Solid state display is multicolored 88
ROM's simplify mathematical tasks 104
A move toward military plastic-packaged IC's 127

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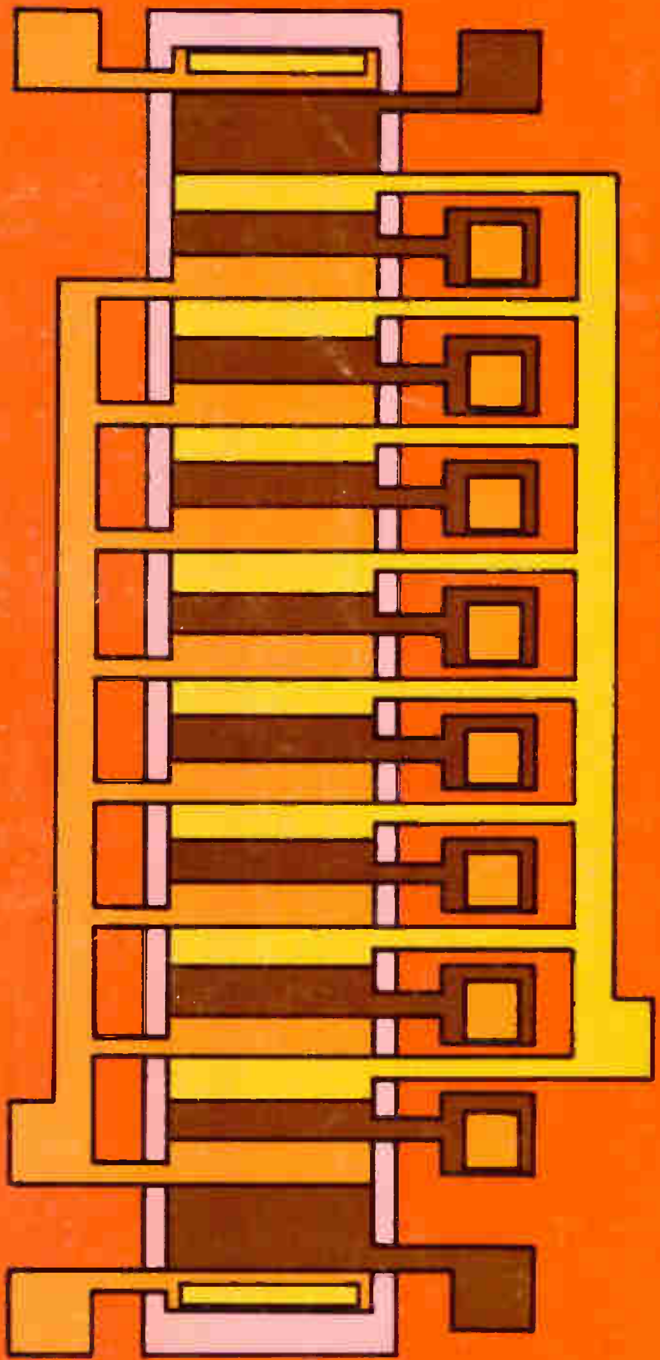
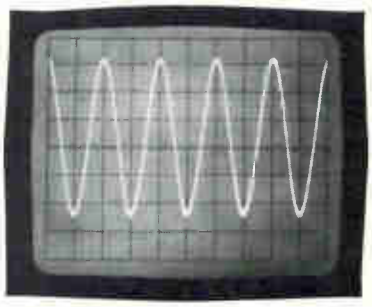
May 11, 1970

Electronics®

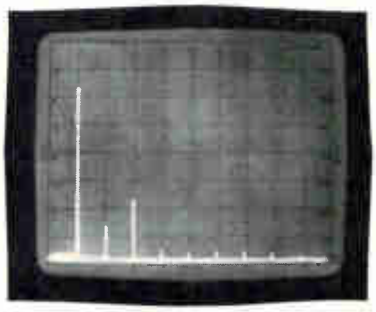


A new look and greater versatility for MOS technology

If you only see this look what you're missing.

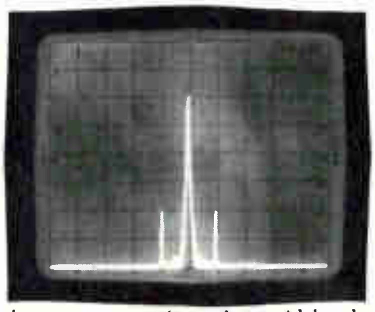


Conventional scope display of 5 MHz signal appears undistorted ⟶

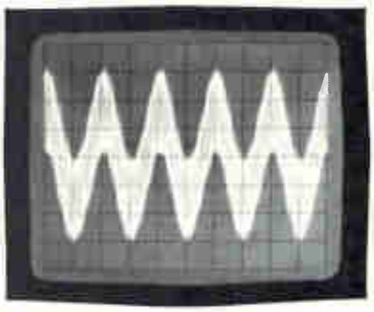


but spectrum analyzer display shows 2nd harmonic 50dB down and 3rd at −40 dB.

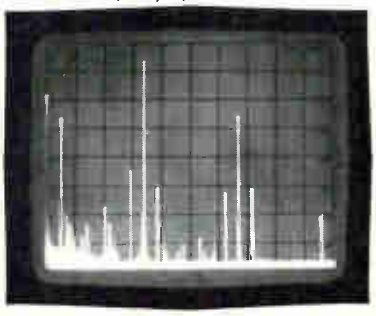
Conventional scope display barely shows 10 kHz AM of 30 MHz carrier ⟶



but spectrum analyzer shows sidebands 40 dB down; i.e., 2% AM.



Conventional scope display merely shows "fuzzy" sine wave ⟶



but spectrum analyzer identifies parasitic oscillations.

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One of the analyzers covers the 1 kHz to 110 MHz range; the other goes from 500 kHz to 1250 MHz. Because frequency response is flat, each provides absolute amplitude calibration — and you can read out in dBm or volts (down to < -120 dBm or 0.1 μV). The $>$ 70 dB distortion-free dynamic range permits you to measure signals with very wide amplitude differences. You can sweep the entire frequency range, then reduce the scan to zoom in for a closeup of any portion down to .0002% of the initial sweep. Selectable bandwidths provide resolution as high as 50 Hz in the 110 MHz instrument and 300 Hz in the 1250 MHz unit.

So why struggle with half the picture in circuit design? The 8553B 110 MHz RF section costs $2100; the 8554L 1250 MHz RF section $3300. Use either of them with the 8552A IF unit ($2050) and a 141T Variable Persistence Display for high resolution ($1700) and you have all the frequency information you need for the complete story in circuit design. Ask your HP field engineer for an applications brochure on this universal lab tool for circuit design and measurement. Or write to Hewlett-Packard, Palo Alto, California 94304; Europe: 1217 Meyrin-Geneva, Switzerland.

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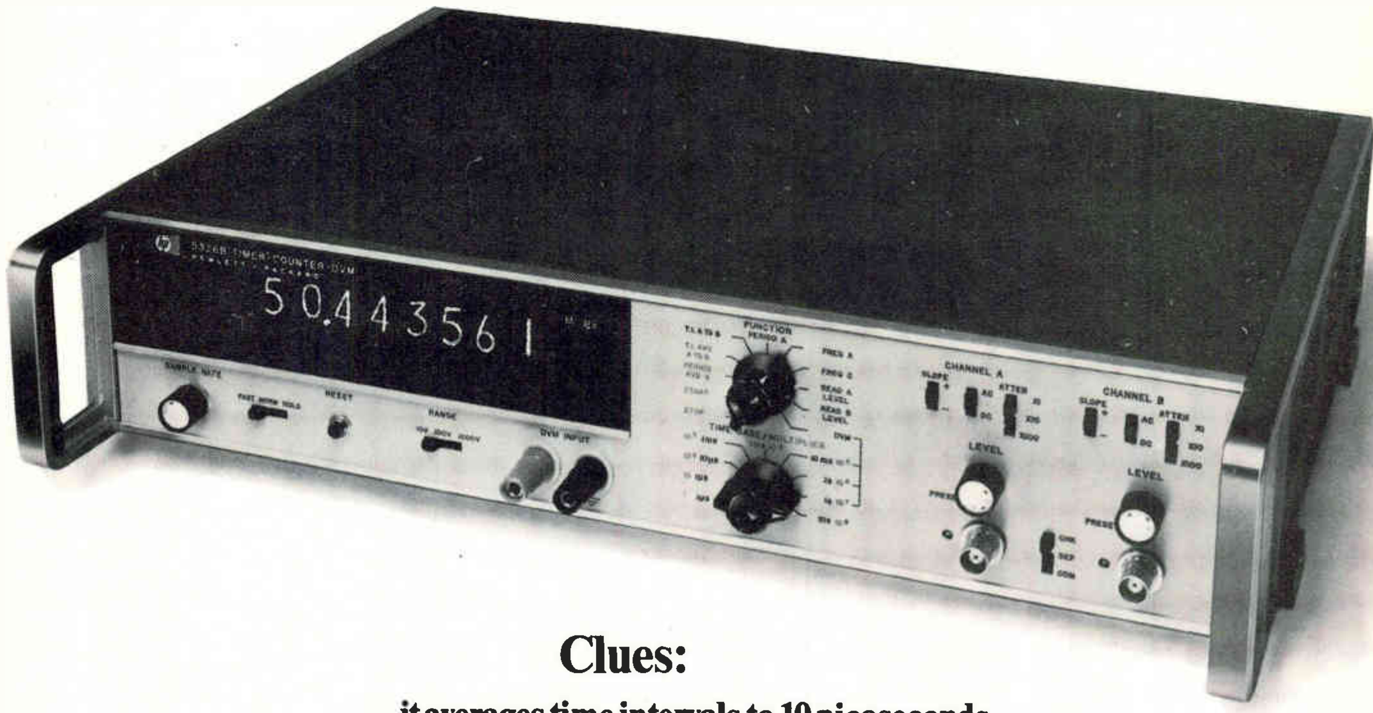
SIGNAL ANALYZERS

Guess the price of HP's new counter



Clues:

it averages time intervals to 10 picoseconds
it has a built-in 0.05% integrating DVM
it's dc to 50 MHz, CW or burst
its counter and DVM are easily programmable

Surprise: $1550. That modest amount buys a Hewlett-Packard timer/counter that does things universal counters never did before. For example, it averages time intervals as short as 0.15 nanoseconds. So you can resolve to 10 picoseconds on repetitive signals.

That modest sum also buys a counter with a built-in integrating digital voltmeter. So it's the only counter that can measure internal trigger level settings or other inputs with DVM precision. Now you can measure 10 to 90% rise times, half power points and other voltage-dependent time intervals. That means unprecedented simplicity, for example, in propagation delay measurements. The counter also features four integration times. As a DVM, it provides three voltage ranges, 60 dB noise rejection and 0.05% accuracy.

Even without these exclusive features, the 5326's are real bargains. They count to 50 MHz direct with seven-digit resolution (eight digits optional), measure period and multiple period average and scale input frequencies by any power of 10 up to 10^8. They measure ratio and they totalize.

With programming and BCD output options, the 5326's fit easily into systems applications. Counter and DVM are DTL programmable through a common connector.

You can get all of these benefits in the 5326B for $1550, or buy the same counter, less the DVM, in the 5326A for $1195. Any way you look at the 5326 A or B—either is a great counter value. Your local field engineer has all the facts about HP's new IC counter line. Give him a call or write to Hewlett-Packard, Palo Alto, California 94304; Europe: 1217 Meyrin-Geneva, Switzerland.

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ELECTRONIC COUNTERS

02003

Circle 2 on reader service card

Electronics

Volume No. 43, Number 10 May 11, 1970

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Probing the News

U.S. Reports

Electronics International

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Articles

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May 11, 1970

Where Swedish engineers shop

● The buying-selling pattern in electronics components and equipment is changing. It is becoming truly international in scope, a trend that was made clear at the Instruments and Measurements Show held in Stockholm in mid-April. The idea of the show, when it was initiated in the 1940's, was to give Swedish electronics companies an opportunity to show off their wares to Swedish technologists. But today, foreign exhibitors outnumber Swedish exhibitors by six to one. This year the U.S. was the leader with 446 firms represented. England followed with 252. In all some 24 countries were represented—even Liechtenstein.

It's equally clear why there were so many buying technologists among the estimated 26,000 people who attended the show. As one Swedish engineer put it, "It's a long way from Stockholm to the IEEE show in New York." Not many Swedish firms can afford even to send their engineers to the Paris Components Show. Similar restrictions apply to companies in almost every other European country—hence the growing popularity of exhibitions like the Paris show and West Germany's Electronica.

At the Stockholm exhibit, nominally an instruments show, the engineers found an array of goods ranging from components through instruments and systems. An engineer from General Instruments' Scottish plant—where some of GI's MIS circuits are both designed and manufactured—said, "We're here to sell to the Swedish calculator market." GI was not alone; the visitor could view the latest in IC's from National Semiconductor, Signetics, Fairchild, ITT and others. Hughes was there with information on its MOS capability. ITT Components showed a veritable supermarket of componentry, ranging from connectors through IC's. Attendees also could roam through an amply stocked Hewlett-Packard exhibit, or examine gear from Tektronix, Teradyne, Fluke, and Rohde and Schwarz.

But the U.S. manufacturers by no means completely overshadowed the local makers. SAAB (Sweden) was showing its marine automation gear. Schlumberger (France) had an impressive display of instruments. The Philips booth was heavily trafficked; a just-introduced compact sampling scope with a bandwidth of 1,700 megahertz was touted by its Swedish maker, Svenska Philips, as much cheaper than U.S.-made scopes having the same frequency range. The giant Swedish firm ASEA was emphasizing computer systems and process control, including equipment for automatic testing of electrical components, gear for monitoring and controlling paper, glass, and steel manufacture, monitoring nuclear power plants, and—with smaller computers like the PDP-8—acquiring weather data, tracking robot targets, and supervising electric power systems. Because ship building is an important Swedish industry, marine automation is a potentially lucrative market for firms like SAAB and ASEA. The Swedish Ship Research Foundation has ordered a computer system from ASEA to be installed aboard the 210,000-ton supertanker Sea Sovereign, the largest ship of the Swedish merchant fleet. The computer is to control the engines from the bridge, handle combustion control, data logging, steering, and carry out navigational functions. It will also do hull-strain calculations, and provide a self-test function.

Neighboring Finland was represented at the Stockholm exhibit by, among other firms, Nokia Electronics, makers of

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gear for telecommunication systems, pcm equipment, data transmission and radio links, and automation and process control systems. Nokia is using IC's heavily in such instruments as data loggers and multi-channel pulse analyzers.

Those who closely examined the Scandinavian equipment at the show—as well as that from other European countries—saw plenty of TO cans and dual-in-line packages bearing familiar symbols like the map of Texas and the batwing "M." It is understandable that Swedish gear should incorporate "foreign" components—particularly IC's, since the semiconductor art is still in its infancy in the Scandinavian countries. ASEA's affiliate, Hafo, for example, is just beginning to supply some IC's, mostly thick-film hybrids.

If the value added by Swedish firms to their final products is small in the component area, it is considerable in system and software design. But even at that some entire subsystems from outside Sweden are incorporated into the end product. For example, Digital Equipment Corp's PDP-8 is the heart of most of ASEA control systems based on small computers, and the ASEA system 1700, built into most of the firm's larger process computer systems, is, in fact, the Control Data Corp.'s System 1700.

So it is easy to see that visitors to the Swedish show would be eager, but selective, shoppers—exhibiting strong interest in U.S. components that they might design into next-generation equipment, examining the instruments carefully regardless of where they were made, and keeping a sharp eye out for subsystems they might incorporate into larger systems, at least until they are able to produce them locally.—D.C. ●

Readers Comment ▶

Tantalizing

To the Editor:

I found a real teaser in your rosy picture of the Toulouse transistor model [Feb. 16, p. 72]. While there are numerous applications noted, I have looked in vain to find a reference to where we can obtain details of the equations that have been developed. It would seem as though there should be some material on the equations either in the open literature or in available reports.

C.S. Iden

Delco Radio division
General Motors Corp.
Kokomo, Ind.

▪ Some details of the equations behind the Toulouse transistor model were published last month in Volume 1, Proceedings of the International Conference on Advanced Microelectronics, which was held in Paris, April 1-10. The paper, "Identification du Comportement des Transistors Bipolaires in Commutation," was authored by G. Rey, K. Lemaire, J.P. Bailbe, and J.P. Daubonne. The proceedings is published by Editions Chiron, 13 Rue Charles Lecoq, Paris 15.

No spinoff

To the Editor:

Your article "Elegantly flat" [March 30, p. 46] mentions that Autotelic Industries is a spinoff of International Scanning Devices of Fort Erie, Ontario. This is not the case. No connection exists between Autotelic and International Scanning, with which we compete directly in the flat-screen field.

Frank V. Tagliarino

Vice president,
Autotelic Industries Ltd.
Fort Erie, Ontario

▪ Autotelic was formed by former executives of International Scanning, and the two companies are indeed separate and in competition with each other.

Voltage typo

To the Editor:

In the new product caption on the BRH/T300 and 600 series, single-phase bridges [April 13, p. 173], there was a misprint. The voltage types should have been 50 to 1,500 volts rather than 10 to 2,500 volts that appeared in the caption.

David L. Mohn

Vice president,
Silicon Products group
Rectifier Components Corp.
Freeport, N.Y.

▪ A gremlin crept in and did the dirty work on the voltages.

Who's Who in this issue

Barnett Heumann Gidley

Two's company—and in the case of the article that starts on page 88, the two are authors Allen M. Barnett and Frederick K. Heumann, and the company is GE. Barnett and Heumann are, respectively, physicist and physical chemist at GE's R&D center. Also shown is Gerald B. Gidley, who prepared the devices described in the article.

Laurence Altman's been busy. *Electronics*' advanced technology editor, who wrote the April 13 cover story on millimeter-wave communications, also is the author of the article on junctionless MOS devices that starts on page 112 of this issue. Altman joined *Electronics* last September after spending several years in industry.

O'Brien

Doctors and computers were the early companions of Donald O'Brien, who wrote the article that starts on page 94: he's done research on developing data processing for the life sciences at the Harvard Medical School. He's now a senior engineer at Laboratory for Electronics.

Hemel

Never one to be tied down too long in one specialty, Al Hemel, author of the article that starts on page 104, has let variety spice his life. Starting in relays and IC design, he's gone to logic circuits at Communication Products Corp.

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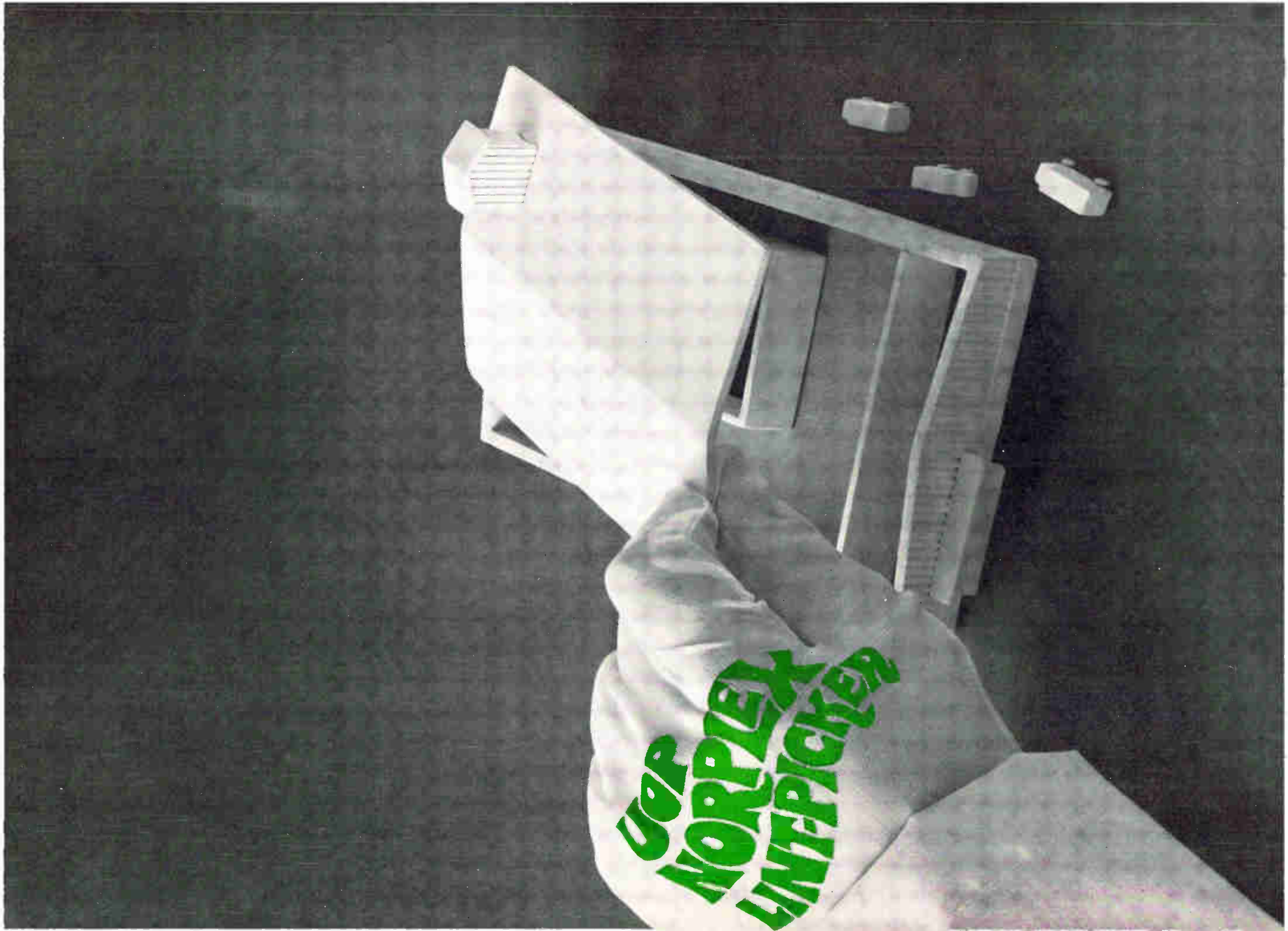
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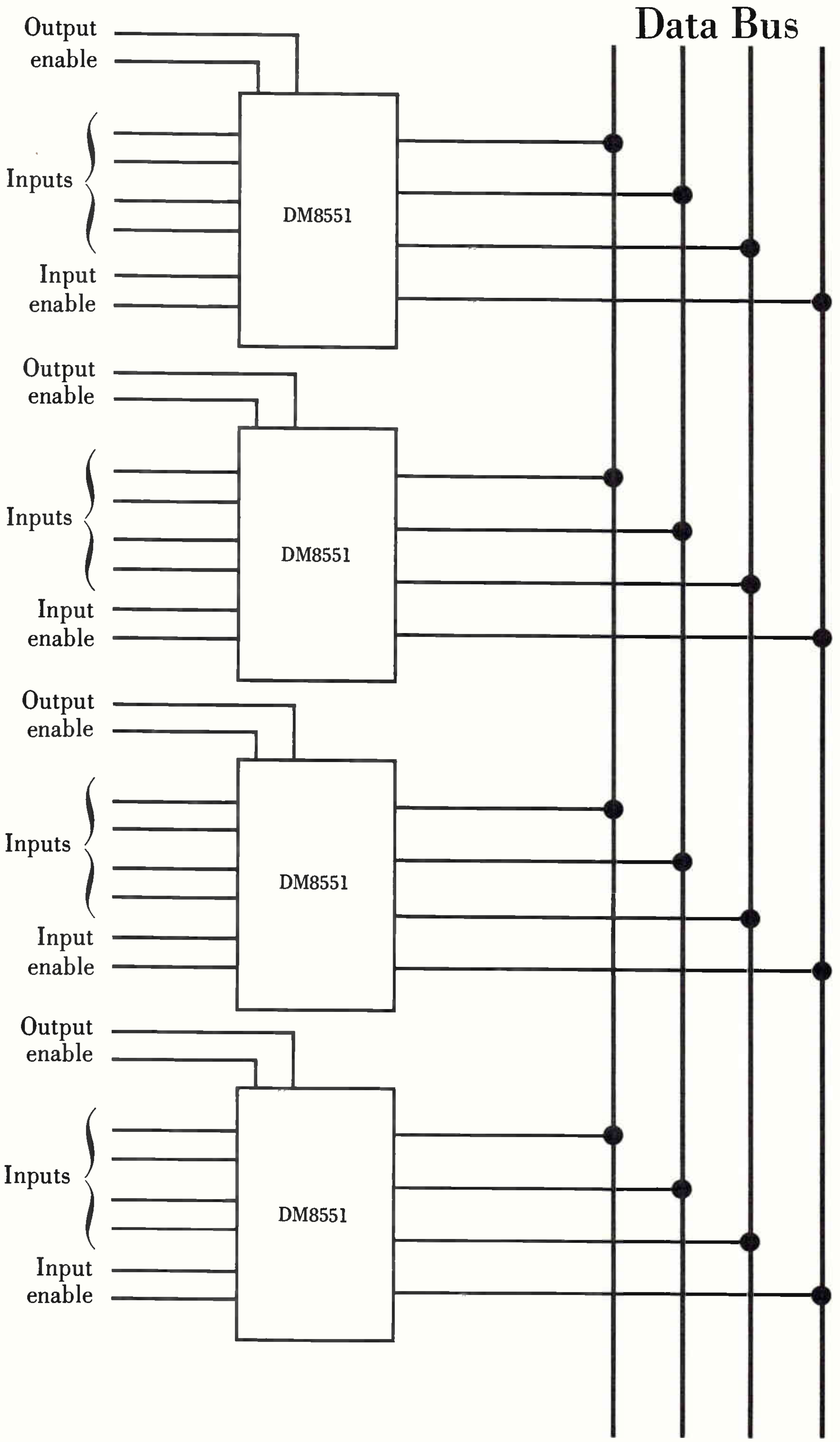
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Who's Who in electronics

Hemmes

Fourteen years ago, Robert A. Hemmes was sweating over the completion of his master's thesis at MIT on a servo-mechanical stabilization system for high-speed railroad trains.

