs to your exact specifications. Tell us the problem. We'll develop the solution.

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