Although his thesis suffered the fate of most such degree requirements—it passed into oblivion—it strongly influenced his career. Today, Hemmes is responsible for $20 million in research, development, and demonstration projects—including high-speed trains—for the Department of Transportation. As assistant administrator for research in DOT's Urban Mass Transportation Administration, Hemmes has been challenged by Secretary John A. Volpe to transform the once-static office of program management "into one dedicated to dynamism" in seeing projects through to completion.

High hopes. Hemmes' goal is to find new ideas, hardware, applications, and techniques that will improve transportation and reduce transportation needs with more efficient scheduling, dual-mode vehicles and route changes. However, in line with the Administration's tight budget policy, UMTA's fiscal 1971 R&D budget was slashed one-third from the previous year's $30 million.

Where does he see the major opportunities for the electronics industry in UMTA's future? In the application of components and systems proved successful elsewhere to help solve public transportation problems.

After graduating from the U. S. Naval Academy in 1948, Hemmes served six years as a naval officer, including destroyer-mine sweeper duty in the Korean war. After his hitch, he returned to college and received his master's degree in 1956 in aeronautical and electrical engineering at MIT, where he also worked on applied mechanics for weapons systems.

Hemmes then rejoined the Navy Department—this time as a civilian employee—in its Bureau of Aeronautics in Washington, where he worked on bomb-delivery systems for two years. In 1958, he became an assistant professor of civil engineering at George Washington University and two years later went to Stanford University. At Stanford, Hemmes—then an associate professor — applied engineering techniques to economic industrial planning and earned a doctorate in industrial engineering.

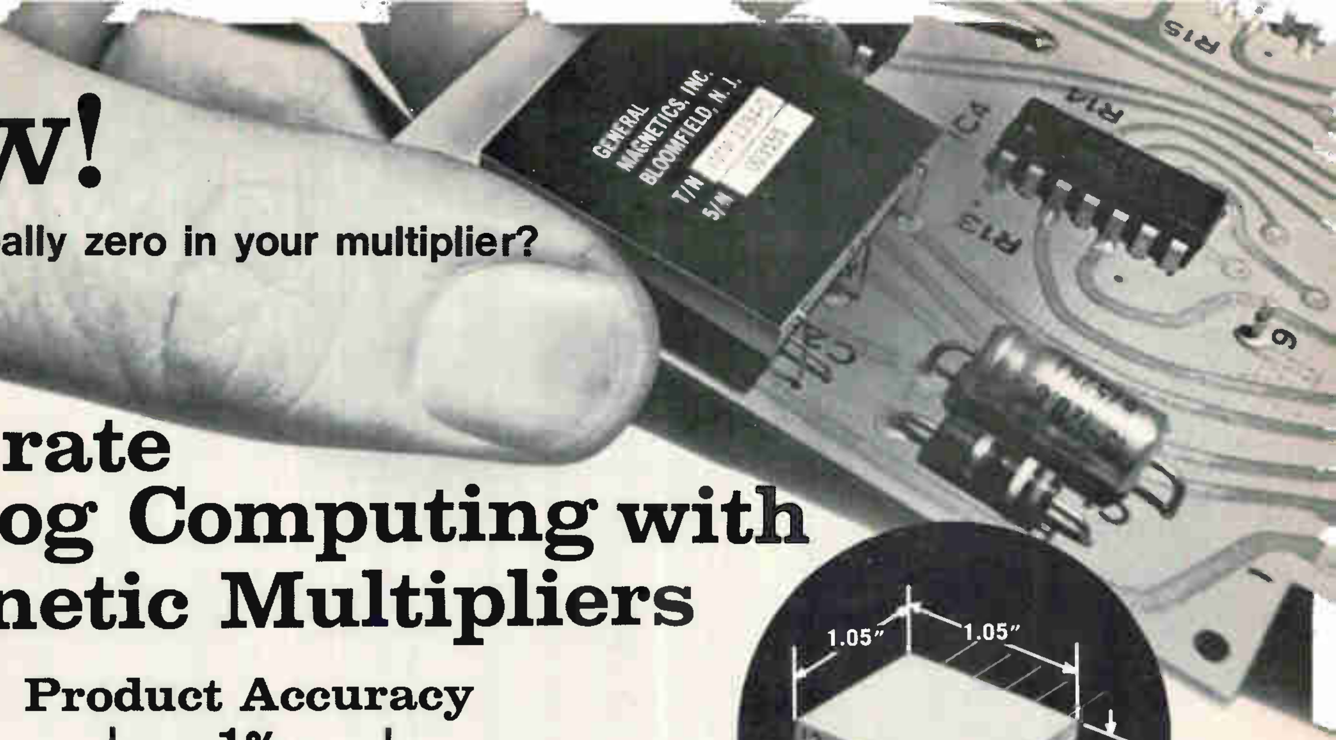
Earlier this year Carlos Villarreal, UMTA administrator and an old friend of Hemmes' from their days at both Stanford and the Naval Academy, asked Hemmes to join him at DOT and help the nation's sorely beset cities save and improve their transportation systems.

Switch. Congress and business have criticized UMTA in the past for being long on studies and short on action. The 45-year-old Hemmes began to change this image immediately after he joined DOT in February at an annual salary of $30,714. His first task was to request progress reports on research projects under way or planned, to determine if too much effort was being spent in any one area—information which had not been readily available before. In addition, UMTA in fiscal '71 will spend more for demonstration projects ($11.5 million) than for all of R&D together ($8.5 million). In 1969, $3.7 million in the $18.3 total budget was spent for demonstrations, and this year $11 million was approved in the $30 million budget.

Apart from larger responsibili-

NEW!

Is 0 x 0 really zero in your multiplier?



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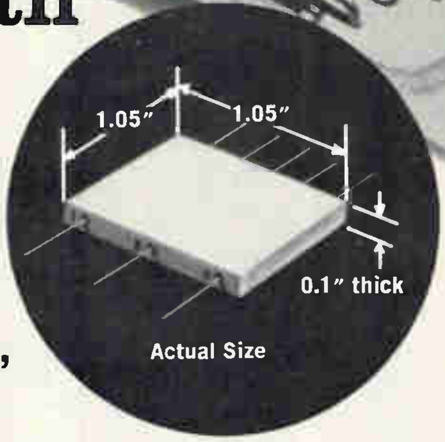

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- Hybrid assemblies mount directly on IC cards.
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±DC X ±DC = ±DC
AC X AC =AC
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Magnetic Modulators

Dynamic Range:

60 db

As an Analog Multiplier of a Bipolar DC signal times an AC signal, the output **product accuracy** is 1% of point, or 2 MV, whichever is greater over a dynamic range of 10,000:1 in each quadrant.

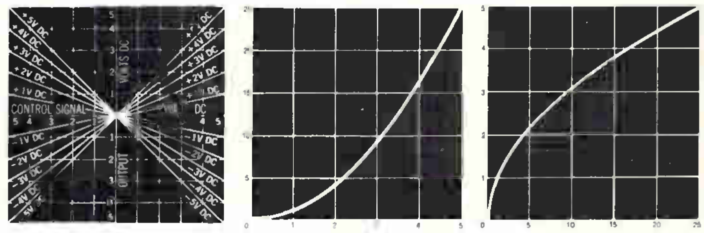
Parameters over the temperature range of —55°C to +125°C :

1) Product accuracy 1% of point or 2 MV whichever is greater
2) Zero Point Drift: ... Less than 2 MV of in phase component
3) Gain Slope Stability: .... Less than 2% change
4) Dynamic range and output wave quality independent of temperature variations
5) Distortion: .... Less than 1%

Typical input/output parameters:

X Signal: .... 0 to ±5V
Y Signal: .... 0 to ±5V
Output: .... 0 to 5V RMS across 5KΩ or greater

Magnetic DC x DC Multiplier — Squaring — Square Root



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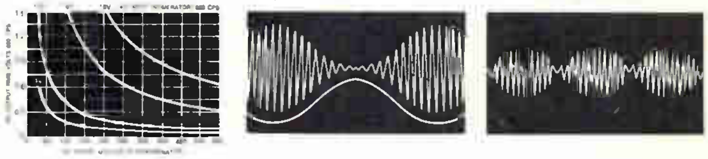


There is No Substitute for Reliability

GENERAL MAGNETICS, INC.

135 Bloomfield Avenue, Bloomfield, New Jersey 07003

ties, Hemmes finds the biggest differences between campus and government life–aside from the responsibility–to be the personal demands of the public to which he must respond and the lack of time to think about his programs. However, he now finds it easier to get access to principal figures in transportation policy, government, and politics and is excited about his potential to influence national policy and participate in the creation and direction of a major new national program aimed at solving urban transit problems.

Hemmes, his wife, the former Alexandra Ossipoff of Honolulu, Hawaii, and their three children reside in McLean, Va., a suburb of Washington.

Of the roughly 5,000 systems installed worldwide or on order from Honeywell's Computer and Communications group, about a third originate in the Computer Control division. That section is expected to grow by half again this year, and Robert C. Baron, its new head of

Baron

engineering, says: "My job is to see that this growth is implemented."

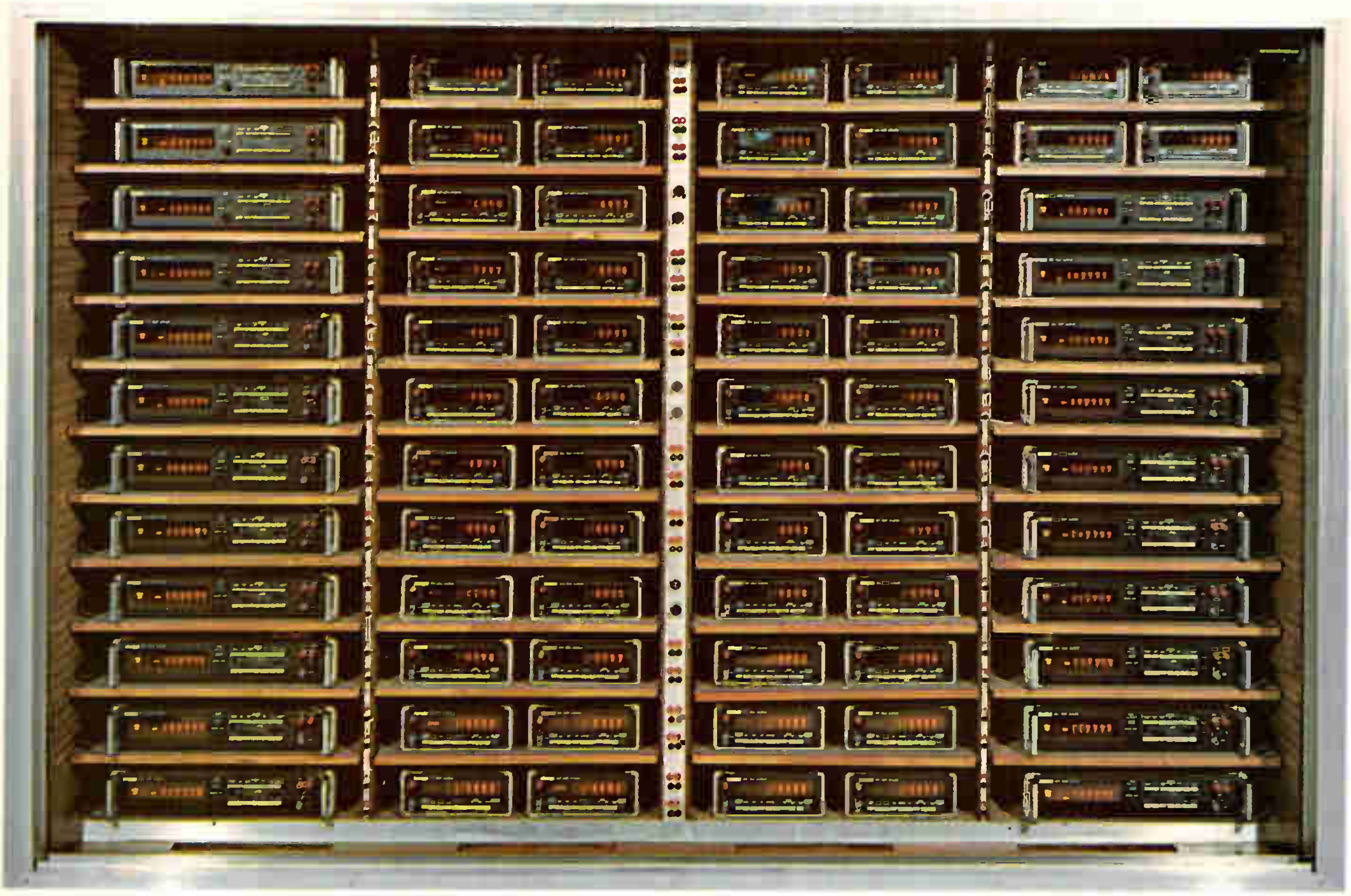
The 36-year-old Baron joined the

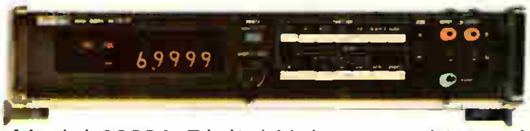
division in 1960 as project manager, data automation, for three Mariner satellites after a stint at Epsco Inc. as a project engineer. In succession he became manager of the Semiconductor Techniques Laboratory, manager of the Module and Memory divisions, and head of digital products. Baron also found time to write several books and some 20 papers on spacecraft systems and circuit design while working his way through the chairs.

Support. In his new post, Baron is responsible for R&D for the entire product line and must "see that CCD is supported by its engineering efforts." To this end he has organized the division's engineering section, creating the new multiple post of chief engineer. There are six—one each in the areas of information systems (including communications and time sharing), the minicomputer, the Series 32 computer, digital products, controllers, and data acquisition and control. Each of these engineers gets a budget and a set of goals for the year, and is in charge of all engineering and programing involved in his area.

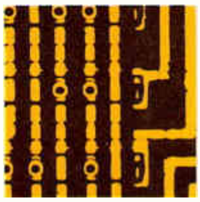
Creating the job of chief engineer, says Baron, "enables us to devote one man per business area, and guarantee that there's someone to worry about it." With a corresponding post in the marketing sector, a one-to-one relationship between engineering and marketing has been established. Moreover, Baron feels the reorganization "will focus on the success of our engineering efforts in specific areas and give the chief engineers more authority." The surge in ideas for new products appears to bear this out.

Several hundred of the division's nearly 3,000 employees work on new products, resulting in "a flood of new product plans," says Baron. Products in several new areas are being evaluated but he won't talk about them—"We don't know which will pay off," he says. However, he does note that several new products will be released each week throughout the year by the Computer Control division, with most of them in computer control applications for the minicomputer and time-sharing systems.





One of the nicest things about our new MSI Multiplexer



Even multiplexers can't escape the advantages of MSI family planning. (When we plan a family, we plan a *complete* family.) Here's proof: The 9322. Our third extremely versatile MSI multiplexer. A high-speed, quad two-input device that consists of four multiplexing circuits with common select and enable logic. Each circuit contains two inputs and one output.

Of course, the 9322 is ideal for moving data from a group of registers to a common output buss. But, being a very versatile device, it has many other applications. For example, it can be used to generate any four functions of two variables.

This latest addition to our MSI family gives us a well-rounded multiplexer capability. In addition to the 9322, we have the 9309 dual four-input multiplexer and the 9312 eight-input multiplexer which feature complementary outputs.

All three devices offer on-chip select logic decoding, fully buffered outputs, typical through delay of 9ns, and complete compatibility with Fairchild DTμL, LPDTμL, TTμL and MSI families.

To order MSI Multiplexers, call your Fairchild Distributor and ask for:

PART NUMBER	PACKAGE	TEMPERATURE RANGE	PRICE (1-24)	(25-99)	(100-999)
U6B930951X	DIP	−55°C to +125°C	$15.80	$12.70	$10.60
U6B930959X	DIP	0°C to + 75°C	7.90	6.35	5.30
U4L930951X	Flat	−55°C to +125°C	17.40	14.00	11.70
U4L930959X	Flat	0°C to + 75°C	8.70	7.00	5.85
U6B931251X	DIP	−55°C to +125°C	15.80	12.70	10.60
U6B931259X	DIP	0°C to + 75°C	7.90	6.35	5.30
U4L931251X	Flat	−55°C to +125°C	17.40	14.00	11.70
U4L931259X	Flat	0°C to + 75°C	8.70	7.00	5.85
U6B932251X	DIP	−55°C to +125°C	15.80	12.70	10.60
U6B932259X	DIP	0°C to + 75°C	7.90	6.35	5.30
U4L932251X	Flat	−55°C to +125°C	17.40	14.00	11.70
U4L932259X	Flat	0°C to + 75°C	8.70	7.00	5.85

is the family it comes from.

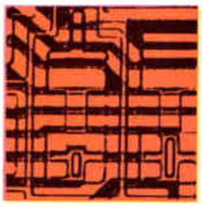
We put together a family plan by taking systems apart. All kinds of digital systems. Thousands of them.

First we looked for functional categories. We found them. Time after time, in a clear and recurrent pattern, seven basic categories popped up: Registers. Decoders and demultiplexers. Counters. Multiplexers. Encoders. Operators. Latches.

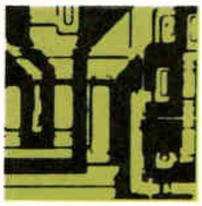
Inside each of the seven categories, we sifted by application. We wanted to design the minimum number of devices that could do the maximum number of things. That's why, for example, Fairchild MSI registers can be used in storage, in shifting, in counting and in conversion applications. And you'll find this sort of versatility throughout our entire MSI line.

Finally, we studied ancillary logic requirements and packed, wherever possible, our MSI devices with input and output decoding, buffering and complementing functions. That's why Fairchild MSI reduces–in many cases eliminates–the need for additional logic packages.

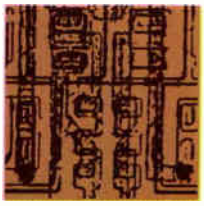
The Fairchild MSI family plan. A new approach to MSI that's as old as the industrial revolution. It started with functional simplicity, extended through multi-use component parts, and concluded with a sharp reduction in add-ons. Simplicity. Versatility. Compatibility. Available now. In military or industrial temperature ranges. In hermetic DIPs and Flatpaks. From any Fairchild Distributor.



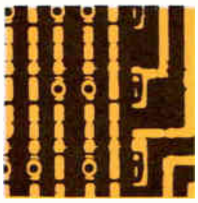
OPERATORS
9304 – Dual Full Adder/Parity Generator



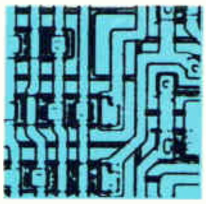
LATCHES
9308 – Dual 4-Bit Latch
9314 – Quad Latch



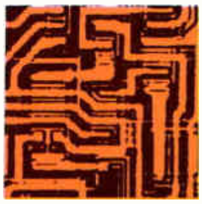
REGISTERS
9300 – 4-Bit Shift Register
9328 – Dual 8-Bit Shift Register



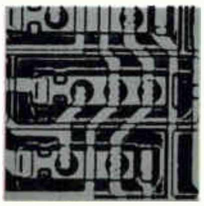
MULTIPLEXERS
9309—Dual 4 Input Digital Multiplexer
9312—8-Input Digital Multiplexer
9322—Quad 2-Input Digital Multiplexer



DECODERS AND DEMULTIPLEXERS
9301 – One-Of-Ten Decoder
9315 – One-Of-Ten Decoder/Driver
9307 – Seven-Segment Decoder
9311 – One-Of-16 Decoder
9317 – Seven-Segment Decoder/Driver
9327 – Seven-Segment Decoder/Driver



COUNTERS
9306 – Decade Up/Down Counter
9310 – Decade Counter
9316 – Hexidecimal Counter



ENCODERS
9318 – Priority 8-Input Encoder

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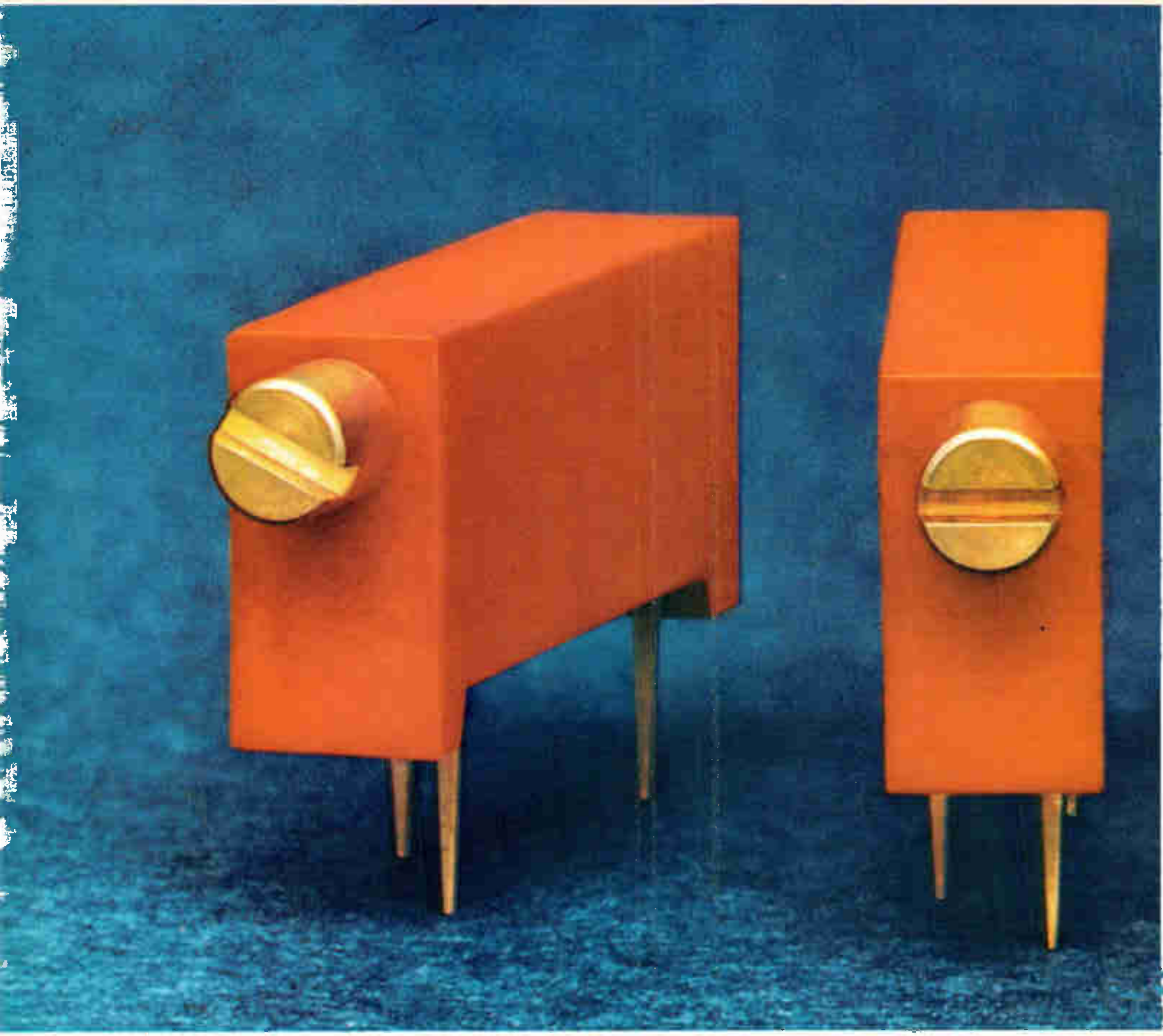
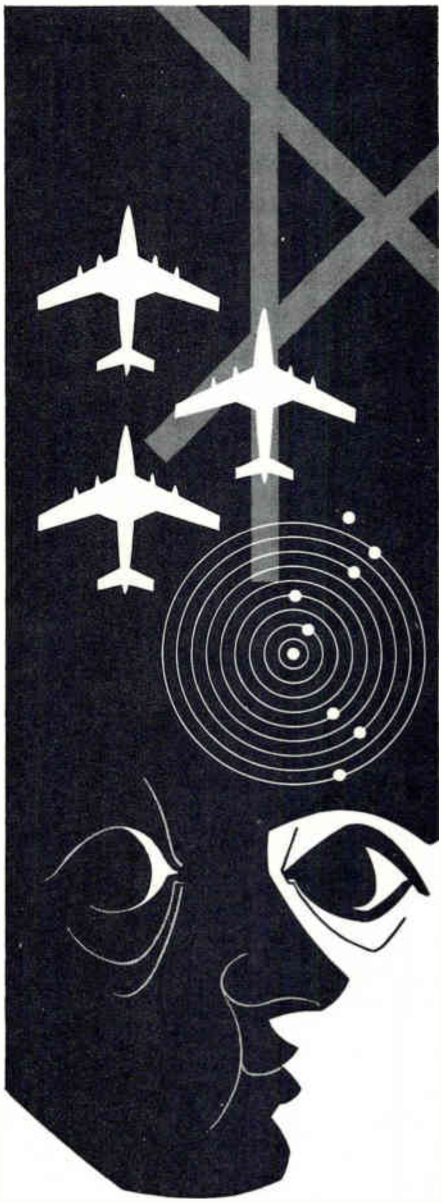


What our extra choice means to you.



Meetings

Calling all communicators

All roads for communications engineers will lead to San Francisco June 8-10 for the International Conference on Communications. Speakers will come from Australia, Austria, Belgium, Chile, France, England, Italy, Japan, the Netherlands, Mexico, Germany, Switzerland, Canada, and the U.S.

The conference, in the San Francisco Hilton, will consist of 48 technical sessions and 259 papers. The conference planners have set aside a session for late papers, and they indicate that a Russian delegation may present a group of papers on communications in the USSR.

The 259 papers will cover data transmission, telephone systems, radio systems—including microwave, millimeter waves, and lasers—computer communications, switching systems, antennas, circuit theory, and satellite operations. The emphasis of ICC, according to Allen Peterson, conference technical chairman, is on data communications as related to computers and data transmission.

Interface. The highlight session is a panel on communications for the communities of man and will focus on the problems of communicating technology to society. Panelists will be F.L. Bates of the University of Georgia, C. Cherry of the Imperial College of Science and Technology of London, H. Haymerle, Austria's ambassador to the United Nations, and H.E. Hoelscher of the University of Pittsburgh.

The session on regional communications satellite systems and technology will include a paper by a group from Stanford University on a low-cost educational tv receiver terminal. Another paper focuses on a multiple-beam antenna for regional communication satellites, while a third deals with Australia's domestic satellite communication system.

Computers will receive a good deal of the coverage, and a session featuring new approaches is the one on voice response from computers. IBM and Bell Labs will have papers. A session on computer communication systems will explore data switching adaptive decision feedback equalizers, and a two-wire d-c baseband system for two-way simultaneous data transmission at high speeds.

Lasers. The sessions on millimeter waves will present papers on the capacity and limitation of these high-frequency systems with special emphasis on point-to-point communication. Laser communications will also be discussed. Among the papers of interest: a CO_2 laser system for space communication, avalanche diode oscillators, system considerations for millimeter-wave space communications, and millimeter-wave relay.

A session presented by IBM of France will highlight the IBM 2750 telephone system. Other sessions on customer telephone systems will hear papers on a new Stromberg-Carlson PABX and common-control key telephone system.

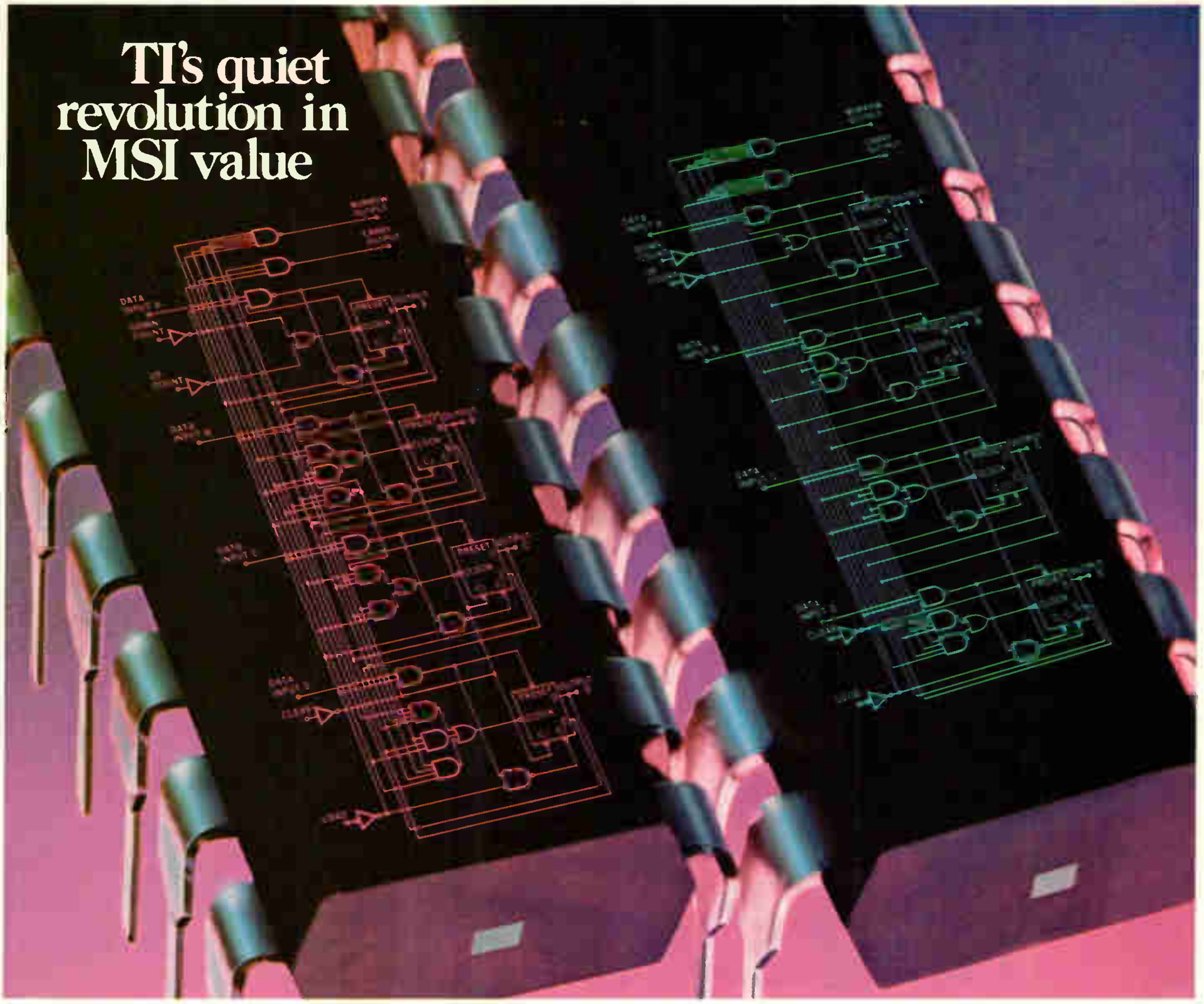
For further information, contact Allen Peterson, Stanford University, Palo Alto, Calif.

Packing it in at MIT

With the growth in large-scale monolithic circuitry, the device package has become a cause of controversy—and as LSI devices grow larger, some experts expect trouble predicting where the device ends and the subassembly begins. At the outside, the 1970's will be a period of flux for packaging engineers. And so nobody east of Chicago who's working with electronic packaging should miss the first annual Eastern Electronics Packaging Conference. It is to be held at MIT, June 8 and 9.

Conference chairman Jack J. Staller, president of the Microsystems Technology Corp., hopes for controversy, and he'll probably get it. Men holding almost any point of view on almost every aspect of packaging from device encapsulation to back-panel wiring and in-

(Continued on p. 24)



Your choice in up/down counters is up. And the price is down.

Count on TI to introduce new TTL/MSI counters priced at about a third of what you usually pay.

The SN54/74192 is a BCD 4-bit up/down counter. The SN54/74193 is a binary 4-bit up/down counter. In 100-999 quantities, the SN74192 and SN74193 both sell for a down-to-earth $7.70, plastic DIP. That's the lowest price going—brought down by TI's big yields and manufacturing know-how.

And these counters are ready now for immediate delivery. That's why you may want to order them instead of the equivalent DM8560 and DM8563. Not to mention the price.

These 54/74 devices are virtually universal counters. They are synchronous and fully presettable. They may be cascaded to n bits, and have fully independent clear. Propagation delay is 27 ns typ; count frequency is 32 MHz typ. You can choose the full military temperature range of −55°C to 125°C or the industrial range of 0°C to 70°C...in either plastic or ceramic DIPs.

Be one-up on up/down counters. Send now for the new 184-page supplement to our TTL catalog. Circle 280 on the Reader Service Card or write Texas Instruments Incorporated, P.O. Box 5012, M.S. 308, Dallas, Texas 75222. That's where the quiet revolution is going on. Or see your authorized TI Distributor.

TEXAS INSTRUMENTS
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Meetings

(Continued from p. 22)

dustrial design will speak.

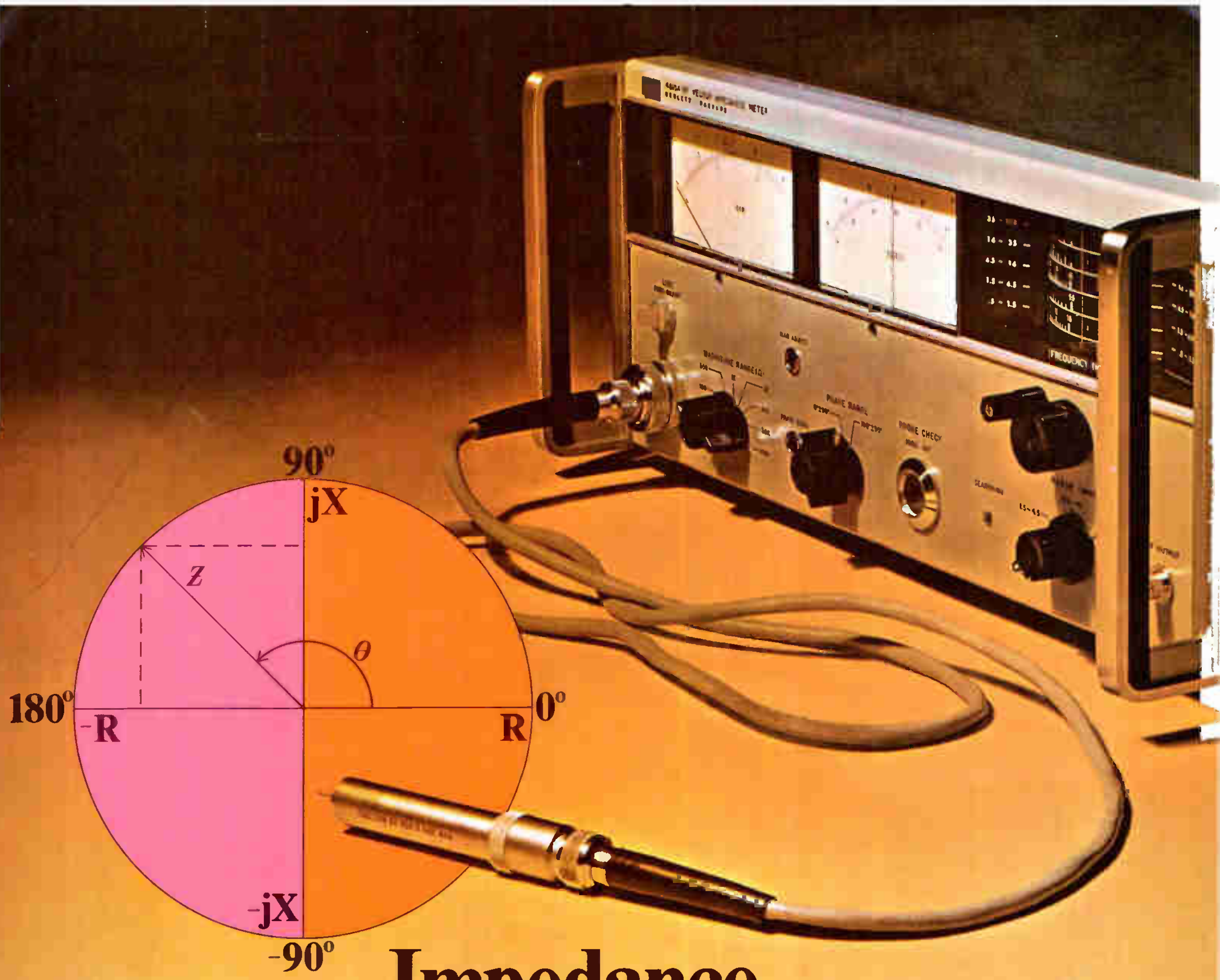
From the gun. This isn't one of those conferences that lets you ignore its first session. At this one —a panel—Robert McMahon of Lincoln Laboratory will participate as head of the IEEE Computer Packaging subgroup and at the same time is sure to have to defend his beam-lead substrate device-packaging concepts. On the same panel are men who will hit most other definitions of packaging: W.J. Allen of Raytheon will cover sophisticated packaging for aerospace systems; D. Hartman of Hughes will talk about his work in automated design, p-c-board layout, and artwork generation; Glen Madland, once with Motorola and now president of his own Microtronic Technology Inc., will show how the closing gap between device and subassembly is changing the entire mechanical aspect of electronic design.

In Session 2, packaging of hybrids and IC arrays is the topic. Session 3 will tell how some in industry are hooking these devices together into subassemblies. Session 4 will discuss subassembly interconnection. And Session 5 will concentrate on the most important topic to any company after the above areas have been explored: design and production automation.

The gamut. So, if your interests run to hybrid microelectronics already judged by NASA good enough for the Grand Tour deep space probes (D. A. Graybill, General Dynamics, in Session 2); or to MIT's view of the impact of LSI packaging on the physical design of systems (Jacob H. Martin of the C. Stark Draper Laboratories, also in Session 2); or to the many tradeoffs between wired interconnections and multilayer p-c boards—as in Session 3—plan to stay all day Monday.

Tuesday's sessions include a paper on applying microwave stripline principles to high-speed logic interconnections by Tore N. Anderson, Winchester Electronics, in Ses-

(Continued on p. 26)



Impedance Measurement goes full circle

The HP 4815A RF Vector Impedance Meter will conveniently measure complex impedance over the entire impedance domain. You get instant, direct readout of impedance magnitude from 1 ohm to 100K ohms and phase angle from 0 to 360°, over a frequency range of 500 kHz to 108 MHz. Now you can easily measure impedances with negative real parts, often present in feedback amplifiers with small phase margin. To measure impedance at multiple frequencies, simply set the frequency, probe, and read. No nulling and balancing, as with conventional bridge measurements.

A convenient probe lets you measure directly in **active** circuits to determine driving point impedance under actual operating conditions, with minimum residual effects. For example, amplifier input or output impedance can be continuously monitored while bias, feedback, load, and frequency are varied. In-circuit measurements for determining loop gain and phase margin can also be made.

The 4815A is also ideal for evaluating **passive** devices, such as components and networks. Use it to characterize transformers, resonant circuits, transmission lines, filters, and crystals. You can measure at actual operating frequencies and make network adjustments while impedance parameters are monitored. For example, antenna/transmission line matching networks can be quickly adjusted. Price: $2650.

To learn more about how easy it is to use impedance for evaluating circuits and components, request Application Note 86 and a special impedance issue of the HP Journal. If you would like to discuss a particular application, call your local HP field engineer or write: **Hewlett-Packard, 100 Locust Ave., Berkeley Heights, N.J. 07922. In Europe: 1217 Meyrin-Geneva, Switzerland.**

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IMPEDANCE INSTRUMENTS

Meetings

(Continued from p. 24)

sion 4. Also in the fourth session is a paper by Loral's Allan Chertoff and James Foti dealing with an extension on their quick-turnaround approach to chip interconnection—only this time dealing with a quick-turnaround subassembly interconnection approach.

For further information contact, Jack J. Staller, President, Microsystems Technology Corp., 53 B St., Burlington, Mass. 01803

Calendar

Electronic Components Conference, IEEE and the Electronic Industries Association; Statler-Hilton Hotel, Washington, **May 13-15.**

Medical Electrical Safety, IEEE, Group on Engineering in Medicine and Biology; Marriott Motor Hotel, Philadelphia, **May 15.**

Packaging Industry Technical Conference, IEEE; Cherry Hill Inn, N.J., **May 19-21.**

Materials for Optical Systems, Optical Society of America; Kresge Auditorium, Little Theater, Massachusetts Institute of Technology, Cambridge, **May 20-21.**

Information Display Evolution and Advances, Society for Information Display; Statler Hilton Hotel, New York, **May 26-28.**

Society of Automotive Engineers Spring Meeting; Roosevelt Hotel, New Orleans, **May 27-28.**

Conference on Precision Electromagnetic Measurements, IEEE; National Bureau of Standards, Boulder, Colo., **June 2-5.**

Silicon Device Processing, American Society for Testing and Materials; National Bureau of Standards, Gaithersburg, Md., **June 2-3.**

National Cable Television Association Convention; Palmer House Hotel, Chicago, **June 7-10.**

Eastern Electronics Packaging Conference, IEEE; Massachusetts Institute of Technology, Cambridge, **June 8-9.**

International Conference on Communications, IEEE; San Francisco Hilton Hotel, **June 8-10.**

The world's most unpre
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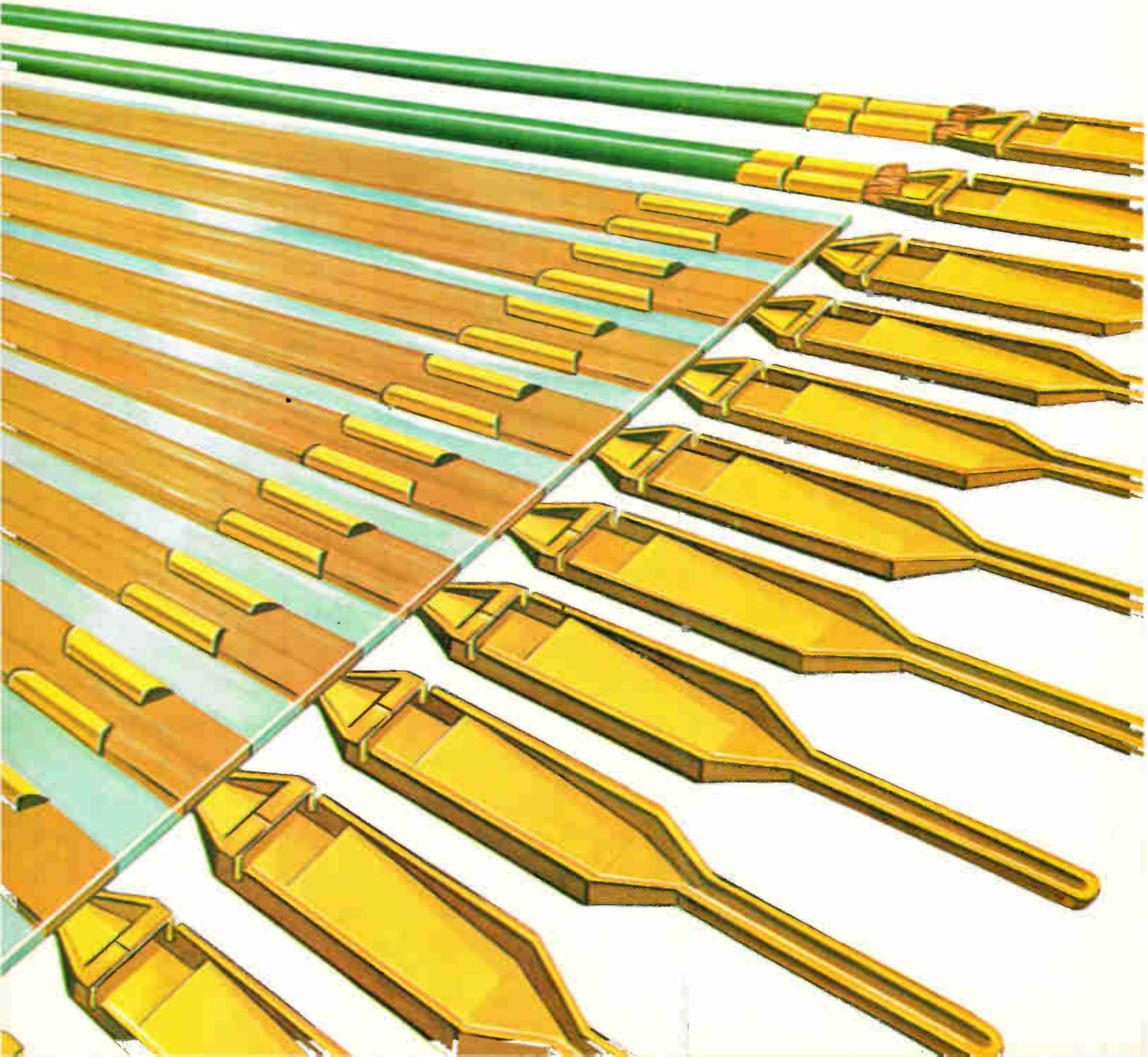
reliable terminations.

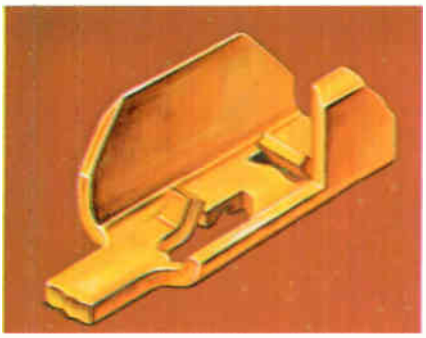


pared flat cable

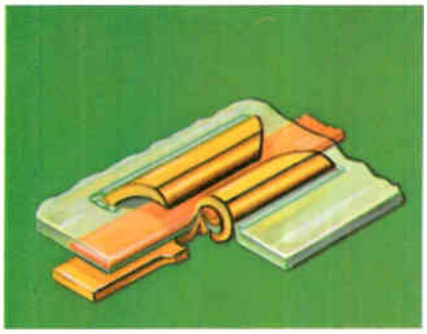
We completely eliminated all flat cable preparation. And replaced it with a Mechanical Termination Technique.

One crimp for each conductor path. That's all it takes to terminate flat cable with our unique method. And it makes absolutely no difference if you crimp on the contacts at the ends of the cable or the middle. Our automatic machine does both. At money-saving speeds.

We displace the insulation, then crimp. The contacts we use are "U" shaped. The edges are sharp enough to penetrate the cable insulation.

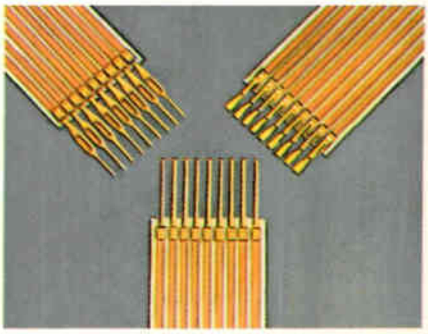


These legs straddle the conductor, and are then rolled 180° to pierce the insulation again. This displacement makes reliable positive contact. Two protruding lances on the under side of the "U" pierce the insulation from the other side. The result is four metal-to-metal-to-metal gastight area contacts in each termination with no deforming effects on the conductor.

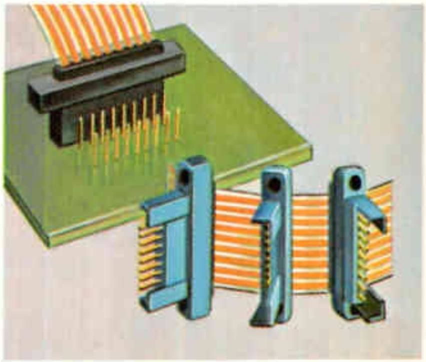


Up to 3,400 terminations an hour. Honest. With a 29 position cable you can really get 3,400 finished terminations an hour. With a 19 position cable you get 2,700. Absolutely no cable preparations — just cut and terminate. It's all done automatically with our precision engineered machine that you can use in your own plant.

Three types of contacts. Crimp snap-in contacts. Square pins .025 inch. And flat tabs for welding or flow soldering to PC boards or components. They can all be crimped to the cable at the ends or any point along its length.



Application. These same pins and sockets can be snapped into housings for the following applications: cable to cable connector, cable to printed circuit board connectors and cable to basic back panel grids commonly used in point-to-point wiring systems. All the above applications can be accomplished with either flat cable or round wire.



Your costs go down as fast as the crimps. Just let the machine do its job and you'll get the lowest installed costs of any flat cable termination method.

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Circle 29 on reader service card

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They've been application-tested from production lots by prospective users with stringent reliability requirements. They do the job. And their energy handling capability is verified by Delco Pulse Energy Testing.

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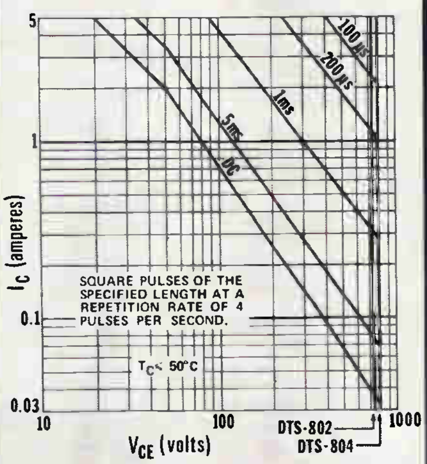
Now you can simplify the design of high energy circuits with reduced size, weight, and component cost. Convert HV tube circuits to solid state reliability without the complexity associated with high current, low voltage devices. And fewer components mean higher reliability.

For prices and delivery or additional data on Delco's new DTS 802 and 804 contact us or your nearest Delco Radio distributor.



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PARAMETER	DTS-802	DTS-804
Collector to emitter voltage (V_{CEX})	1200V max.	1400V max.
Collector to emitter voltage (V_{CEO})	1000V max.	1000V max.
Sustaining voltage (V_{CEO} sus)	750V min.	800V min.
Emitter to base voltage (V_{EBO})	5V max.	5V max.
Collector current (I_C) continuous	5A max.	5A max.
h_{FE}, I_C = 3.5A, V_{CE} = 5V	2.2 min.	2.2 min.
*P.E.T.; I_C = 7A, V_{CE} = 200V, t_p = 300 u sec, duty cycle <4%	420 mJ min.	420 mJ min.

*Pulse Energy Test

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Electronics Newsletter

May 11, 1970

Air Force may ask for proposals on I/CNI study

The Integrated Communications, Navigation, and Identification approach to avionics may take a step toward hardware development this month, according to Col. Waldo E. Bertoni, chief of the communications unit for the Air Force Electronic Systems Division. **If fiscal year 1970 funds can be released, ESD will quickly request proposals for a six-month study for what is called U/CNI (for Unified/CNI).** Bertoni isn't putting a price tag on the multicontractor study effort, but allows nine months for evaluation afterward, and implies that it may be possible to ask for bids on prototype hardware late in 1971 or early in 1972.

Meanwhile the low-cost CNI system [*Electronics*, July 21, 1969, p. 115] proposed as a technology demonstrator is said to have proven unnecessary. **"Just about every technique we need is already or almost on the shelf," says Bertoni.**

During the briefings that led to the junking of the so-called thin-thread CNI, ESD also may have found the way to phase in CNI without massive dumping of existing avionics. Project manager Lt. Col. Thronton Doss says **U/CNI probably would use a time-division multiplexed sampling system to tap the output of each avionic black box in quick succession, and then transmit their outputs to the ground digitally.**

Viatron cuts payroll in drive for profit

While denying rumors that its backers are pressing it—and announcing a price rise—Viatron has released 294 nonproduction personnel—including 22 engineers. Also, all employee members of the board of directors have taken 25% pay cuts. **The reason, according to executive vice president Joseph Spiegel: the company is determined to turn a profit this month.**

"No one critical to product development or production has been let go," says Spiegel. As for the cash-flow rumors, he adds: "We have no senior debt, and there's plenty of cash in the bank." He also points out that those who leave will take their stock options with them. Still, Viatron, whose System 21 display terminal was designed to lease for $39 a month in its simplest configuration, lost $9.47 million on sales of less than $1 million during the year ended last October.

Viatron's vendors appear to be taking the news in stride. **One MOS supplier says that Viatron "almost does business COD—none of this 120-day accounts-receivable stuff."**

Meanwhile, Viatron is gearing to produce more than 850 data entry consoles in May; March production was 613 units. Spiegel says backlog is rising at about 15% per month. And at the Spring Joint Computer Conference, the firm showed a TTL-prototype of its new 16-bit 2140/2150 computer. **Insiders say Viatron came within one wafer of showing an all-LSI machine;** reason is that Viatron still is zeroing in on self-aligned-gate processing. Probe yields are running about 40%—"embarrassingly low," according to Jay R. O'Donald, array engineering manager—but rising fast toward the target of 70%.

TRW lists MIC's putting out 10 watts

TRW's Semiconductor division is extending its power-at-frequency technology from discretes into microwave integrated circuits. The division will announce a line of standard hybrid power-amplifier modules within the next two months, **probably including six or seven devices ranging in output up to 10 watts at 2 gigahertz.** Gains as high as 23 decibels have already been achieved, with a 20% bandwidth, in units being made for custom applications.

TRW Semiconductor officials believe they are first into production with outputs up to 10 watts in microwave IC's and add that the forthcoming standard units will be the first on the market, ahead of developmental efforts under way at RCA [*Electronics,* April 14, 1969 p. 100] and Texas Instruments. Small-quantity prices will be about $1,000, but they'll drop "well below that" for 100 or more, one spokesman says. He sees the power MIC amplifiers being used in telemetry, industrial microwave communications, and phased-array radar.

SAM-D flying right on course

Apparently recovered from last fall's Pentagon rumblings about technical difficulties, **the Raytheon Co. says that the SAM-D missile development phase is right on schedule.** There had been a budget cut caused by slippage in the program [*Electronics,* Nov. 10, 1969, p. 63], but House slashes were restored later.

Floyd Wimberly, the Raytheon vice president who heads the SAM-D program, says that only a minor hitch in range instrumentation last month at White Sands prevented the firing of the first locked-fin propulsion test vehicle. **By autumn, he adds, the missile should be in test with fins unlocked for aerodynamic and control checks.**

Also, the SAM-D phased array radar antenna—a horn-lens combination with about 6,000 individual phase shifters—**exceeded performance targets for gain, side lobe suppression, and monopulse null depth in its very first test.** Thus, integration of the radar, guidance, and computer systems at Raytheon's Bedford laboratories also is on time. Wimberly expects a demonstration of the system's electronics by next spring.

Raytheon and the Army already are beginning to work out the detailed engineering development of the SAM-D; **Wimberly predicts that the largely digital system will use as few as 40 interchangeable IC modules** to keep spares and maintenance overhead as low as possible and operational readiness well above 90%.

NASA budget still unsure

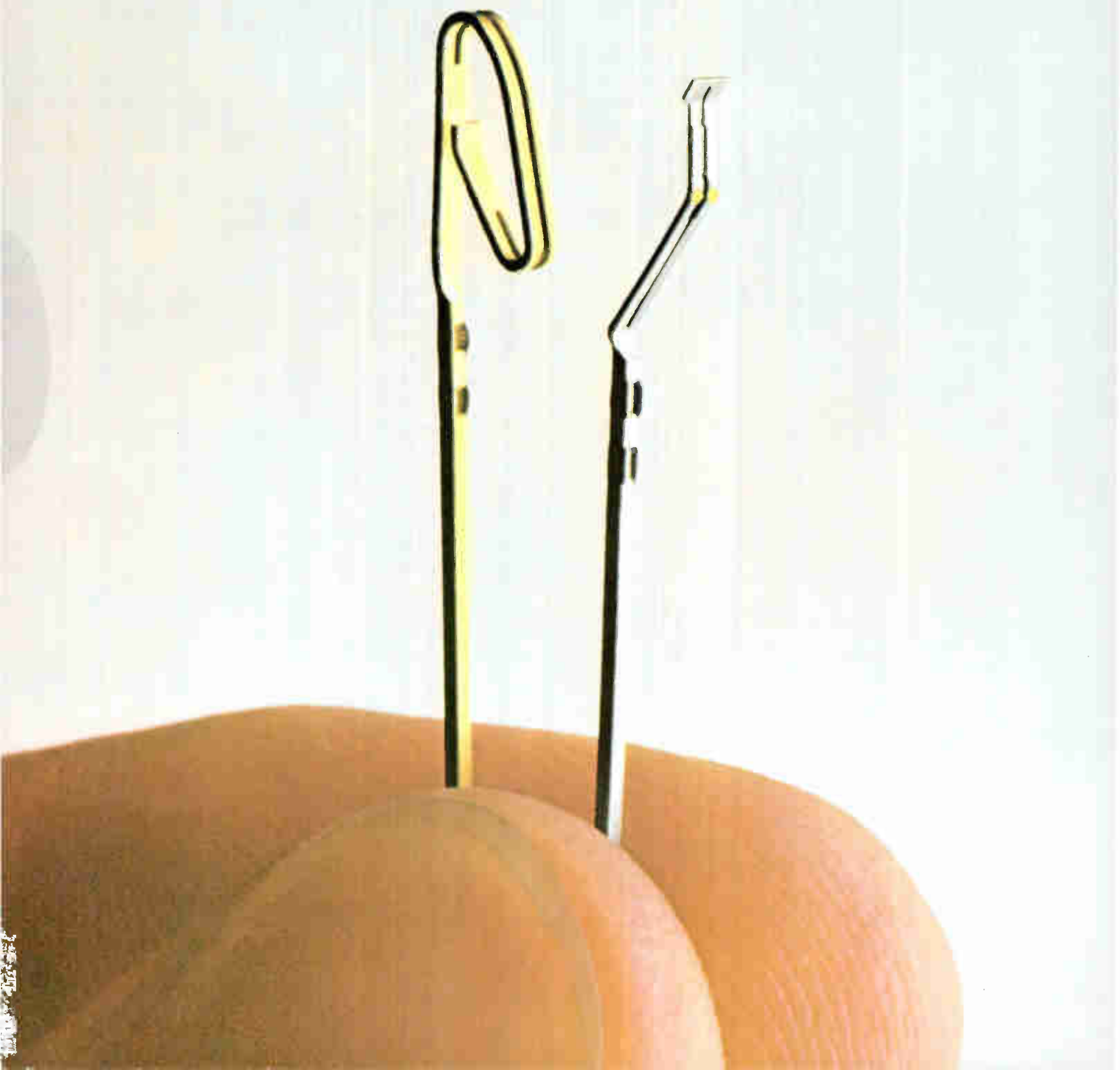
NASA has far from won its budget ballgame with Congress, despite the surprisingly small $30 million token cut made by the House last month. The House voted to authorize $3.6 billion for the space agency in fiscal 1971—$268 million more than the amount sought by the Administration. **NASA didn't really expect to get the nearly $300 million added by the House Committee on Science and Astronautics** and is unsure how the full House cuts of $14.5 million for the expanded Apollo program and $15.5 million from the larger Space-Flight Operations program might affect them.

The Senate version of the bill may not get to the floor until the week of May 11, because of more pressing business—chiefly the Senate's concern over U.S. involvement in Cambodia. However, last month the Senate Aeronautical and Space Sciences Committee cut the Administration's $3.3 billion request by $17 million.

Game of the name

RCA finally has the right to call its video playback system "SelectaVision" **after reaching a friendly agreement with Telemedia Systems.** Telemedia, which owns the name "Selectivision," had claimed infringement by RCA.

Sylvania ushers in the Golden Age of connectors.

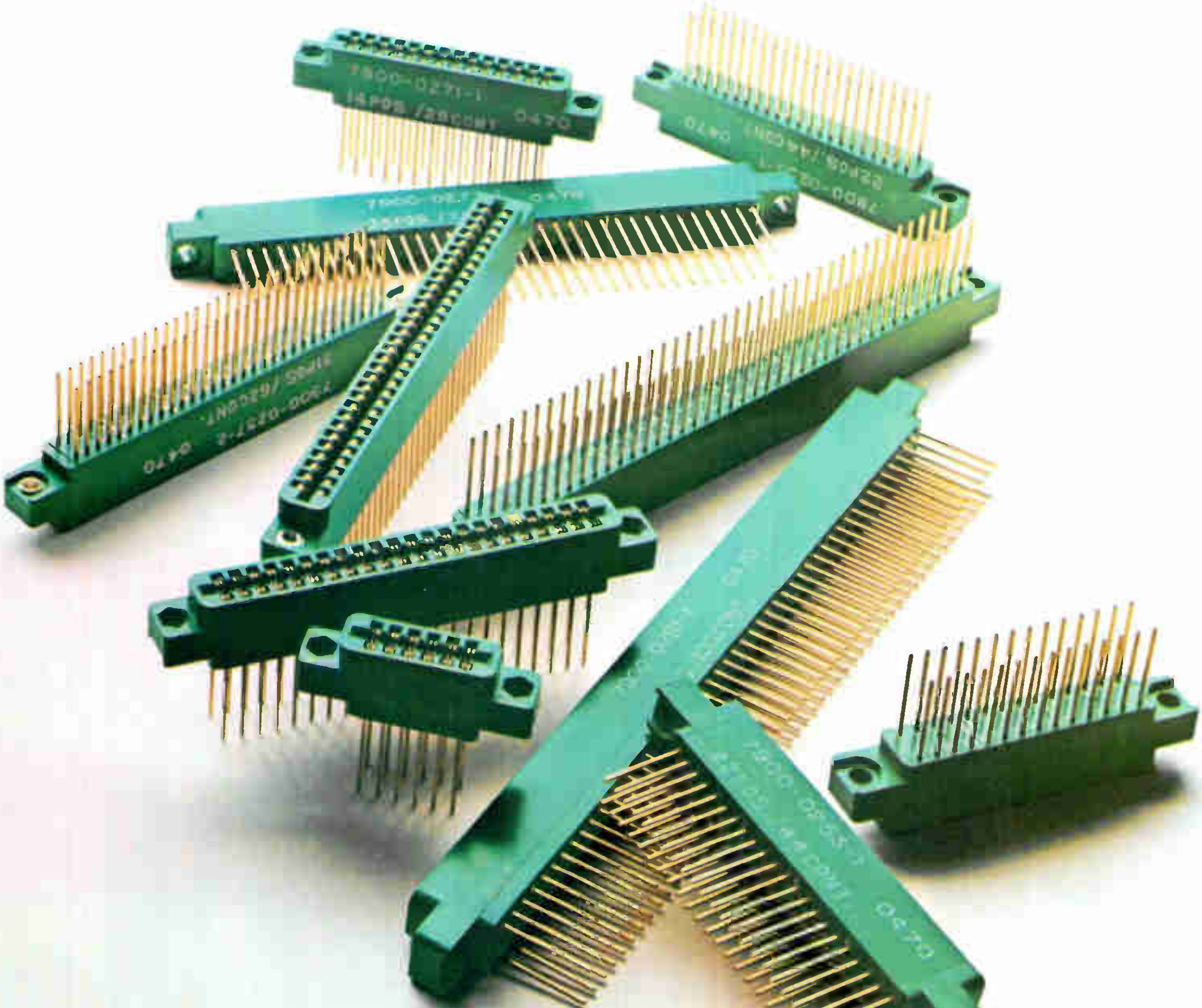


With two new off-the-shelf

Now we can give you quick delivery even on connectors that used to be considered custom jobs.
Our first new line of PC-card edge connectors runs from 12 to 100 contacts with .125″ contact spacing.
Our second gives you 36 to 100 contacts with .100″ contact spacing.

For any connector in these lines, you can choose either gold-plated bellows contacts or gold-dot contacts which we've been making reliably for years.
No other manufacturer gives you this freedom of choice of contacts throughout a complete line in the same moldings.
With these connectors, we even manage to save

custom lines.



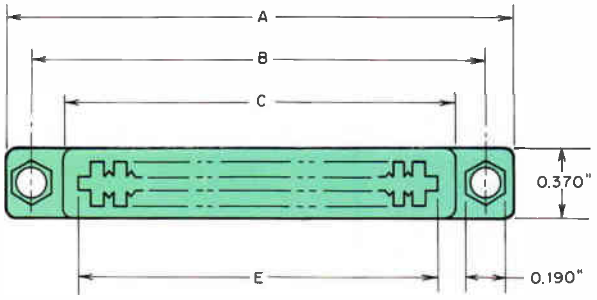
you money. Tooling costs are on the house. And if you choose gold-dot contacts, they'll cost you less.

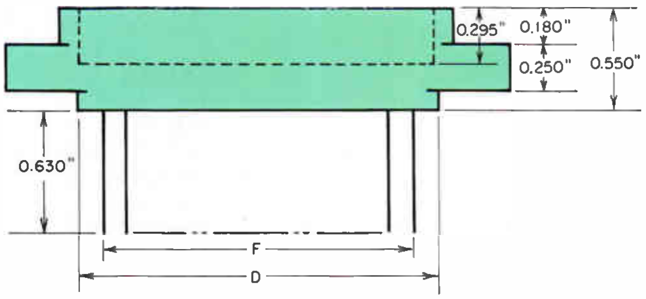
Our new connectors—including the gold-dot types—are designed to meet Mil Spec C21097B. Which means they're designed to give you 500 or more trouble-free insertions. We're able to hold the locus point on contact tails within .010″ radius of true position, so you won't have any trouble with your programmed wiring machines.

The main thing is—we've speeded up the process of getting you good connectors.

And that's as good as gold.

Even the oddballs are conventional.





.125" Contact Centers
(Rated for 800 volts DC)

Number of pairs/ contacts	A	B	C	D	E	F
6/12	1.555	1.295	1.035	.875	.875	.625
10/20	2.055	1.795	1.535	1.375	1.375	1.125
14/28	2.555	2.295	2.035	1.875	1.875	1.625
15/30	2.680	2.420	2.160	2.000	2.000	1.750
18/36	3.055	2.795	2.535	2.375	2.375	2.125
22/44	3.555	3.295	3.035	2.875	2.875	2.625
28/56	4.305	4.045	3.785	3.625	3.625	3.375
31/62	4.680	4.420	4.160	4.000	4.000	3.750
35/70	5.180	4.920	4.660	4.500	4.500	4.250
40/80	5.805	5.545	5.285	5.125	5.125	4.875
44/88	6.305	6.045	5.785	5.625	5.625	5.375
49/98	6.930	6.670	6.410	6.250	6.250	6.000
50/100	7.055	6.795	6.535	6.375	6.375	6.125

.100" Contact Centers
(Rated for 600 volts DC)

Number of pairs/ contacts	A	B	C	D	E	F
18/36	2.635	2.375	2.060	1.950	1.900	1.700
20/40	2.835	2.575	2.260	2.150	2.100	1.900
22/44	3.035	2.775	2.460	2.350	2.300	2.100
25/50	3.335	3.075	2.760	2.650	2.600	2.400
28/56	3.635	3.375	3.060	2.950	2.900	2.700
30/60	3.835	3.575	3.260	3.150	3.100	2.900
31/62	3.935	3.675	3.360	3.250	3.200	3.000
35/70	4.335	4.075	3.760	3.650	3.600	3.400
36/72	4.435	4.175	3.860	3.750	3.700	3.500
40/80	4.835	4.575	4.260	4.150	4.100	3.900
43/86	5.135	4.875	4.560	4.450	4.400	4.200
44/88	5.235	4.975	4.660	4.550	4.500	4.300
49/98	5.735	5.475	5.160	5.050	5.000	4.800
50/100	5.835	5.575	5.260	5.150	5.100	4.900

Some technical details

Read between the lines for oddball connectors, such as 19/38 or 46/92. We supply these, too.

Connectors are designed for use with .062"-thick printed circuit cards. They are rated at 3 amps, voltage drop not to exceed 30 mV at rated current. Temperature range: —65 to +125 °C.

Connector bodies of diallyl phthalate. Choice of bifurcated gold-plated bellows or gold-dot contacts. Choice of mounting holes: with or without bushing. Choice of plastic or metal polarizing keys.

For more information, write to: Sylvania Precision Materials, Parts Division, Warren, Pa. 16365.

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D/A Converters: Make or buy?

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*Model MDA 10-H is also available for 300 ns settling times (does not include output amplifier).

2

GUARANTEED PERFORMANCE

You just unpack the DAC 10-H and plug it in. No external trim pots, output amplifier or other components are required . . . apply ±15V power and your input signals. DAC-10 H is ready to go, with performance tested and guaranteed. No debugging, no trimming, no missed deadlines. Speaking of performance, compare the features with the alternative modular converters in the adjacent chart. DAC-10 H is clearly the Best Buy for all applications where up to 10-bit resolution and accuracy, moderate speed, and input logic flexibility are required.

3

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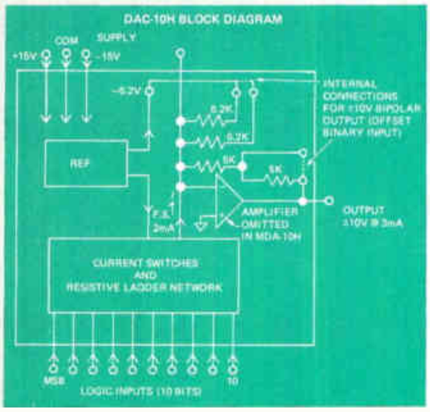
Delivery is normally from stock. That means no lost circuit design time, no parts inventory, no manufacturing delays, no production slippages. Evaluation samples are instantly available, too . . . just contact the applications engineering staff at Analog Devices or your local sales office. Evaluate the DAC-10-H in your circuit against your requirements. Find out for yourself that the new DAC-10 H is the answer!



	ANALOG DEVICES	BECKMAN	FAIRCHILD	SPRAGUE
MODEL	**DAC 10-H**	845†	μA722†	UM1500†
BITS	**10**	8	10	10
REFERENCE	**Yes**	Yes	Yes	No
OUTPUT AMP	**Yes, (741)**	Yes, (741)	No	No
RESISTOR NETWORK	**Yes**	Yes	No*	Yes
CODE	**Binary or BCD**	Binary only	Binary or BCD	Binary only
POWER SUPPLY	**±15V**	±15V	±6V	+3V, −20V
PRICE (1–9)	**$75.**	$75.	$75.*	$79.

*Plus resistor network @ $31 in 100 quantity
†Based on published data as of 15 Jan. '70

SPECIFICATIONS

Resolution:	10 bits binary
Accuracy:	±½ LSB (0.05%)
Data Inputs:	TTL or DTL Compatible
Output Voltage:	Unipolar models: 0V to −10V Bipolar models: ±5V; ±10V
Amplifier Output Current:	5mA
Settling Time to .05%:	20 μs (MDA - 10H: 300 ns)
Linearity:	±½ LSB
Temp. Coefficient:	±50ppm/°C (0° to 70°C)
Power Requirement:	±15V @ 25mA

Comprehensive data sheets with complete specifications and applications information are available. Evaluation samples may also be arranged. Contact Analog Devices or your local sales office.

205/536-1969	303/781-4967	317/846-2593	514/683-3621	613/224-1221
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213/595-1783	305/565-7029	414/465-1550	518/372-6649	713/622-2820
214/231-4846	312/774-1452	415/941-4874	602/274-6682	716/695-1001
215/643-2440	313/886-2280	416/247-7454	604/926-3411	913/831-2888
216/261-5440	314/725-5361	512/732-7176	607/748-0509	918/622-3753
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Circle 39 on reader service card

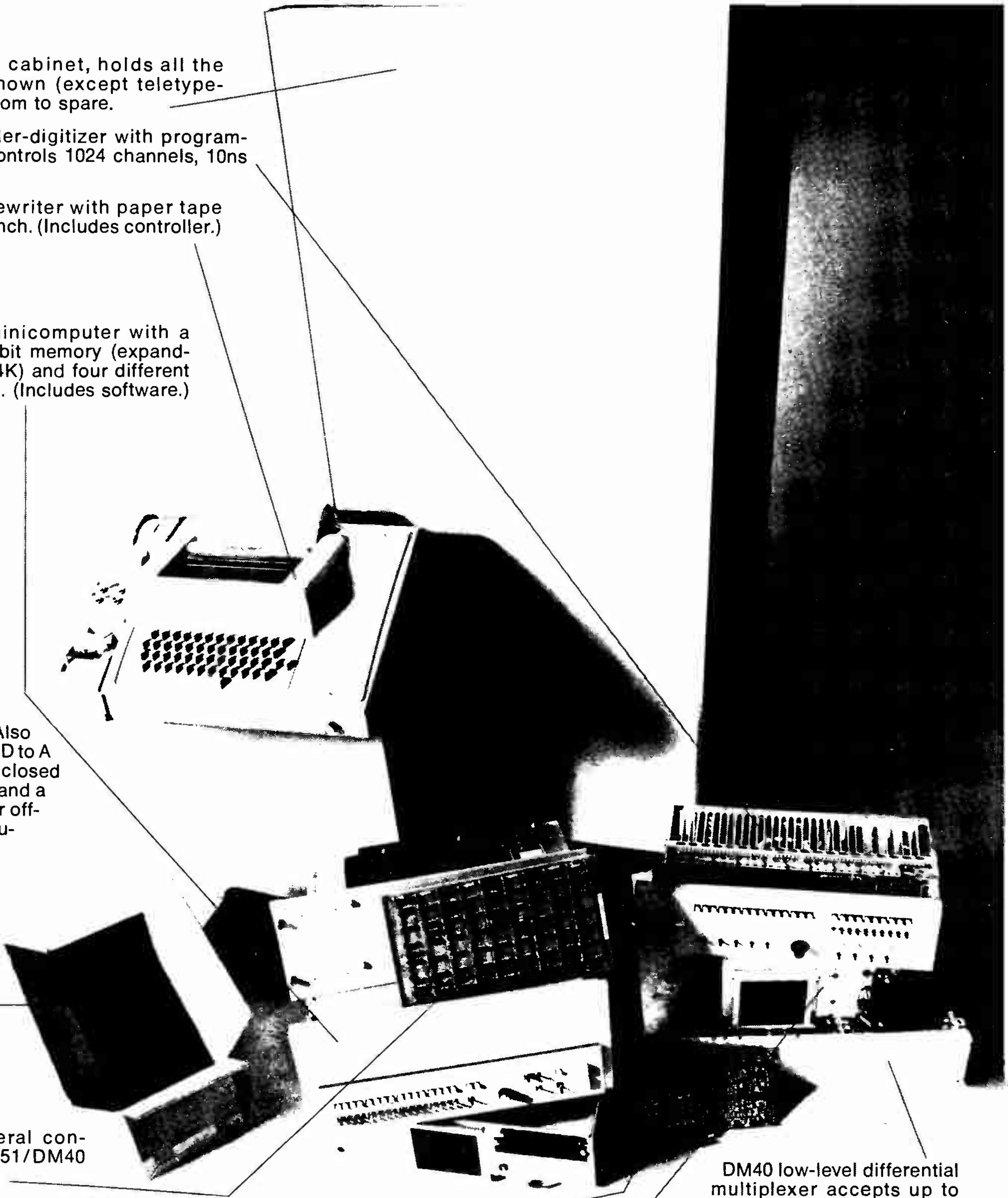
YT19 system cabinet, holds all the equipment shown (except teletypewriter) with room to spare.

CD51 controller-digitizer with programmable gain, controls 1024 channels, 10ns aperture time.

TE33 teletypewriter with paper tape reader and punch. (Includes controller.)

CF16 minicomputer with a 4K x 16-bit memory (expandable to 24K) and four different I/O modes. (Includes software.)

Optionally available: MR50 high-level multiplexer and associated channels (approximately $2400 extra), if you want to mix high and low level signals. Also 10, 12 or 15-bit D to A converters for closed loop systems, and a variety of other off-the-shelf instruments and options to solve virtually any data acquisition problem.



PE20 peripheral controller for CD51/DM40 combination.

OP50 multiplexer switch card contains 8 switches with screw terminals. Each DM40 accommodates up to 16 such cards. Switch cards with other terminal types also available.

OP59 power supply for up to eight DM40s.

DM40 low-level differential multiplexer accepts up to 128 input signals (optionally expandable to 1024) in the range ±2.5mV to ±10V full scale, at a rate up to 20kHz, and with a CMR of 120db at DC.

All instruments and interfaces will be cabinet mounted and functionally tested together prior to delivery. If you're in a hurry, call (213) 679-4511, ext. 3668 or 3391.

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The last reason you should buy our data acquisition system is the price: $21,600.

Value-added tariff appears home safe

Despite political appeal in killing schedule that protects U.S.-made parts assembled abroad, trade-balance factors are likely to stave off repeal

The politics of repealing Section 807 of the U.S. tariff schedule has definite appeal, but the economic realities do not. Thus, the controversial section—which assesses a duty only on the value added to a product made of American-made parts but assembled outside the U.S.—is not in serious trouble despite the sound and fury being generated at the current Tariff Commission hearings in Washington. Politically, it may be expedient to support repeal of 807 and garner the labor vote, but the value-added provision contributes too much to a steadily diminishing favorable trade balance to make repeal economically desirable.

Nevertheless, organized labor is pushing strongly for repeal in hearings before the Tariff Commission and Congress. Though support of labor's position is noticeably absent within the Nixon Administration, unions believe they have a strong champion in Rep. Wilbur Mills (D., Ark.), the powerful chairman of the House Ways and Means Committee. However, Capitol Hill insiders contend Mills' heart isn't in it.

With it. Though the specter of protectionism rises more frequently now in Congress whenever the issue of international trade comes up, a large majority of the members fully realize that they are living in an era of the multinational corporation and that offshore assembly of unfinished goods is playing a positive role in the nation's economy. Under Section 807 last year, some $339 million worth of goods came into the country, a large proportion of which were electronics ranging from integrated circuits to tv receivers.

The Electronic Industries Association stands firm on retaining 807 because with labor accounting for 50% of component cost, it can mean 25% less than the cost of domestic production. The only duty on products returned to the U.S. is on value added—mostly labor. Labor costs in underdeveloped countries where products are being assembled run between 10 and 40 cents an hour, says the AFL-CIO.

Organized labor charges that the basic idea behind EIA's support of 807 is company profits, not reduction of prices to consumers. The International Union of Electrical Workers, the International Business Equipment Workers, and the International Association of Machinists and Aerospace Workers, in a joint statement to the Tariff Commission, say that in such products as color tv, the "suggested retail prices are often three to four times as much as the cost of the product landed in the U.S." In addition, American multinational corporations, through licensing agreements and joint ventures, have licensed much of the "important technology that has enabled their Japanese competitors to outcompete them in the U.S. market."

The unions cited some 20 domestic electronics plants that have shut down—they made tv's, radios, tape recorders, semiconductors, IC's, tv tuners, and computer assemblies—because the so-called runaway plants made them unnecessary. Among these are Zenith in Chicago, whose tv sets are being made in Taiwan; Westinghouse at Edison, N.J., whose color tv's are being made in Japan and Canada; Transitron, Fairchild Camera & Instrument, General Instrument, Motorola, Cornell Dubilier, and Erie Technological Products, whose semiconductors and IC's are being made in Taiwan, Hong Kong, Mexico, Okinawa, and Portugal; and Sperry Rand, with computer assemblies being produced in West Germany and Japan. "Such firms should not be further rewarded with tariff-duty exemptions," the unions assert.

Advanced technology

The blues

If Thomas Edison could hear that his little incandescent bulbs will be replaced by diodes that emit in all colors and are capable of lasting more than a decade, he'd probably approve. True, such devices are not yet here. But their time may be near at hand now that RCA says it has solved the problem of obtaining efficient blue emission, mostly by improving materials.

The story is an evolutionary one. Red came first. Reasonably efficient red emission from gallium-arsenide-phosphide (GaAsP) diodes was achieved several years ago, but with this material other colors were not possible. Next came gallium phosphide (GaP). Depending on the dopants, GaP could emit red or green light. Still no blue. At that time it was generally agreed that practical blue emission called for a new approach.

Covering. Not long ago that approach was found—a new technique that used simple GaAs infrared light-emitting diodes covered with special phosphor materials. Through the multistep absorption of infrared photons, such a light-emitting system could be tailored to emit red, green, or blue. And equally important, the emission of all three primary colors opens the door to any color by simple mixing on the same phosphor.

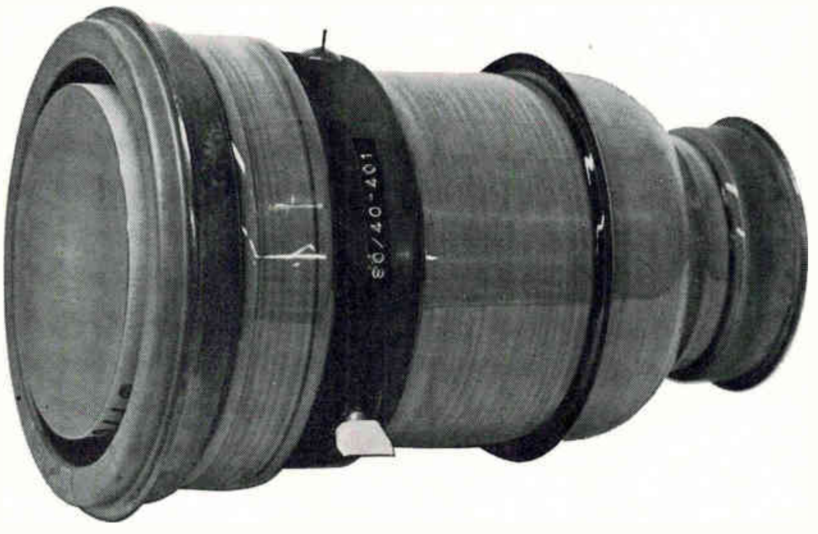
Still all was not rosy. Although several laboratories were working with this method—GE, Bell, RCA, and others—the efficiency for blue emission remained discouragingly low, primarily due to the inefficient process by which the phosphor converts i-r light to blue light in comparison to red and green.

In fact, to get reasonably bright continuous outputs in blue at room temperature, the diodes had to be operated at current density levels so high that life expectancy was low and much heat was dissipated.

Now, RCA feels it has made a significant advance in the whole process of upconversion using the phosphors. In the light-emitting business as long as anyone, RCA claims to have succeeded in obtaining a blue source that operates continuously with an estimated brightness of about 60 foot-lamberts, a level that can be seen clearly in normal room illumination. What's important is that this brightness is achieved by using the old, but simple, GaAs light-emitting diode running at only about 50 amperes per square centimeter. At this modest current density no special diode heat sinking is required. What's more, green emission obtained by the same process is even brighter—several thousand foot-lamberts.

Elevated. In the upconversion process, the i-r light emitted from the GaAs diode is absorbed in the phosphor and upconverted to yield visible light of the desired color. Two of the lower energy photons yield one higher energy photon for red or green emission, or three of the absorbed photons yield one even more energetic photon if blue emission is desired. The efficiency of the i-r visible light conversion process and the emitted color depends on the rare-earth dopant used with the phosphor host.

RCA's results are particularly impressive because relatively low-cost, high-volume GaAs diodes are used instead of the more exotic compounds. Besides, there's no known semiconductor compound capable of being made into a p-n junction to yield even more moderately efficient blue emission.



Zoom tube. While communications systems and computers are helping law enforcement agencies now [**Electronics**, April 27, p. 115], technology holds out the promise of giving even more help to lawmen in the near future. The Army's night vision lab at Ft. Belvoir, Va., has declassified two variable magnification image intensifier tubes built by Varian/EMI —a cooperative venture between Varian Associates and Great Britain's Electrical and Musical Industries. Varian/EMI is planning to market the tubes to industrial-commercial users. The tubes are high-resolution gated zoom intensifiers that amplify low-light level scenes imaged on their fiber-optic faceplate. The model VLI-105 has an 80-mm diameter input and a 25-mm output; the VLI-106 has an 80-mm input and a 40-mm output. Variable magnification (zoom), which is accomplished electrically rather than mechanically, allows the entire input image to be displayed on the output screen, or only 25 mm or 40 mm of the input image or anything between can be displayed.

Communications

Building bits

Commercial communications satellites receive data on several channels from ground transmitters, amplify it, and beam it back to the receiving point. However, the Communications Satellite Corp. would like to use only one carrier for the uplink to the satellite to conserve bandwidth and eliminate the intermodulation-distortion problems caused by multiple channels.

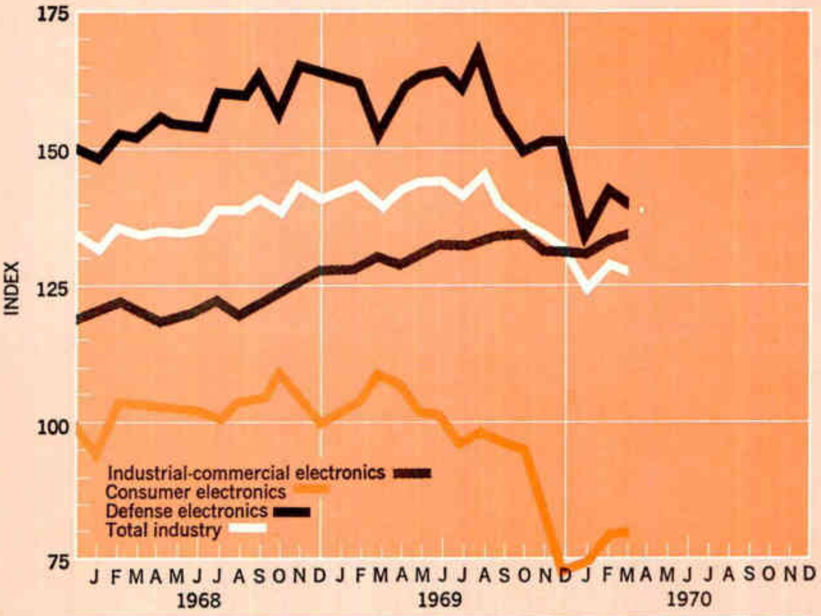
Engineers at Motorola's Government Electronics division have developed and operated a 1-billion-bit-per-second pulse-code-modulated communications link that would give Comsat all it needs and then some. And the L-band gigabit data link, which Motorola senior engineer Carl Ryan says is a first in the industry, would put all the data on one uplink carrier.

Part way. Ryan, in charge of Motorola's wideband data-processing group, holds a patent on the multiplier circuitry that is one of the key components in the data link. He says existing data links go as high as about 800 megabits per second, but Motorola isn't stressing just gigabit capability. Ryan says the technology embodied in the data link, which was operated publicly for the first time at the IEEE National Telemetering Conference in Los Angeles late last month, is economically feasible for anyone needing data rates greater than 50 megabits per second.

A gigabit-a-second capability is probably twice what Comsat needs in the next three years, but there have been requirements approach-

Electronics Index of Activity

May 11, 1970



Total electronics production in March ended a three-month rise by edging downward 1.3 index points to 128.6. The decline also added to the drop from March 1969—16.9 points.

While two of the three index areas showed March increases, they were not enough to offset the 2.7-point sag in defense electronics to 141.2 from February's revised 143.9. Consumer electronics moved up 0.6 point to 80.3 from 79.7. This was the consumer area's third month-to-month increase in a row. Industrial-commercial also rose fractionally—0.5 point to 135.1 from February's 134.6—for the fourth month in succession.

Segment of Industry	Mar. 1970	Feb. 1970*	Mar. 1969
Consumer electronics	80.3	79.7	110.8
Defense electronics	141.2	143.9	164.9
Industrial-commercial electronics	135.1	134.6	129.9
Total industry	128.6	129.9	145.5

Indexes chart pace of production volume for total industry and each segment. The base period, equal to 100, is the average of 1965 monthly output for each of the three parts of the industry. Index numbers are expressed as a percentage of the base period. Data is seasonally adjusted.
* Revised.

ing that rate. Ryan says Motorola had a request for quotations for a 630-megabit system a year ago. He feels the beauty of the Motorola equipment is that the firm developed the functional blocks critical for high-data-rate pcm in a modular fashion so that they can be tailored to the customer's needs.

Although the system accepts either wideband analog signals or high-data-rate digital signals, the potential customer that Ryan seems interested in now would have wideband analog inputs. This could be real-time photography for reconnaissance applications; the system could handle 12 to 15 television channels. Ryan says it can accommodate almost any kind of analog input up to about 40 megahertz in bandwidth. But it could also accept, say, 10,000 digitized voice channels.

Hybrids. The critical portions of the system, which Motorola builds itself, are made with three basic kinds of hybrid integrated circuits: a wide-band video amplifier, a wideband multiplier and signal switch, and phase-detector circuits. The video amplifier and multiplier have bandwidths greater than 1,000 Mhz; the phase-detector circuits use hot-carrier diodes and transformers, and Ryan says, "We can get 2,000-Mhz bandwidth out of these, but the components can be bought. What we've done is made them compatible with our microstrip transmission-line construction techniques." The Government Electronics division pioneered the technology embodied in the multiplier and signal switch in 1965, and has been refining it ever since to boost the bandwidth to today's level.

These are the building blocks that go into the digital multiplexer and four-phase modulator that are the critical boxes in getting gigabit data rates out of the airborne or spaceborne transmitter portion of the Motorola system. If the input is analog, Motorola also would build the analog-to-digital converter, but the up-converter and traveling - wave - tube amplifier needed for the transmitter can be bought outside.

The receiver, which would probably be ground equipment, consists of a preamplifier, down-converter, an intermediate-frequency amplifier, four-phase modulator, and a matched-filter network. The portions where the basic building blocks are used again are the four-phase modulator and the matched-filter bit synchronizer. In addition, the digital demultiplexer and d-c converter uses the phase/detector circuits in its serial-to-parallel conversion function.

Forth and back. A parallel-to-serial converter in the transmitter's digital multiplexer can handle eight channels of data. Actually there are two sets of four channels each, which are multiplexed by emitter-coupled-logic (MECL 3) gates into two channels, each with 500 megabits, which are then reclocked to get a timing accuracy of 0.2 nanoseconds. They then go to the four-phase modulator, which puts the data into one channel, sends it to the up-converter and on to the twt amplifier, through the antenna, and to the ground receiver. There the preamplifier, down-converter, and i-f amplifier massage the data before it's sent to the four-phase modulator. At that point the opposite sequence to that in the transmitter takes place—in the four-phase modulator, matched-filter network, and digital demultiplexer.

Ryan says the cost per bit of data transmission, especially from a satellite, would be much cheaper with the gigabit link than with conventional pcm systems. He says a 10-megabit setup might cost $1 million, and even if the Motorola system costs twice that, it offers 100 times the data rate.

Lasers

Opening the window

For high-speed data recording, the oscilloscope and camera have serious limitations. If the sweep rate is fast enough to display the leading edge of a pulse or the detail in high-frequency data, the sweep time usually would be so short that very little data can be displayed and photographed. In fact, one of the best h-f scopes on the market today has a display window of only 100 nanoseconds when operating at a scan rate fast enough to resolve 100-megahertz data.

The Resalab Corp.'s Scientific division in Menlo Park, Calif., thinks it has overcome the problem with a new laser system for multichannel h-f data recording. Called Resacord, the Resalab system is capable of recording up to 25 channels simultaneously on the same time base with a rise time of 3.5 nsec and a frequency response of 100 Mhz. What's more, the system has a record window of 20 microseconds—100 times longer than most scopes.

Complex. The recorder consists of a pulsed argon laser, a system of beam splitters that provides the multichannel capability, an electro-optical modulator for each data channel, and a special camera that records the intensity-modulated laser beams on photographic film. The camera, which is evacuated during operation, contains a single-sided mirror that rotates at 2,500 rps. This provides the scan to sweep the modulated laser beams across a length of 16-mm photographic film.

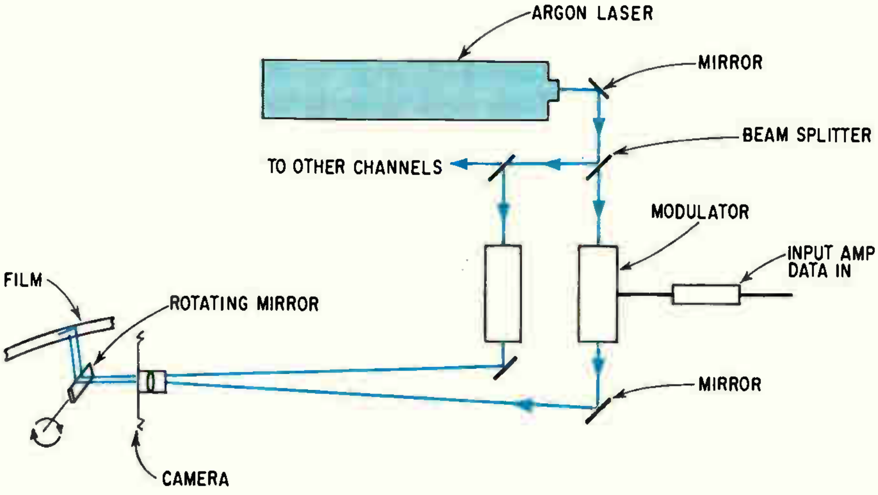
Data reduction is accomplished with a companion system consisting of a computer-driven microdensitometer that scans each track of data in 4-micron increments at 4,000 increments per second, and digitizes the data for storage on magnetic tape. The computer then analyzes or correlates the data as desired. Or, the data can be displayed on an x-y plotter. Resalab says that its system stores 1,200 data tracks every eight hours.

Systems delivered thus far have eight-channel capacity—six for data, one for timing, and one for recording an unmodulated beam from the laser. This unmodulated trace is scanned during readout for variations in laser intensity.

Not limited. An important feature of Resalab's system is that the length of the record window is not limited to 20 μsec. Other record windows (and resultant rise times) available by slowing the mirror's rotation: 29 μsec with 4.4 nsec rise, 72.5 μsec with 9 nsec, 159 μsec with 18 nsec, and 333 μsec with 35 nsec.

The system also offers accuracy of ±400 volts, a bandwidth of 30 kilohertz to 100 Mhz, a film capacity of 100 frames, and an interval between recording of 60 seconds.

Another version, now in development, will use a scanning technique much like that of a video tape recorder to produce a continuous recording capability. Instead of scanning a finite length of film, the beams will scan across the film at an angle, with an overlap between the end of one scan and the beginning of the next.



Rapid reader. Multichannel recorder (two channels are shown) uses incoming data to intensity-modulate argon laser beam which exposes density-modulated image on 16-mm film.

Government

Awacs delayed—again

There is at least one Air Force officer who believes that Awacs doesn't stand for Airborne Warning and Control System at all. He claims it's an acronym for A Wild and Crazy System—and he questions if it will ever fly. That question is being asked more frequently in Washington following the latest delay in contractor selection for Awacs, a program that was initiated in 1963.

Still sensitive to Congressional

criticism of high cost overruns and poor management controls on a variety of programs—notably the Air Force's C-5A supertransport—the Defense Department held up selection of an Awacs contractor at the last minute and told the Air Force to draw up a tighter contract. That action by the new Defense Systems Acquisition Review Council (DSARC) headed by Deputy Secretary David Packard, will push back the choice of a contractor to July at the earliest—the Air Force says it will have to solicit new bids based on the new document from Boeing and McDonnell Douglas, the two prime competitors.

Cost plus. Packard's DSARC told the Air Force that its proposed contract "would not provide the degree of management control and flexibility deemed necessary during the development phase of the system." So the Air Force says it plans to use "the more conventional cost-type contract with appropriate incentive provisions."

For the subsequent production phase, the Air Force plans a fixed-price, incentive-fee award with "not-to-be-exceeded ceiling prices." As for the competing Westinghouse and Hughes radars, the Air Force says it plans "appropriate incentives and/or award-fee arrangements" for the prime "to motivate the contractor to achieve radar performance as close to the objective as is economically feasible."

Preliminary tests of the radar—to be mounted in a big "mushroom" atop the fuselage of either a DC-9-62 or a Boeing 707-320C—indicate that better integration of radar, computers, displays, and communications are needed. But the Air Force has another, larger problem with Awacs. Congress again is raising the more fundamental question of whether Awacs is truly essential. In the view of one Senate Armed Services Committee insider, "The Air Force has gotten along without it for seven years now, and the need for continental air defense diminishes every year."

Thinking big. The Air Force successfully fought that battle earlier by expanding the Awacs function to provide a tactical mission in addition to its strategic defense role. And the Air Force thought it made its Awacs case by pointing out that an airborne lookdown capability is essential to detection and tracking of low-level bombers carrying standoff air-to-surface missiles.

Now that the Air Force has persuaded Packard that it needs Awacs, there is no question that an award will go through this summer. However, some Air Force sources are beginning to suspect that the frequently delayed system may be jinxed, and that eventually a hostile Congress will prevent Awacs from ever getting into production even though the Soviet Union already has its system airborne.

Shaping science

The research community contends it is in far more difficult straits than defense contractors when it comes to finding new sources of Federal funds, and the contention appears valid. Where military-hardware makers began to feel the fiscal pinch some 18 months ago, researchers argue that they have been faced with a 30% drop in U. S. support over the past four years when measured in what Presidential science adviser Lee DuBridge calls "real dollars."

Indeed, the DuBridge scientific demeanor gave way to some very strong emotion in his latest declaration that cuts in science funding, coupled with a decentralized and inefficient system of Federal support, threaten to "destroy or call a moratorium on knowledge."

New agency. One Capitol Hill answer to the problem has just come from Emilio Q. Daddario's House subcommittee on science, research, and development, which calls for immediate establishment of a new independent agency to handle all basic research support excepting mission-oriented efforts such as defense and space. It would be called Niras for National Institutes of Research and Advanced Studies [*Electronics*, Aug. 18, 1969, p. 56].

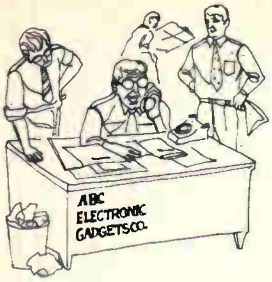
As predicted when Rep. Daddario (D., Conn.) began looking into the problem last summer, his proposal calls for incorporating the National Science Foundation into a subcabinet department made up of three institutes, two of which would incorporate basic physics and electronics efforts. The Niras institutes would include:

- Natural sciences, composed of NSF research programs, Federal science information programs, and a National Institute of Ecology.
- Education, made up of education programs of the NSF and the Office of Education, training programs of the National Institutes of Health and other units of the Department of Health, Education and Welfare, and institutional support of the OE, HEW, NSF, and the Defense Department.
- Arts, humanities, and social studies, comprising the National Foundation of the Arts and Humanities and a new National Institute of Social Sciences incorporating NSF programs.

No rescue. Though Daddario's concept has been modified from a year ago when there were rumbles that the House's resident science expert was talking of a Cabinet-level department of science—a concept DuBridge opposes—there is little current evidence that the plan will translate into legislation despite an initial favorable reaction among much of the scientific community. The problem: the Nixon Administration is conducting its own study of Federal support of science through its Commission on Executive Reorganization headed by Litton Industries' Roy L. Ash.

The Administration has already proposed a national federation of higher education and is expected to disclose new plans for funding health sciences plus restructuring of environmental agencies—each of which will affect science-support policy. And, apart from the obvious politics that a Republican Administration is unlikely to support a program developed by a Democratic Congressman, Daddario has already indicated he won't be around to push his program with his announcement of plans to run for Governor of Connecticut this fall.

Regardless of what DuBridge says about the desirability of cen-



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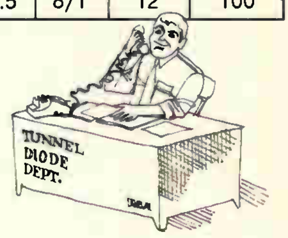
40561	4.5	5.5	6/1	25	1800
40562	9	11	6/1	25	900
40563	18	22	6/1	30	600
40564	45	55	6/1	40	350
40565	90	110	6/1	40	150
40566	4.75	5.25	8/1	15	1200
40567	9.5	10.5	8/1	15	600
40568	19	21	8/1	20	400
40569	47.5	52.5	8/1	25	200
40570	95	105	8/1	25	100
40571	4.75	5.25	8/1	8	600
40572	9.5	10.5	8/1	8	300
40573	19	21	8/1	10	200
40574	47.5	52.5	8/1	12	100



Circle 47 on reader service card

tral funding for science, there is no indication that it has White House support. If anything, such support is most unlikely at this point.

Medical electronics

Sensitive approach

The same sort of mental deduction that allows a listener to spot a sound source "between" stereo speakers has been adapted to the so-called Boston Arm to give amputees an artificial kinesthetic sense, and thus, much better control over the position of the arm.

Kinesthetic sense is not considered one of the common five senses; rather it's the product of the brain's correlation of nerve impulses from joints, muscles, skin tissue, and the like. As a result, this mental "signal processing" enables us to place our hands with accuracy even though we can't see them—we are aware of our arm's position even though it may be behind our back.

Location. By contrast, the Boston Arm uses electromagnetic impulses emitted by the biceps and triceps to control the motors which move it. Although in one sense the arm is controlled by the nervous system through these muscles, there's nothing to aid positioning except sight, or the sound of the arm's small motors. Amputees couldn't use the Boston Arm in the dark, or out of sight, and at other times they were preoccupied with the arm's operation, at the expense of reflexive acts, conversation, and other skills that require concentration.

While a graduate student at the Massachusetts Institute of Technology, David S. Alles, now a scientist at Bell Labs in Allentown, Pa., thought he saw a solution to the problem. By studying the physiology of the upper arm Alles found that the brain could process tactile inputs in the same way it processes audible ones: by placing two vibrating transducers a few inches apart, he discovered it was possible to move a phantom signal between them by varying the frequency, amplitude, or time of the signals applied at each transducer.

Then another MIT graduate student, Stephen D. Reimers, proved it worked. He used two logarithmic potentiometers in the artificial elbow to vary input to two amplifiers which in turn powered two tiny torque motors placed a few inches apart at the stump. As the elbow moved, the transducers were fed varying amounts of 100-hertz energy at about 100 bursts per minute. The transducers moved back and forth on the skin to minimize bone or deep tissue pickup which might be uncomfortable or interfere with the arm's electromagnetic control sensors.

Feeling. The effect on the amputee was like being stroked on the skin between the two transducers corresponding to elbow's position. Reimers also found no interference with the electromagnetic pickups used to detect flexing of the biceps and triceps.

In about 9,000 tests, the arm proved to be as easy to position accurately as mechanical arms even though the amputee couldn't see the arm in action, or hear the soft whine of its motors. Formerly it had been only about half as accurate. But instead of becoming accustomed to the arm in less than an hour, amputees needed about a day to get full use from the artificial kinesthesia—but nobody felt this was a bad tradeoff.

Now, according to MIT mechanical engineering professor Robert W. Mann, some undergraduate students have begun "product improvement" by replacing the torquer with smaller, less energy demanding piezo-electric transducers.

According to Mann "we used a man-machine system approach to close a servo loop by putting the computational power of the brain between the tactile transducers and the muscle sensors."

Next move

A strain-gage transducer whose output can control up to 15 household appliances may make it possible for quadruplegics to turn on lights or operate an electric wheel chair. The transducer, developed by Tufts University researchers, takes advantage of most quadruplegics' ability to still control their biceps. For those quadruplegics lacking such control, however, the transducer will not provide any help.

The device, measuring just 1½ by ½ by ½ inches, consists of a thin flexible beam to which are attached two strain gages, one above and one below the center. When one gage extends, the other contracts. At either end of the beam are two small cylinders touching the skin. The whole transducer is encapsulated in silastic and taped to the shoulder of the quadruplegic.

Words. The relative motion between two points on the skin can be controlled by slight movements of the body, and the transducer produces analog voltage signals proportional to these deflections of the skin. The signals go to a relay logic module with flip-flops and a logic tree, so that different degrees of deflection cause the transducer to produce, in turn, different four-bit words.

The logic module has a row of four lights, all of which are off when the skin is relaxed. If the patient moves his shoulder forward, the second light goes on; if he moves forward a little more the third lights. In all, there are 16 states possible when turning four lights on and off; when all are on, all previous commands are erased, leaving 15 words to control 15 appliances. So far, William J. Crochetiere of Tufts' Department of engineering graphics and design, working with quadruplegic student William Powell, has controlled up to eight appliances with the transducer.

"It takes only 10 minutes to learn how to control the transducer; the big part is memorizing the vocabulary of positions and lights with which to control the appliances," says Crochetiere.

Wire barrier. Right now the patient's mobility is limited by the wiring that connects the transducer to the logic module. "We're work-

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ing on replacing this with a telemetry system," says Crochetiere; "then the patient could tool around his apartment in his electric wheel chair and control appliances from any point." He hopes to solve this problem by the fall.

The transducer and logic module could also be used by stroke victims and the elderly with restricted mobility, and a control circuit has been developed that can control a d-c motor to move an artificial limb clockwise or counterclockwise. Limbs such as the Boston Arm are controlled by electromyography (EMG), which Crochetiere feels is awkward. The new skin transducer can be worn under clothing and the bulge it makes is hardly noticeable. However, Crochetiere says it is not as natural to use as EMG and he thinks "the optimal prosthetic will have hybrid controls," that is a blend of EMG and cutaneous sensors.

Instrumentation

Making room

Oceanographic vessels, usually jammed with both scientific personnel and equipment, need precise position location for correlation of gathered data. This sometimes means leaving a scientist ashore because an operator for the navigation satellite receiver and other equipment must be taken along.

To help avoid this tradeoff, Magnavox has developed a 150-foot-accuracy integrated Transit navigation satellite receiver/computer that derives its position from signals transmitted by the Navy's Transit satellites, declassified and renamed Navsat in 1967. The unit, called the MX 706, measures only 8¾ inches by 15⅝ inches by 26 inches.

Both the receiver and the computer, which is a 16-bit system having 8,000 words of core memory and a 2-microsecond cycle time, are rated for military specifications and housed in the same box. The controls, including an 11-key keyboard, are on the front panel.

Less man. According to Michael Simmons Jr., navigation product manager, the two-channel MX 706 uses computer software to do most of the digital processing and minimizes the operator's role.

A standard navigation program, consisting of 8,000 words, is automatically loaded from a magnetic tape cassette inside the cabinet when the operator presses a front-panel switch. The program loading also executes an immediate self-test to verify that the magnetic tape reader, computer, and receiver front panel are functional malfunctions are displayed as alphanumeric error codes on one of three front-panel Nixie displays. The operator can also initiate a test that automatically locks the receiver on an internal test-generator signal and checks for proper operation of the receiver, computer, and interface.

Staff engineer John F. Clark says the 706 gets substantially more accuracy than other receivers by having shorter interval doppler counts. The Navsat sends a message every two minutes, and transmits a word describing the orbit of the satellite every 4.2 seconds. To date, most receiver systems have collected, processed, and reduced satellite data and done doppler counting in the receiver itself. Typically, the doppler counting has been done in two minutes. By contrast, the 706 takes a 50-hertz bit rate from the satellite and, after digitizing, puts out the rate to the computer every 20 milliseconds. The computer sorts the data and accumulates doppler counts during 23-second periods.

Clark claims this results in fourfold improvement over the 600-foot accuracies of earlier receivers, while minimizing errors due to ship's motion.

Sticking around. Unlike most receivers, which sweep a relatively wide fixed window of frequencies during a signal-acquisition search, the 706 search window can be computer-controlled to avoid spurious signals and minimize acquisition time. If a satellite lock is lost, the receiver would stay in the vicinity of where the lock was lost and step in the direction of the satellite doppler frequency; there is no need for a wide-sweep search mode.

By using software for most of the digital processing and formulating of the 6,100 bits in each two-minute satellite message, Magnavox has eliminated the need for the conventional digital buffer between the receiver and the computer. And as a result, Magnavox has cut more than 500 integrated circuits from the receiver.

The equipment features three Nixie displays that can provide, with one-second updates, either present time, latitude and longitude, or the last satellite position fix. By pushing a panel button, the operator can also display the expected time rise of the next satellite pass, elevation angle at closest approach, and an identification code telling which satellite it will be. The frequency to which each receiver is tuned can also be displayed, both as a trouble shooting aid for the receiver and as an indication of where the satellite is in its pass. The satellite signals are typically from 26 to 40 kilohertz below 400 megahertz depending on where it is in its pass from horizon to horizon.

One cloud on those horizons is the likelihood that the current two-hour wait between satellite sightings will not be shortened. Originally to have been a 15-satellite system, Navsat has only four birds in orbit.

Patents

IBM vs. Xerox

Have you heard the story about IBM turning down the chance to buy the Xerox Corp. because IBM questioned the potential of copying machines?

It's a Wall Street saw so well worn that it's no longer funny. Of course, it never was funny to IBM, which has finally decided to challenge Xerox on its own ground. And even less amused is Xerox, which has filed for a Federal injunction against IBM charging violation of 22 patents.

IBM, except for denying that its copier infringes any Xerox patents, is saying characteristically little. It does counter only with the contention that its copier uses an organic chemical photoconductor for which IBM received a patent in 1969. A search of U. S. Patent Office files shows the photoconductor absorbs light in the ultraviolet spectrum, but is insensitive to longer wavelengths for color. According to the record, an electrostatic charge is left on a photoconductive surface, such as a selenium drum, through light exposure.

Hardware. Of the 22 Xerox patents allegedly infringed, however, Patent Office records show most dealing with equipment inventions, rather than concepts. For example, one of the patents Xerox mentions is an infrared heater. It brings image powder to fusing temperature while at the same time heating the paper so it can act as a heat source in the fusing process. The heater was used by IBM in each of three examples presented to the Patent Office when application for the photoconductive composition was filed in 1966. Xerox obtained a patent on the i-r fuser in June 1969—six months before the IBM patent was granted.

In the three examples given by IBM to validate its photoconductor invention, IBM used Xerox equipment. However, it has since patented its own heat fuser.

In addition to alleged infringement of patent involving the i-r fuser and its power sources, and transport for moving the image-bearing material, Xerox alleges infringement of these patents:

- An illumination system wherein a vapor control center in a fluorescent lamp is heated by an element which maintains the center at a given temperature when the lamps are de-energized. The vapor control-center patent also includes a scanning station and a radiation image projection system.
- Electrographic copying apparatus, including rotation plate, scanning lens, and an image-transfer process using a powder image.
- Also, patents on developing, sheet-handling control, paper feed, an image fusing device, powder filter and plate-cleaning apparatus, copy-counting system, and sheet-stripping apparatus.

For the record

Stretch. There's a good chance the magnetic-tape rehabilitation facility at NASA's Goddard Space Flight Center in Greenbelt, Md., may be expanded. A NASA-SFC report on the magnetic-tape program at Goddard should be ready in a few weeks. NASA reports it has increased the flow of analog and digital tapes from scientists and experiments, after all meaningful information had been extracted and placed in the National Space Science Data Center, in response to recommendations of a recent General Accounting Office review. GAO said that "because of its [Goddard's] limited capacity for rehabilitating tapes, Goddard was not realizing the potential savings possible from greater use of rehabilitated tape." As of Oct. 31, 1969, GAO said, about 110,000 reels of tape awaited rehabilitation. NASA requires annually about 203,000 reels of analog tape and 219,000 reels of digital tape. New tapes cost about $20 per reel for analog and $11 for digital, while the cost to rehabilitate tape is only $4.63 in-house and about $1 more when done outside.

Biggie. If the proposed Bureau of Public Roads' demonstration project of the Electronic Route Guidance System in Washington [*Electronics*, April 27, p. 74] is a success, and a large-scale operating system is okayed, the winning contractor may get an initial award worth $15 million. BPR officials told the House Appropriations Committee that the initial installation and operating costs for instrumenting 1,000 intersections—which would provide service on all primary traffic arteries and some collector streets—are estimated at $15 million. According to these officials, "This estimate is for a dynamic version: one which is capable of considering congestion, weather,

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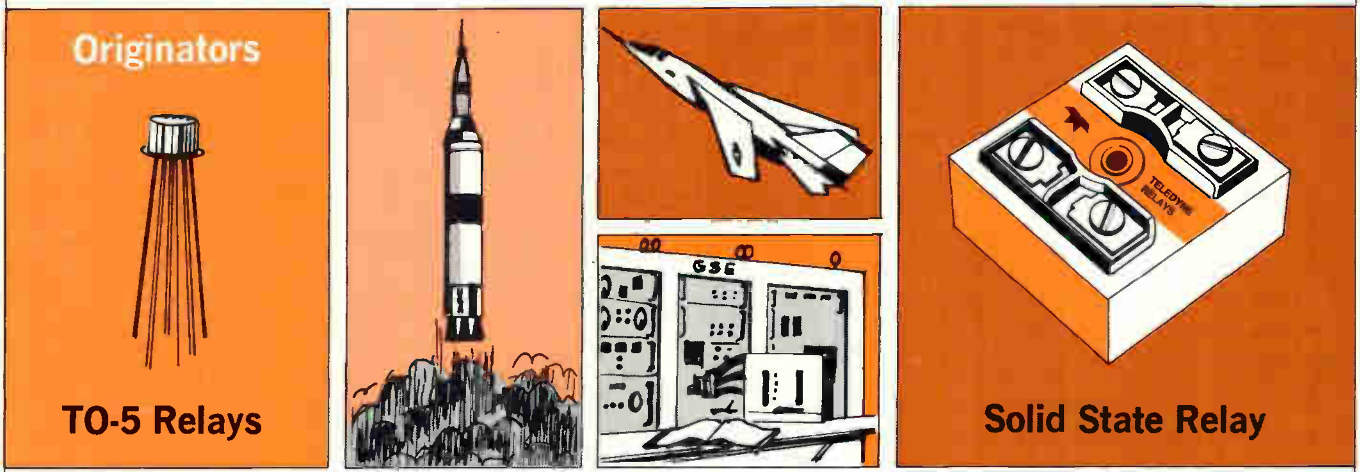

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etc., and routing traffic more uniformly over the entire highway network." They added that annual operating costs, including central-computer facilities, communications, maintenance, and staff, may be $3 million.

Dangers. NASA's Marshall Space Flight Center has issued requests for quotations for studies on potential nuclear hazards of the proposed space base and on future lunar explorations. Forty-five firms were asked to submit bids by May 12 on the 12-month, $400,000 space-base study to identify the possible hazards and to recommend approaches for either their elimination or reduction to acceptable risk levels. Bids were scheduled to be returned May 5 for the 11-month, $300,000 moon study, which will consider the temporary moon bases, shelters, surface drills and other tools, equipment, and flying and surface roving vehicles for missions beyond Apollo 19 if and when they are approved.

Nimbus award. Gulton Industries' Data Systems division has been awarded a $1.6 million contract by the Commerce Department's Environmental Science Services Administration to build an infrared temperature-profile radiometer for the Nimbus-E weather satellite, scheduled for a 1972 launch. The radiometer's small field of view—35 kilometers square—will permit more reliable soundings of the atmosphere's temperatures from the spacecraft down to the earth's surface in partly cloudy areas and will measure the distribution of water vapor in the atmosphere. Earlier similar instruments aboard Nimbus 3 and 4 had larger fields of view—approximately 225 km square—which made it difficult to measure the different temperatures through a cloud cover over the earth.

Downcurve. The Zenith Radio Corp. has reported lower sales and earnings for the first quarter of 1970. Earnings for the three months were $6,066,000, or 32 cents per share. This was down from the record first quarter earnings of $11,-966,000, or 63 cents per share in 1969. Sales for the period of $128,-555,000 were down from the record 1969 first quarter of $185,469,000. Joseph S. Wright, chairman, said the slowdown in business activity continued to be particularly evident in consumer electronics where unit sales to dealers of color and black-and-white television, phonographs, and radios were down sharply from the year earlier.

Far-sighted? When it comes to investing in the future, the American businessman is no slouch. Overall, industry plans to spend $82.3 billion for new plants and equipment in 1970—9% more than it did last year. This, according to McGraw-Hill's annual survey of businessmen's plans for plant and equipment investments, is due to industry's optimistic expectation that it will need additional capacity in the years ahead despite the economy's current slump. Electronics-related industries, however, are showing mixed reactions when it comes to spending. Instrumentation houses, extremely bullish, plan on spending 24% more than they did in 1969, whereas the aerospace industry is expected to spend 20% less than in the previous year. Outlays for electrical machinery, on the other hand, will rise about 12% over what they were last year. This year's buzzword is ecology, with industry spending reaching nearly $2.3 billion for pollution-control equipment, much of it going into the coffers of electronics firms.

Precedent. After a jury trial in the 98th U.S. District Court in Austin, Texas, Magnavox has been ordered to pay the Charles Partlow family $212,000 in damages caused by a fatal tv-set fire resulting from a defective flyback transformer. The decision, according to Tom C. Davis of Austin, lawyer for the plaintiffs, is significant because it's the first such award granted by a jury. The ruling was that the television set was defective when it left the manufacturer's possession and thus Magnavox, rather than the maker of the faulty transformer, was responsible for the two deaths caused by the fire.

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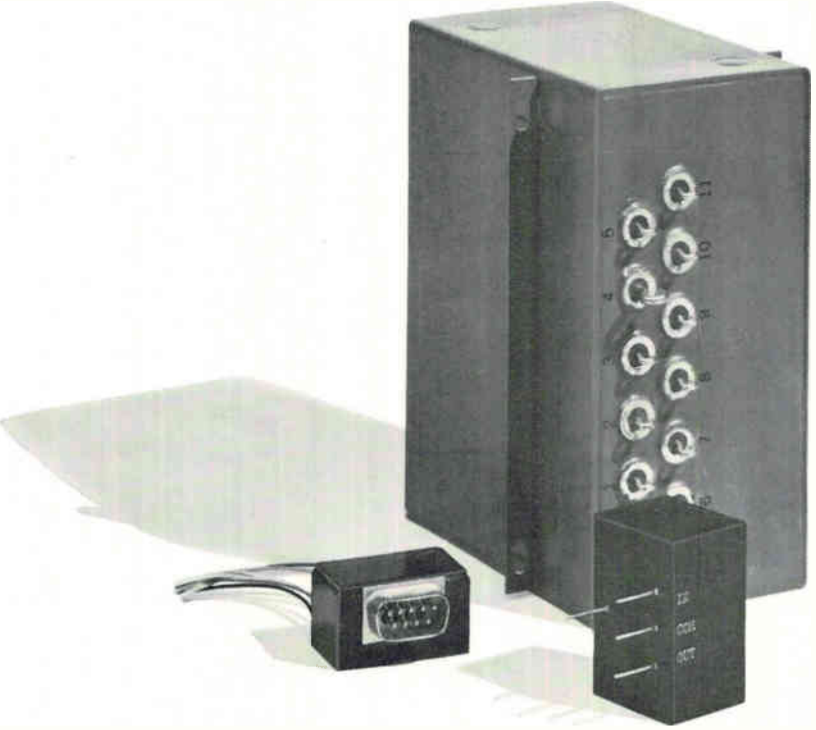

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A quick guide to magnetic drives: torque transmitters that work when other methods won't.

Magnetic drives offer you some relatively inexpensive solutions to difficult torque transmission problems. For instance, a magnetic drive can transmit torque through a non-magnetic barrier without using any mechanical connection. And because the system completely eliminates seals, it eliminates problems of leakage, maintenance and contamination.

3 basic types of magnetic drives.

1) *Synchronous drives* are equivalent to a shaft connection. Two basic arrangements are axial and radial. Axial drives consist of two Indox magnets or two Alnico side pole rotor magnets. Axial thrust is a maximum at zero load and diminishes as more torque is applied.

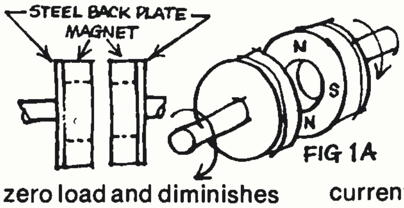

FIG 1A

Radial drives consist of two ring magnets and have no axial thrust. Because of starting inertia, the outer magnet normally drives the inner one.

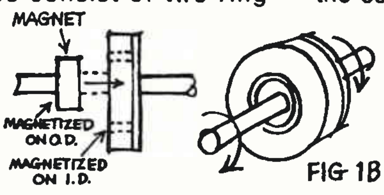

FIG 1B

When the maximum torque of a synchronous drive is exceeded, the driven member stops. This can offer important protection in event of overloading. And you never have to replace shear pins or worn frictional surfaces.

2) *Eddy current drives* use the field of a rotating permanent magnet to induce eddy currents in a conducting material. Interaction between these currents and the magnetic field gives rise to the torque of the coupling. Torque varies with the relative speed of the members. Eddy current drives use driven members of aluminum or copper in the form of cups, tubes or discs depending upon the configuration needed.

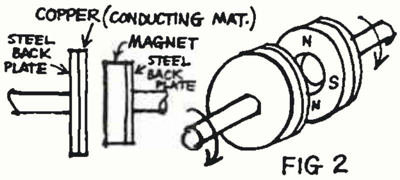

FIG 2

3) *Hysteresis drives* use the magnetic field of a rotating permanent magnet to drive the material of the hysteresis member through its hysteresis loop. The unit is synchronous provided the maximum torque isn't exceeded. Beyond this point the torque is independent of the slip speed and remains constant.

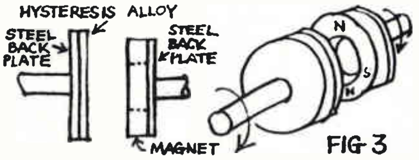

FIG-3

Hysteresis drives operate at close gaps. But unlike eddy current drives, hysteresis drives transmit constant torque.

Design aids available free.

The basic factors to consider in magnetic drive design include:

- radial or axial gap configuration
- relationship of torque to slip speed
- ambient operating temperature
- non-magnetic material through which torque must be transmitted
- maximum torque to be transmitted
- critical nature of the alignment.

We're anxious to help answer your questions. And we would like to send you some useful aids that include graphic presentations of important factors in magnetic drive design. Just write Indiana General, Magnet Products, Valparaiso, Ind. 46383.

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PD7401	Quad 2 Input Pos. Nand Gate with Open Collector Output
PD7402	Quad 2 Input Pos. NOR Gate
PD7404	Hex Inverter
PD7405	Hex Inverter with Open Collector Output
PD7410	Triple 3 Input Pos. NOR Gate
PD7420	Dual 4 Input Pos. Nand Gate
PD7430	8 Input Pos. Nand Gate

DEVICE	DESCRIPTION
PD7440	Dual 4 Input Pos. Nand Buffer
PD7450	Expandable Dual 2 Wide 2 Input And-Or-Invert Gate
PD7451	Dual 2 Wide Input And-Or-Invert Gate
PD7453	Expandable 4 Wide 2 Input And-Or-Invert Gate
PD7454	4 Wide 2 Input And-Or-Invert Gate
PD7460	Dual 4 Input Expander
PD7470	JK Flip-Flop

DEVICE	DESCRIPTION
PD7472	JK Master Slave Flip-Flop
PD7473	Dual JK Master Slave Flip-Flop
PD7474	Dual D Type Edge Triggered Flip-Flop
PD7475	Quad Bistable Latch
PD7476	Dual JK Master Slave Flip-Flop with Preset and Clear
PD7482	2 Bit Binary Full Adder
PD7483	4 Bit Binary Full Adder
PD7491A	8 Bit Shift Register

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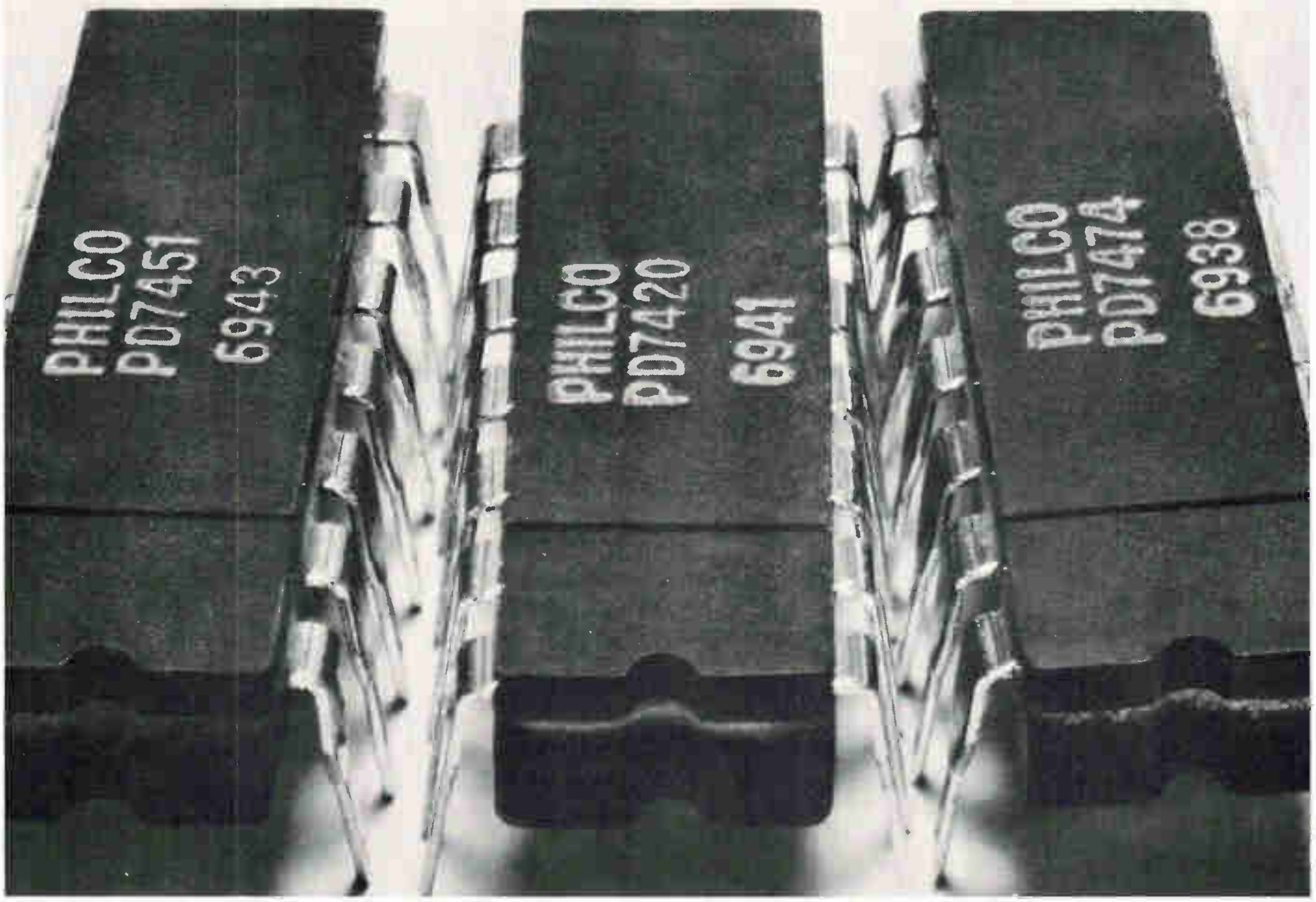

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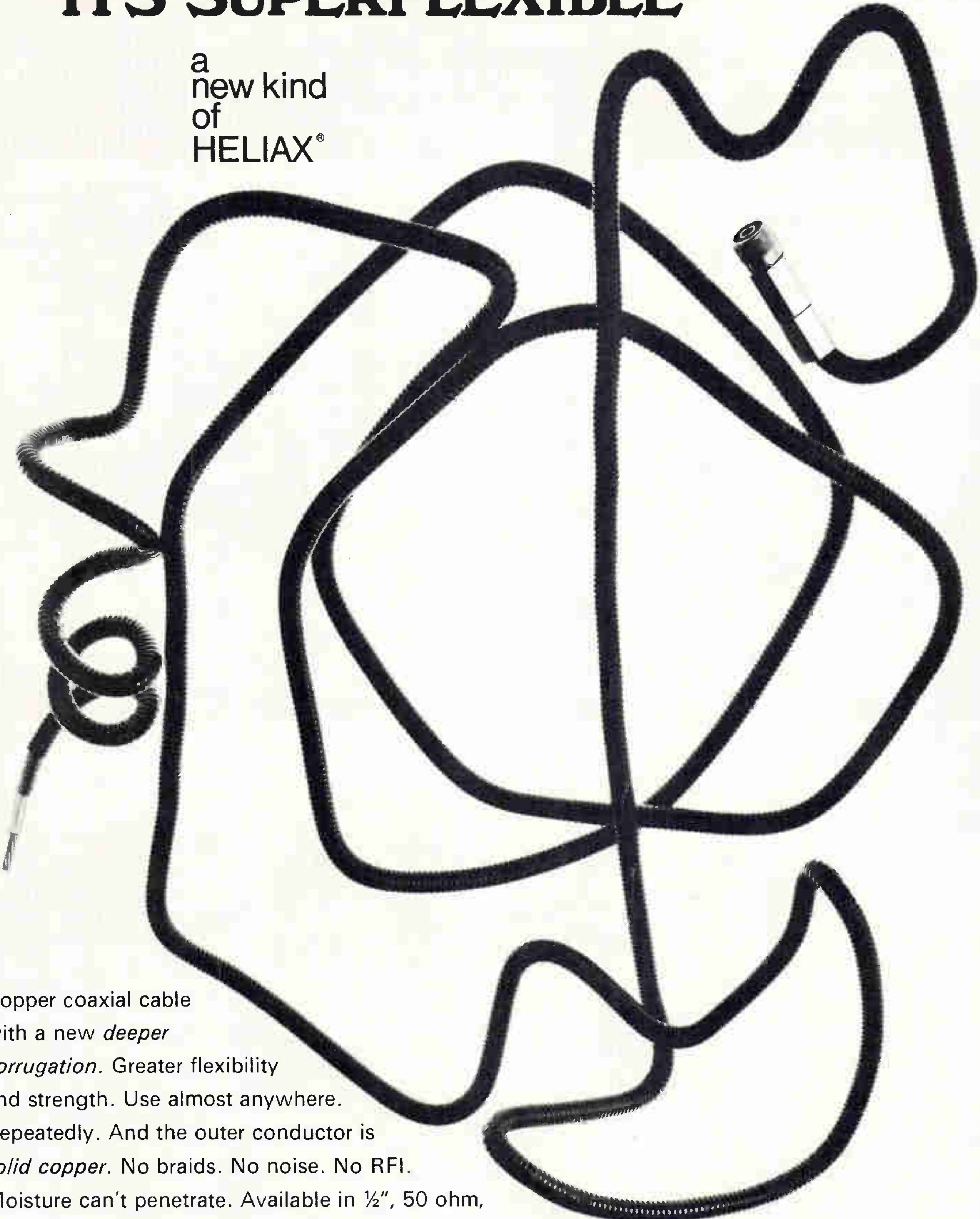

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Circle 62 on reader service card

International Newsletter

May 11, 1970

Chinese utilize approved frequency for its satellite

Mainland China may not be a member of the International Telecommunications Union (ITU), but it's acting like one. When China launched its first space satellite, it picked 20.009 megahertz as the broadcast frequency for its anthem, "The East is Red." The frequency is one earmarked by the ITU for space research and selected so as not to interfere with spectrum users in other countries. Though the signal is easily received with relatively simple equipment, the frequency is one that has difficulty penetrating the ionosphere in daylight hours.

But military-communications specialists, who have already dubbed the satellite Chicom 1, suspect the Chinese didn't launch more than 380 pounds of space hardware just to play a tape recording. Thus, they are monitoring the satellite carefully to determine if other frequencies are being used by China for clandestine research. Though sources say it will take some time, perhaps weeks, to make a final determination of the satellite's mission, no disclosure by U.S. intelligence is expected.

The satellite's size suggests to U.S. officials that there are more experiments on board than just a recorder, and that data from these will need to be telemetered to earth. Not ruled out is the possibility of reconnaissance gear since Chicom 1's elliptical orbit, with its 68.5° inclination to the equator, will send it over many major cities.

What favorably impresses Washington officials is China's voluntary demonstration of frequency cooperation by using an ITU-specified frequency in its first space venture. Some spectrum authorities feared that spectrum chaos could result if China had not gone along with the ITU.

West German firm plans multilingual tv sound system

With an eye on wide-open markets in many multilingual countries, researchers at Standard Elektrik Lorenz, an ITT subsidiary in West Germany, are hard at work on a 12-channel tv sound system. All 12 channels, each in a different language, can be transmitted synchronously with one video channel. And 24 channels can be transmitted in special cases.

The 12 audio signals, with a 13-megahertz bandwidth, and the video signal are transmitted as an integrated unit, which can be recorded on magnetic tape and sent over cable to an antenna. Current communications satellites that transmit video signals in frequency-modulated form are capable of receiving and retransmitting the integrated signal. The audio signals, time compressed by a factor of 1 to 385, are inserted between individual pictures in the 12 empty lines which normally constitute the no-transmission period between pictures.

Although Lorenz calls this system a proposal, predevelopment work already has been done. The system, using discrete components, is operating in the lab and further work is being done on incorporating MOS techniques into the system. The big obstacle now is not technical, but political—getting international tv authorities to agree on standards.

Philips gears up for cassette vtr's

The Philips group is all set for a big push into the low-priced cassette video recorder market. Starting around the middle of next year, Philips will offer three basic vtr's for consumer applications. One, designed only for playback of black-and-white programs, will probably sell for between $275 and $330. The second, for playback of color programs, will range between $385 and $412. The third unit, complete with a built-in receiving portion, and with a recording and playback system for both monochrome and color, will be priced at about $550.

The Philip vtr's use a pocketbook-size cassette containing 0.5-inch magnetic tape that's good for 60 minutes. With the most expensive unit, it's possible to record one program while watching another.

Agreements on basic standards and dimensions for the equipment have already been made between Philips and other European electronics producers. These firms include West Germany's AEG-Telefunken, Grundig Werke, Blaupunkt and Loewe-Opta, and Italy's Zanussi. More companies are expected to reach similar agreements with Philips soon.

BBC radio goes digital

Now that tests with television sound signals have shown the British Broadcasting Corp. that it's perfectly feasible to distribute sound from studio to transmitters in digital form [*Electronics,* Feb. 16, p. 69], the corporation plans to digitize its radio broadcasting network. A distribution technique that BBC has been developing will be tested operationally next year.

The change is intended to improve the quality of all sound broadcasting, but its biggest effect will be on the quality and simplicity of stereo distribution. At present, the BBC rents audio-band a-m cable links from the Post Office, but these deteriorate with time, and it's been difficult to arrange properly matched channels for stereo distribution. The corporation's plan is to carry a number of digitized sound channels time-division-multiplexed onto wideband tv-type distribution links. It believes this will provide stable, well-matched stereo carriers. In parallel with this work, the corporation is developing digital tape recorders which have a better signal-to-noise performance than present recorders, and hence improve input quality to the distribution system.

Another step in Japan's European push

Mitsubishi Electric is going to apply the domino theory to push its computer invasion of Europe. First to be attacked is the rich West German market. Once a solid sales base is established there, the Japanese company will start promoting its wares in the rest of Europe. Mitsubishi, with European headquarters in Hamburg, is now setting up a network of computer sales and service organizations throughout the country.

Starting towards the end of this year, Mitsubishi will offer two medium-sized computers—the Melcom 83 and the Melcom 84—to German customers. Both machines use magnetic-disk storage units for 10,000 words, expandable to 100,000 words, a feature which is unusual for medium-sized computers. The 83 model, complete with tape-punching and reading equipment, will sell for roughly $17,900 and the 84 for about $22,900.

On the wing to Switzerland: the A-7 Corsair

It now looks as if the A-7 Corsair II will be the Swiss Air Force's next-generation combat jet. The U.S. aircraft has been recommended—over the Italian Fiat G-91—by a defense committee that has been looking at possible replacements for Switzerland's obsolescent complement of British-built fighters.

If it comes, the order will be big. The Swiss Federal Government, which must implement the committee's decision, has earmarked $300 million for the next line of aircraft. Until the Corsairs come, the French-built Mirage III will remain the front-line combat jet.

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West Germans roll out radio system for snarled motorists and traffic

Schaub-Lorenz's Infar interrupts car radios and tape equipment with pilot tone, allowing ultrashortwave receiver to pick up road-condition broadcasts

Broadcasts about road and traffic conditions can do a lot to ease traffic jams by warning motorists to use alternate routes. But such broadcasts can only be really effective if every motorist in a certain area gets the message. The alert must get through even if the driver is tuned to the wrong station, listening to his car's tape system, or riding in a car with no standard audio equipment at all.

A system that can get the word through despite these obstacles has been demonstrated by Schaub-Lorenz, a West German subsidiary of the International Telephone and Telegraph Corp. and a big entertainment-electronics producer there. The new system is in the running for adoption by the nation's Fourth Radio Program, which will be set aside for traffic reports.

The operation of the Schaub-Lorenz system is simple. Together with a news and musical program, the station operating on the traffic channel sends out a 19-kilohertz pilot frequency, an inaudible tone. When traffic information is to be broadcast, this pilot tone is switched off for the duration of the announcement. The initial tone interruption cuts out the channel to which the driver may be listening and cuts in the traffic channel. This channel is received by a small additional ultrashortwave receiver in the car. The pilot tone can also cut out tape equipment.

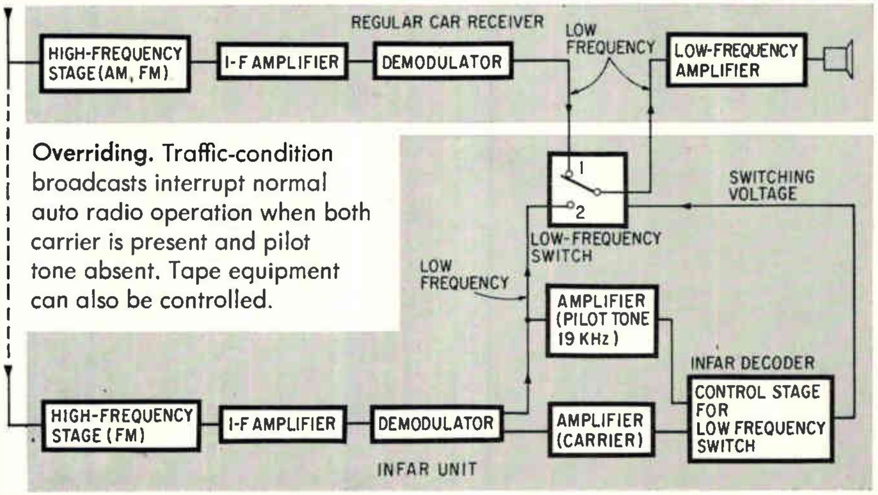
Zone of silence. However, unwanted channel switching would occur if the car travels through a zone of radio silence, such as a tunnel or high-rise building area. To prevent such unwanted switching, Schaub-Lorenz engineers established a second criterion. The carrier of the traffic radio station must be present before channel switching can take place. This is done by a simple AND circuit: there's a voltage only when the pilot tone is interrupted and the carrier of the traffic station is present. Thus, Schaub-Lorenz dubbed its systems Infar, the acronym of the German words for "information broadcasting by automatic radio".

The company has high hopes that Infar will be introduced on a country-wide basis, and this may well occur within two or three years. The firm also sees a big future ahead for Infar in other countries like Italy, Holland, France and Sweden—countries that are considering setting aside a channel specifically for traffic information.

Infar has several important strong points. For one thing, the system is easy to implement because it is compatible with existing radio-transmission standards. For example, the 19-khz pilot tone need not be specially produced at the station. A pilot tone is already being used in stereo broadcasting.

Kept simple. Another advantage is that the additional electronics gear required in the car can be held to a relatively low cost. The Infar unit is nothing but an ultrashortwave receiving unit whose design can be kept simple since it need only operate in the 100- to 104-Mhz range and, thus, requires no expensive band filters. For tuning, some fixed or pretuned circuit arrangement, or an electronic tuning scheme, is feasible in any future mass-produced Infar units. Furthermore, it doesn't require a low-frequency portion or a loudspeaker. Infar operates into the low-frequency and loudspeaker portion of the regular car receiver.

Other parts of the Infar unit—the AND circuit for example—could be



Overriding. Traffic-condition broadcasts interrupt normal auto radio operation when both carrier is present and pilot tone absent. Tape equipment can also be controlled.

based on integrated circuits, and this would further keep costs down. Schaub-Lorenz figures that once the Infar unit is mass-produced, it could well sell for less than $30.

What about those drivers who don't want to bother with a car radio? The Infar unit itself can come complete with a low-frequency portion and a loudspeaker. The unit would sound off only when the pilot tone is interrupted. For traffic bulletins to come through the unit would of course have to be on whenever the ignition is on.

West Germany

On the stands . . .

If they were looking for breakthroughs in semiconductors and similar devices, visitors at this month's Hanover Fair might have done well to just stay at home. Semiconductor houses, both European and American, appear to be little inclined to stir up the market with any significant new advances with their order books bulging, plants working at full capacity, and a $50 million-plus market for IC's in sight for West Germany alone—much higher than expected.

True enough, Hanover this spring did present some interesting devices, such as 1-nanosecond emitter-coupled logic and new linear IC's for consumer electronic applications.

Link-up. Gunn diode, being mounted in heat sink, is heart of videophone link.

Gear. But whatever was lacking in the semiconductor field was more than made up by new communications systems and instruments—some of them rated as world firsts. For example, one eye-opening communications system demonstrated at Hanover was a Gunn-oscillator microwave link intended for video telephone transmissions, a system which its developer, West Germany's Siemens AG, says is the first ever that's built around Gunn devices. Also of note was a new type of flexible waveguide that AEG-Telefunken has designed for production model Concordes, the French-British supersonic airliner.

Instrument designers, too, showed up with equipment hot out of their labs. For example, Rohde and Schwarz, West Germany's top-ranking instrument maker debuted new frequency analyzers featuring a dynamic range of up to 100 decibels. And Great Britain's Microwave and Electronics Ltd. rushed onto the scene with a microwave sweep generator so hot that the company didn't even have specification sheets ready. The sweep generator offers plug-in YIG-tuned Gunn oscillators for first time in a sweep generator.

The Siemens video link is a four-channel system that uses two Gunn elements at each terminal, one in the outgoing video channel and the other in the outgoing audio channel. The maximum power each oscillator delivers is 50 milliwatts.

The 20-mw average power of each Gunn oscillator is amplitude-modulated. With a modulation of 50%, the output power of an oscillator thus varies between 10 and 30 mw. This power is fed to a pair of bandpass filters whose output is combined in another bandpass filter. The combined video-audio signal goes to a hybrid coupler and then to a small parabolic antenna.

Wavy. AEG-Telefunken's new flexible waveguide, based on the firm's present flexible lines, was especially made for the Concorde. In that plane, high-frequency energy must be carried over a 30-foot distance from the antenna at the tip of the plane's tilting nose to weather-radar equipment just below the cockpit. The new flexible waveguide, called E 100 is laid out for a frequency range from 8.5 to 10.0 gigahertz. It can handle peak power of 150 kilowatts and has a vswr of less than 1.03 for each of its two sections. Its attenuation is less than 0.98 db.

In the instruments field, the big attention-getters at the Rohde and Schwarz stand were the company's three new frequency analyzers of the FAT series. Besides their high dynamic voltage range—up to 100 db or 0.1 microvolt to 30 volts—the instruments are noted for their versatility. They can be used for Fourier analysis, frequency measurements, voltage and noise measurements, analysis of acoustic phenomena and vibrations, and, in conjunction with a built-in mixer, for sideband measurements up to 300 megahertz.

The new British sweep generator, the star attraction at the stands of Microwave and Electronics Ltd. features a range from 250 Mhz to 40 Ghz. The instrument, model 1000/1020, is unusual in that it can take either YIG-tuned Gunn oscillators, conventional backward-wave oscillators or transistor oscillators as plug-in energy sources. For low-power, 6- to 12-Ghz measuring and test applications, engineers will want the YIG-tuned Gunn oscillators, an energy source with a lifetime of 20,000 hours, according to the company.

. . . and in the air

Judging from the lineup of planes at the Hanover Air Show earlier this month the West German aircraft industry is about to take off into the blue. Indeed, although aerospace sales—$400 million for 1970—won't be significantly higher than last year's, overall prospects are better than ever before.

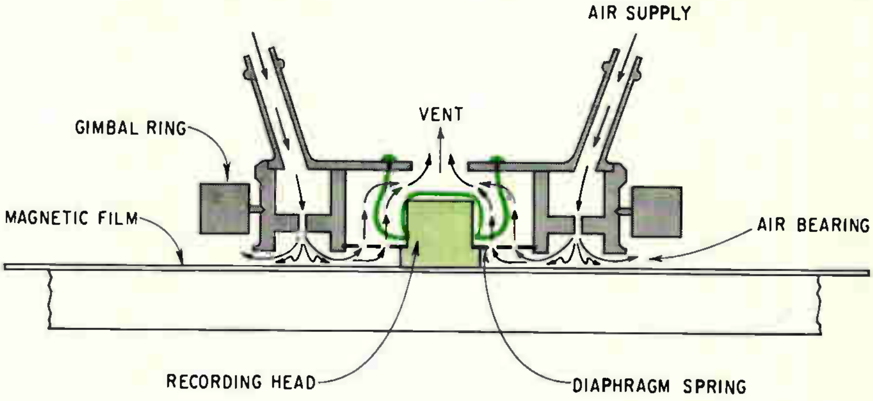
For the first time, three projects are on the industry's drawing boards simultaneously: the Airbus A300B, the Franco-German large-aircraft venture; the VFW 614, the German business jet; and the multirole combat aircraft that the Germans, French, and Italians intend to build. All three projects stand a pretty good chance of being continued through the serial production stage. What's more, the Germans and the French are now dickering about a jet trainer.

In addition, the spacecraft sector has gotten some whopping orders, for this sector's share of total aerospace sales is roughly 20% this year. Two West German aerospace firms have landed nearly $75 million in satellite contracts [*Electronics*, Apr. 13, p. 69]. Also the German-French Symphonie, communications satellite is taking on shape. And if the Bonn government should decide to participate in some sort of post-Apollo program with the U. S., more orders will fall to the industry.

Gearing up. Optimism, on the rise after many years of relative calm in the industry, prevails in much of the avionics sector. Companies, although still up against some fierce competition from other Western countries, notably the U. S. and Great Britain, are gearing up to provide the equipment that's needed. Of this, there was plenty of evidence at Hanover.

For example, Teldix GmbH, a joint subsidiary of AEG-Telefunken and the Bendix Corp., showed up with a new stabilization system intended for the Symphonie satellite. The system is designed to hold the satellite stable enough for an antenna-ground-station alignment that deviates by no more than 0.3°. The system is essentially a momentum wheel whose rotational speed is controllable between 2,700 and 3,300 rpm.

The Teldix wheel, the first to go into a commercial satellite, is essentially a brushless d-c motor designed as a spoked-type wheel and installed in a hermetically sealed, evacuated housing. Rotation control is by optoelectronics effects. Light from three gallium-arsenide diodes is interrupted by small cams connected to the wheel. Photo-transistors sense the resulting light intensity and control power to the motor's stator.



Hovering. Recording head in ICL 10,000-bit-per-inch system rides on disk with a loading controlled by pumped air. Wear-resistant material coats the disk.

Great Britain

Packing them in

Tomorrow's computers are going to need magnetic-disk memories of very high capacity, and Britain's International Computers Ltd. is well on its way to achieving packing densities of 10,000 bits per inch. Company researchers have attained such densities by using compressed air to maintain head-to-disk separation, cobalt-phosphorus recording material and a rhodium wear-resistant surface.

On any disk file, the maximum number of bits that can be packed into an inch of track depends on the thickness of the recording surface, the width of the gap in the recording head, and the distance between the moving recording surface and the stationary head.

Reducing surface thickness and recording-head gap width below present levels is not difficult, so the practical limit is set by the minimum distance necessary for the head to clear the disk surface. Using a modern flying head in the research lab, the separation can be reduced to around 1 micron at the trailing edge—at the expense of high risk of rapid wear due to contact with dust and high spots on the disk. In practice a separation of 2 or 3 microns is used.

Gave it up. ICL's approach is to abandon altogether the search for the smallest possible flying separation, and instead to run the head deliberately in contact with the disk surface. The two men who have developed the system, Ian Turner and Alan Terry, claim that the problems of wear and instability can be overcome by designing a special suspension for the recording head and using a wear-resistant coating over the recording surface. The separation can't be eliminated altogether because the coating will be about 0.1 micron thick. Turner believes that other factors, such as lack of perfect geometrical conformity between the contacting surfaces, minute and unavoidable rounding of the corners of the recording head at the gap, and aerodynamic effects will add up to an effective separation around 0.5 micron.

Nevertheless, this makes it possible to use a much smaller gap in the recording head—0.9 microns—and a very thin layer—0.3 microns—of cobalt-phosphorus as the recording medium, which all adds up to the big improvement in bit density. The wear-resistant coating is rhodium, 0.1 micron thick. The two say that a wear life of well over a billion passes of one track has been achieved at a surface speed of 1,000 inches per second.

The system is an integrated whole, but the main novelty is in the head and its carrier. To keep specific pressures between head and disk surface to a minimum, the contact face of the nickel-zinc ferrite head is as large as possible and cube shaped. Mass has been kept down to 0.1 gram to keep inertia low for following imperfections of the disk surface closely, but with minimal damage. Total load against the surface is 5 grams, which is controlled by balancing pumped air pressure and spring pressure in the head carrier.

Carrying. The head is carried in the middle of a beryllium-copper diaphragm spring, which pushes the head against the disk. The spring in turn is mounted in the center of a hollow brass ring, which has holes facing the disk. Another spring pushes the ring towards the disk. Tubes feed air at 20 pounds per square inch into the ring. Escaping through the holes, the air maintains the ring at a closely controlled height above the disk. Terry says the system is not sensitive to minor variations in air pressure. He also points out that the head doesn't crash if the disk stops.

France

Acoustic fallout

Research in reducing the noise of aircraft engines has produced a neat bit of electronics fallout: an electret microphone smaller than a collar-button, the low cost and high performance of which should offer new solutions to sound reproduction problems in areas ranging from medical to consumer products.

The midget microphone was developed by the French government's big aerospace research lab —the Office National d'Etudes et de Recherches Aerospatiales (ONERA)—which needed an accurate means of studying minute pressure fluctuations in the gases that roar through jet engines.

These pressure variations are a major cause of engine noise, which ONERA engineers hope to reduce by design changes in engine compressor vanes. Redesigning means measuring how vanes and gas streams interact, and a good way to take readings is to tie a mike to a vane during an engine run.

Rugged test. Finding a microphone rugged enough to take such punishment was a major problem. It had to work under temperatures up to several hundred degrees C. and pressure fluctuations up to 160 decibels. Either condition is enough to destroy any commercial microphone researchers could find.

Moreover, the microphone had to be thin enough to fit flush with the surface of the vanes, only about a quarter of an inch thick. Otherwise, the flow resistance of the microphone would falsify readings.

The high voltage needs of ordinary dynamic microphones prompted ONERA engineers to turn to electret-effect devices, developed after the pioneering work of G. M. Sessler and J. E. West of the Bell Telephone Laboratories. Developing a suitable electret microphone required considerable innovation, since those developed by Bell Labs, Japan's Sony and others will work only up to 100 db.

ONERA engineers jumped this hurdle by designing a field effect transistor into the microphone to act as an impedance adapter.

Using this arrangement, an initial ONERA microphone, 7 millimeters in diameter by 5 mm long, gave a sensitivity of 200 millivolts at 134 db—several times higher, say ONERA designers, than the microphone Sony put in a commercial tape recorder.

The latest, button-shaped French electret microphone measures only 5 mm in diameter by a scant 1.5 mm thick. Its sensitivity, of course, is lower: only 10 mv at 134 db. But engineers say some proprietary improvements in the microphone's electrode—which they hope to patent shortly—should push sensitivity up to 100 mv.

Easy on ears. The microphone's transistor helps push a clean signal through the 150-foot wire necessary to protect researchers from high engine noise levels.

The microphone has a frequency range of 10 hertz to 100 kilohertz. It covers amplitudes of 110 to 190 db, with a linear response to somewhat beyond 160 db.

ONERA will start looking soon for companies interested in manufacturing the microphones under license. ONERA sees medicine and ultrasonics as two areas of likely early applications. Because the microphone does not require high manufacturing precision, in mass production—around 100,000 units—it should cost under $4.

In the interval

Measuring minuscule time intervals is a growing preoccupation of researchers in a variety of fields—from nuclear physics to laser design.

A number of highly precise—and highly expensive—instruments exist for measuring time intervals in the millisecond range. But all measure only one or two intervals. Researchers with a string of phenomena to measure have had to buy a string of instruments. And at $5,000 and up each, the investment can mount quickly.

At the biennial Mesucora measuring instruments show, being held in Paris later this month, France's Thomson-CSF will unveil what its designers claim is the world's first multiple-interval timer.

It can measure up to 64 intervals of 1 msec each, arriving one after the other on a single coaxial cable or through separate inputs. Resolution, depending on the model, goes up to 100 picoseconds. And the unit's price range, from $10,000 to $16,000, starts at only double that of some instruments offering one-interval measurements.

New wrinkles. Moreover, the French unit offers some new wrinkles not found on competing machines. An optional semiconductor-memory drawer, which pulls out of the instrument's front panel, can record measurements in dangerous or difficult locations—an explosives testing range, for example. Battery-powered and small enough to fit in a researcher's coat pocket, the semipermanent memory, based on MOS integrated circuits, can play back a series of test measurements at a later date.

The meter's calculating circuitry is contained in another modular drawer that can be replaced by other drawers capable of measuring different numbers of intervals at varying degrees of precision. Four different drawers are currently available.

Thomson-CSF developed the interval timer for France's Atomic Energy Commission. The company now hopes to sell it to private research laboratories, in the U. S. as well as in France.

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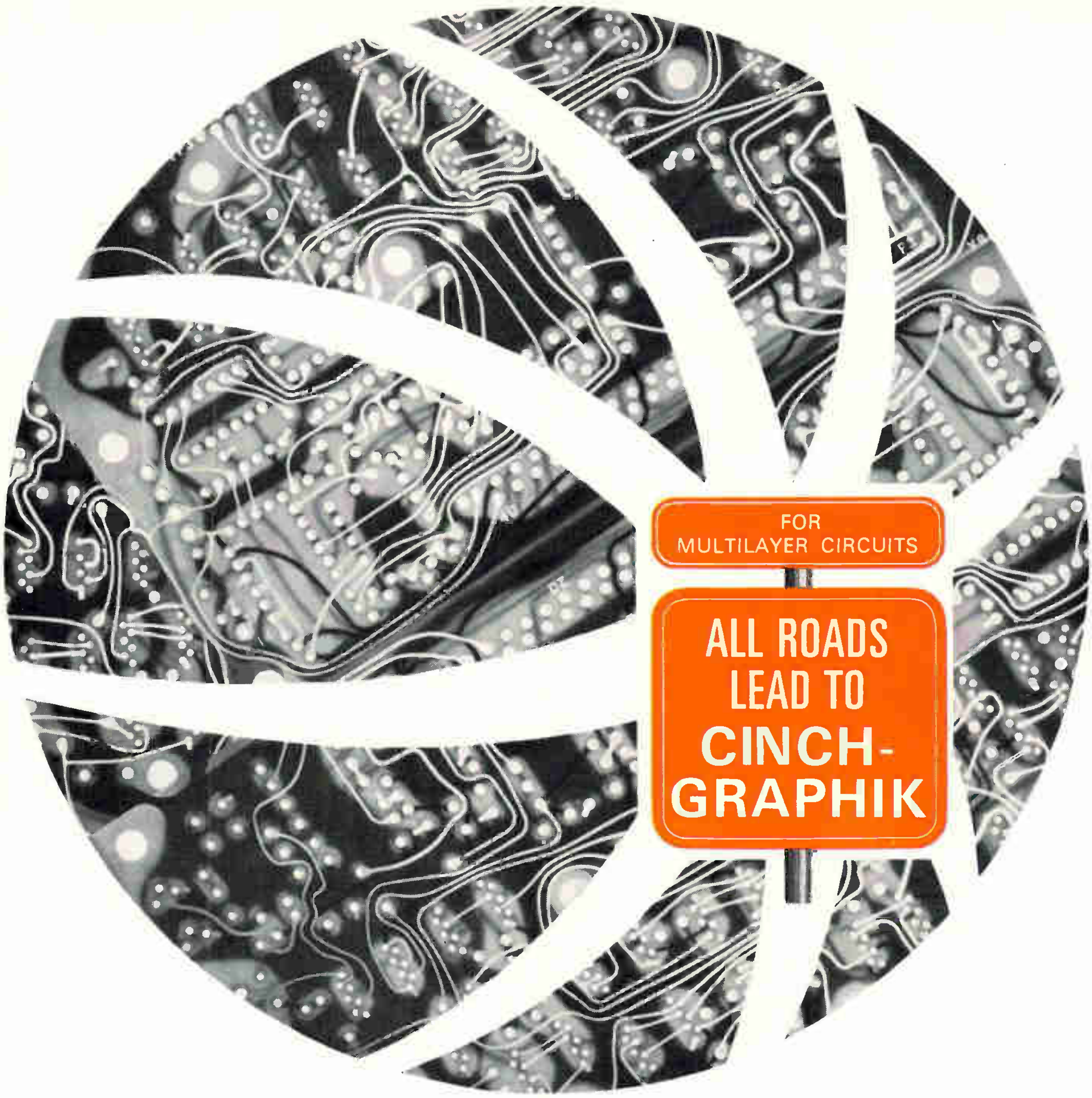

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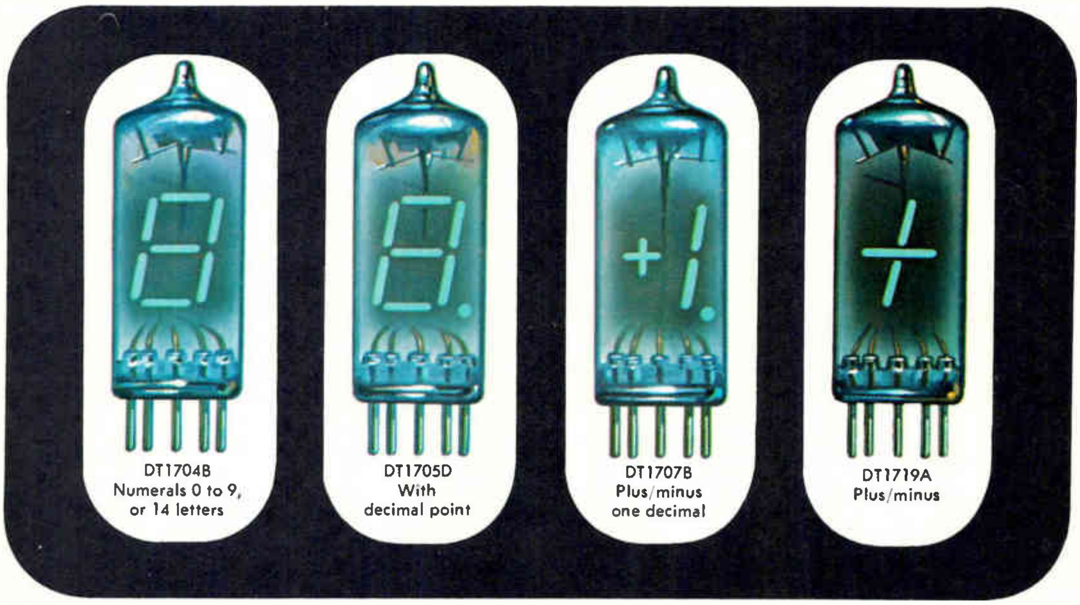

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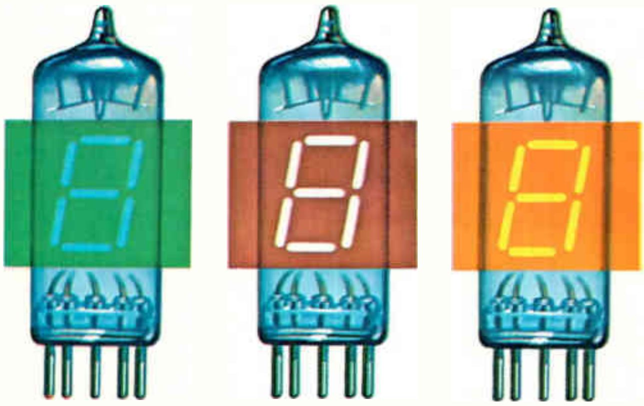

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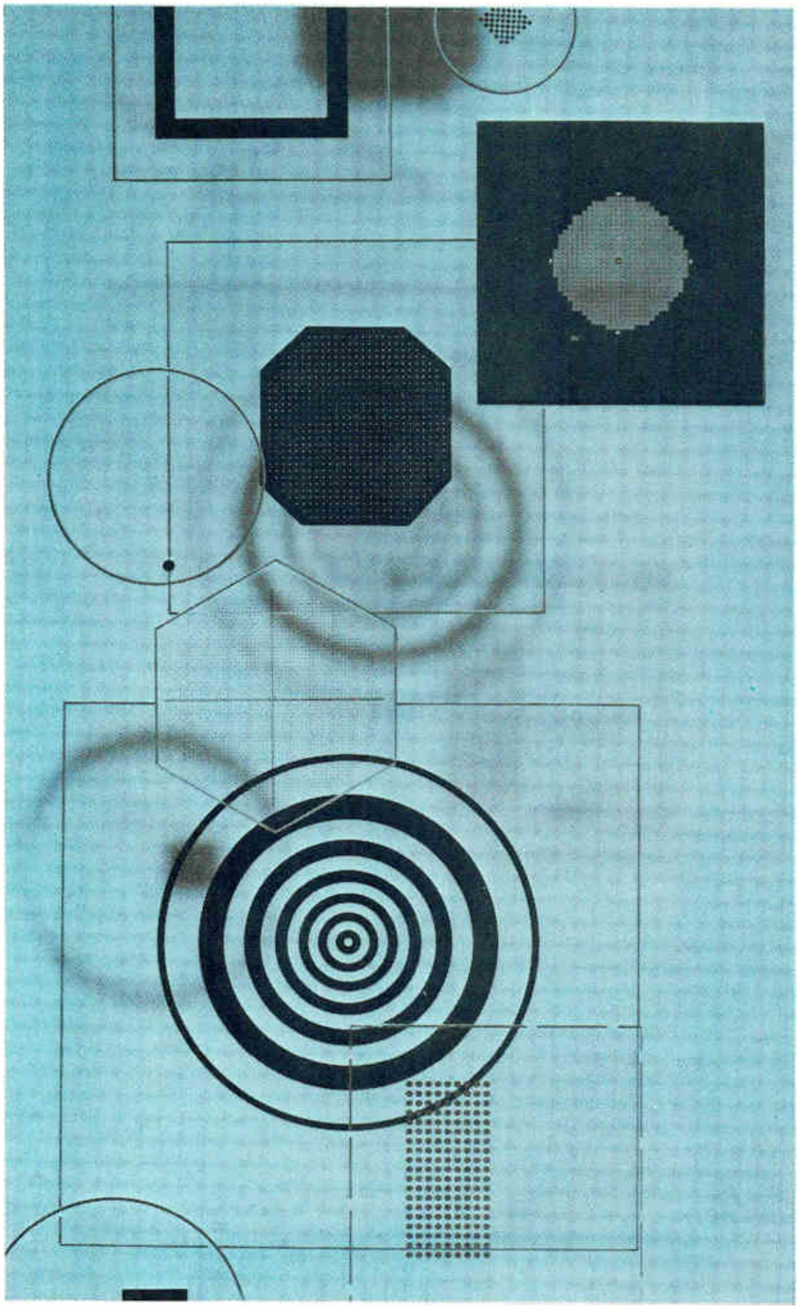

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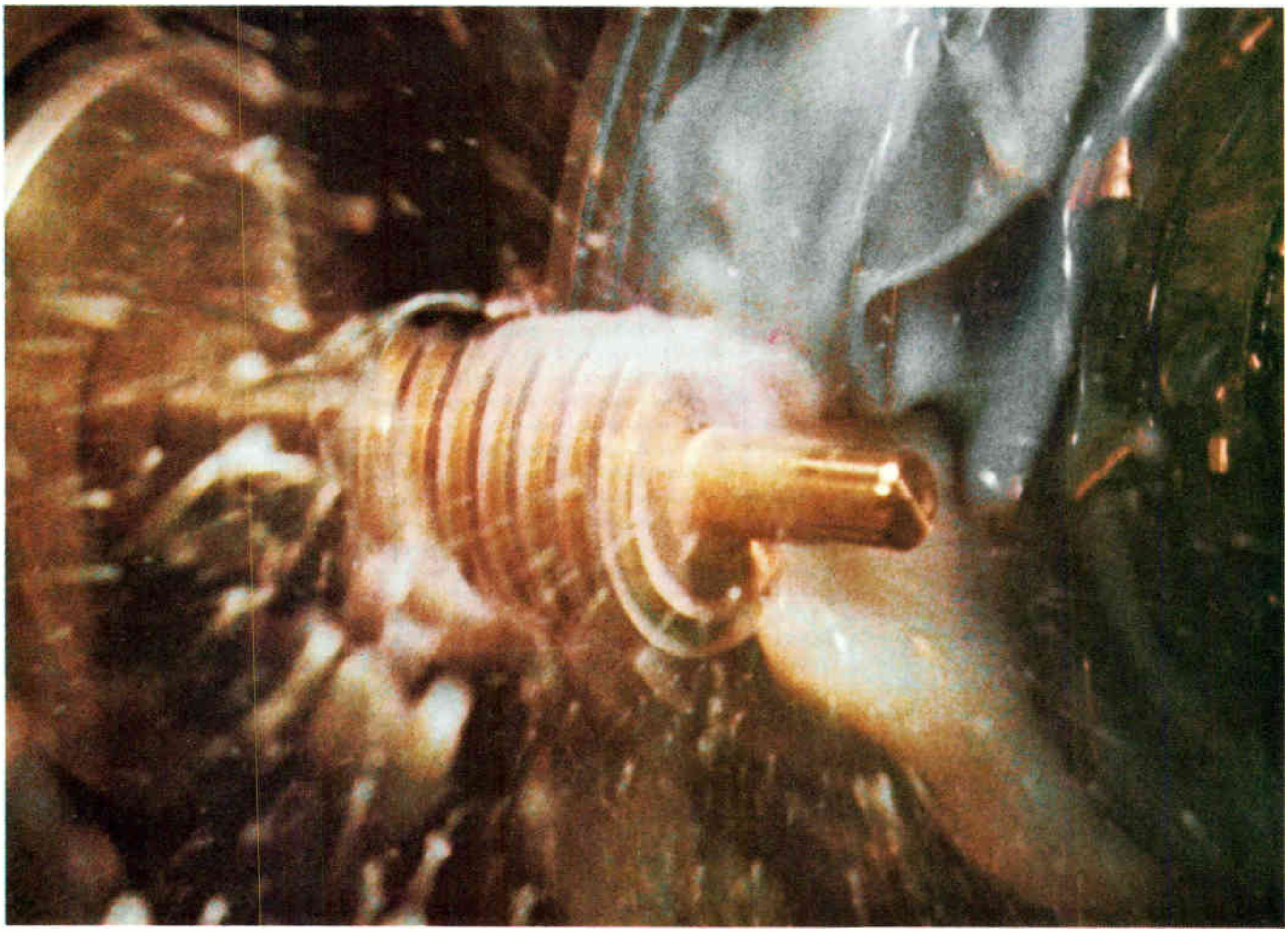

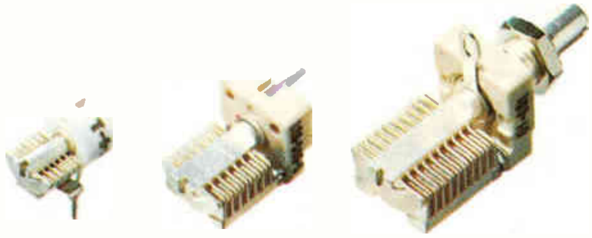

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Washington Newsletter

May 11, 1970

417 R&D programs cut by Pentagon . . .

A Pentagon review of its 6,615 research and development projects—following a Congressional ban on nonmilitary R&D—has eliminated 417 programs. They amount to 6% of the total and would have been worth $8.25 million in fiscal 1971. The Defense Department is disqualifying 183 research projects from future funding and will not finance another 221 studies and 13 development programs planned for next year.

The unannounced action resulted from an amendment proposed by Senate Majority Leader Mike Mansfield (D., Mont.) that was tacked on to the fiscal 1970 Defense Appropriations bill requiring that all DOD research meet a military requirement.

Biggest loser among the services was the Navy, which was told to drop nearly 9% of its 2,495 programs—a loss of nearly $4.5 million.

Much of the total cut, according to insiders, is tied to Project Themis, a program started by former Defense Secretary Robert S. McNamara to develop a broader geographical distribution of R&D expertise throughout the nation by providing universities with seed money.

. . . but NSF could fund some projects

Some of the R&D projects dropped by the Pentagon under the ban on nonmilitary research could be picked up by the National Science Foundation. This is said to be one of the reasons why the National Academy of Sciences, which has overlapping membership with the NSF, turned down the Defense Department's request for a review of the programs that were cut. The Pentagon was trying to get the academy to participate in its attempts to justify program reviews. Another reason for the academy's refusal, according to stories making the rounds, is the "subjective interests" of some of its members. Instead, the Congressional economic watchdog, the General Accounting Office, is reviewing the DOD program cuts and will later report to Capitol Hill.

The National Science Foundation has an extra $10 million bankroll in its fiscal 1971 budget request which it could use to pick up the funding on some of the canceled DOD research.

Airlines set to go with time-frequency collision avoidance

RCA may have waited too long to unveil its radio interrogation and response system that it calls Secant—separation control of aircraft by nonsynchronous techniques [*Electronics*, April 13, p. 46]. This is indicated by acceptance of first technical specifications for a time-frequency collision avoidance system by the airlines electronic engineering committee of Aeronautical Radio Inc., and by a Washington briefing scheduled for May 12 by the Air Transport Association. The ATA will brief government and industry executives on its final report of systems tests. RCA will report on its system at the ATA-sponsored meeting, but one official says the company will have to demonstrate that Secant has "stupendous merit and is fantastically better" for the airlines to drop their nine-year investment in time-frequency CAS and wait until the new system is available—estimated by RCA to be 1973 or 1974.

Competing time-frequency systems developed by McDonnell Douglas, Bendix and a joint Sierra Research and Wilcox Electric effort will reportedly cost substantially more than Secant, but they will give a pilot instructions for evasive maneuvers rather than merely warn him, as Secant does, that an aircraft is in his vicinity.

Washington Newsletter

Army wants to buy Tacfire hardware in 1971 for TOS

Army documents show that **the Combat Development Command expects Litton Industries' tactical fire direction system equipment**—due to its modularity—**to satisfy many of the component requirements for the tactical operations system,** and that procurement of TOS is planned for September 1971. This would appear to write off the hopes of Control Data Corp., which still is pushing its 18-pound Alpha computer for the TOS. **However, Control Data believes it is still in the TOS picture.**

The command's plans for what it calls TOS-75 as an integral part of its Army-75 program still needs approval by the Department of the Army. CDC completed its TOS-75 study in March. On approval of its plans, the command says, **engineering development of TOS-peculiar hardware will be undertaken.** Though the Army now hopes to field an operational system **by June of 1974, that date may slip.**

Cryoelectronics: 1980's power source?

The Federal Power Commission is supporting development of cryoelectronic power transmission as a means of avoiding blackouts while meeting rising urban power requirements. The fact that power companies are now considering the use of **niobium transmission lines supercooled to —425°F for high-voltage a-c could take some of the sting out of the anti-pollution forces,** which are opposed to the construction of new power plants in urban areas.

Union Carbide's Linde division has demonstrated the feasibility of superconducting transmission through niobium tubes immersed in liquid helium. Capacity of an extremely pure niobium cable is estimated to be 25 times that of a conventional cable, indicating that one 20-inch pipe system could handle up to 10,000 megavolt-amps at 345 kilovolts—more power than is currently consumed by all of New York City.

Harsha charges Army with reprisal against bidder

Rep. William H. Harsha (R., Ohio) **charges the Army Electronics Command with "reprisals" against an unnamed small electronics company** which, he claims, sought to underbid the Admiral Systems Corp. for production of 191 tactical AN/GSH-6 recorder/reproducers for high-speed burst transmissions. **Harsha contends that the small firm's unsolicited bid opened the sole-source procurement to competition and shaved two-thirds of the $1 million cost.**

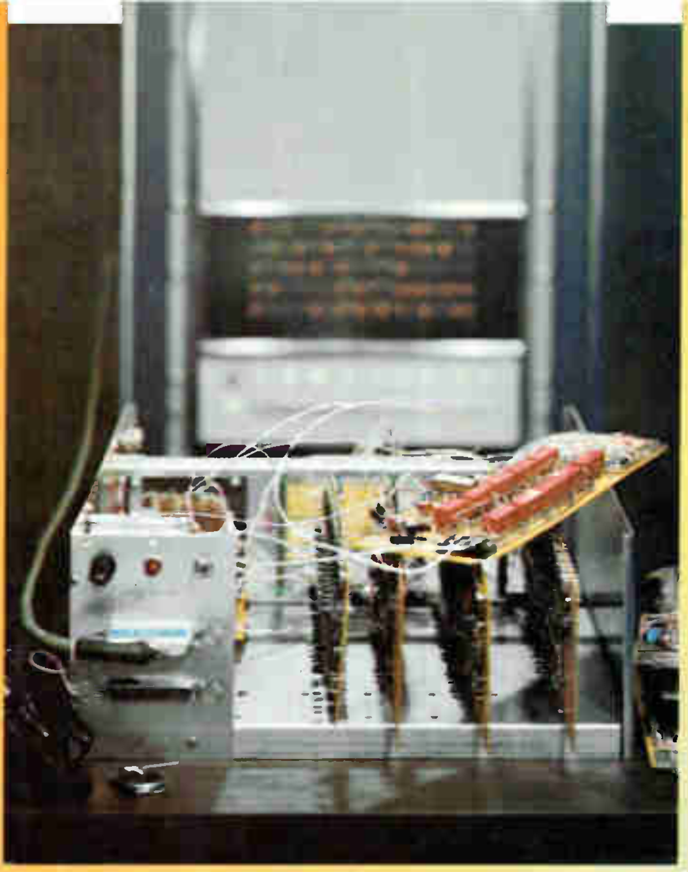
An award for the 300-words-per-minute Morse code recorder and reproducer **was made late last March to the lowest of five bidders,** Raycomm Industries of Freehold, N.J., for $333,000. Admiral's $377,000 bid was second. Harsha alleges that ECOM's Chicago office initially certified falsely **that the Army had an "urgent" requirement for the AN/GSH-6 and should buy 200 units for $1 million** from Admiral as "the only known source who can meet the required delivery schedule."

Stress performance as standards guide

Commercial and industrial product standards eventually will be based on uniform performance criteria rather than specification standards, predicts Lewis M. Branscomb, director of the National Bureau of Standards. Moreover, he sees the time when products will be labeled with hours of mean life. Such labeling already is near at hand: the Federal Trade Commission plans to order light-bulb makers to take this kind of action.

Although Branscomb's forecast is being construed as a response to the demands of consumer interests, one Capitol Hill aide sees the NBS director's comments as "a spinoff from the military-industrial complex."

TRIAL and ERROR



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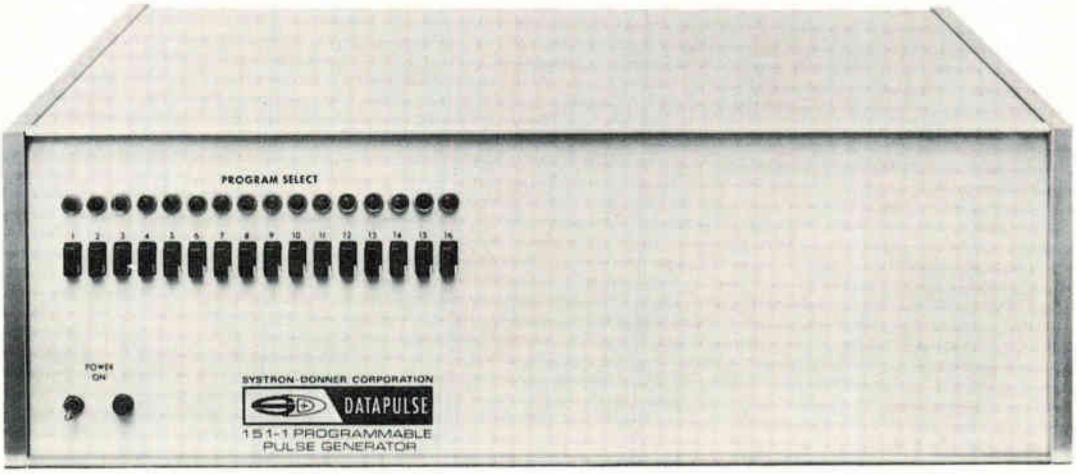

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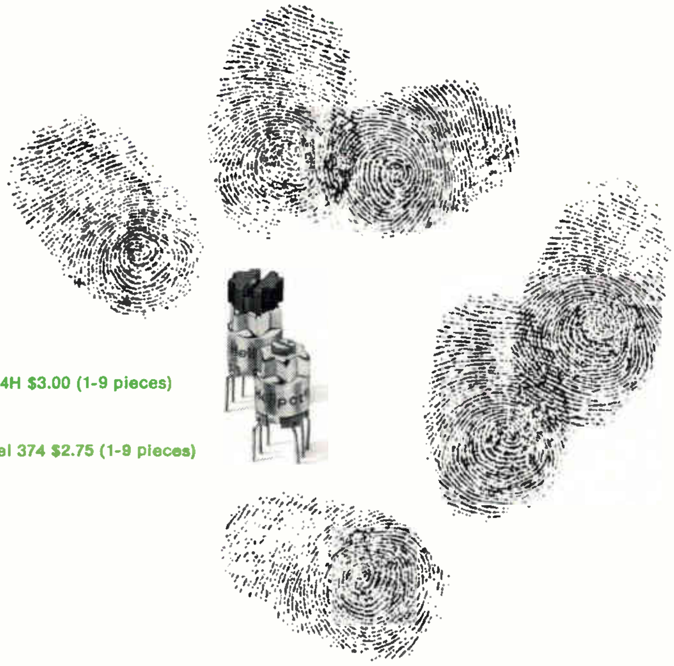

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Article Highlights

Red, yellow and green in a semiconductor alphanumeric display
page 88

A promising approach to a mass market for solid state alphanumeric displays is based on a silicon-doped gallium arsenide diode that emits infrared light. A key feature is a phosphor coating that converts the i-r to visible light—and in a variety of colors. The materials don't cost much, and fabrication costs should decline once monolithic processing methods have been perfected.

Etching memories in batches
page 94

Etched permalloy technology applies the techniques of semiconductor manufacturing to batch-fabricated memories. A pattern of conductors is etched on a copper-clad epoxy board, then successive layers of permalloy, insulation, and copper are deposited and etched to make an array of toroids with interweaved conductors. The technique offers better yield, easier handling, simplified testing, and miniaturization.

Making small ROM's do math quickly, cheaply, and easily
page 104

The familiar lookup-table approach can be combined with equivalent-function techniques to make small, inexpensive read-only memories perform mathematical functions in a computer. This combination offers speed and efficiency, while the use of multiple, readily available small ROM's averts the need for having an enormous capacity contained in a single memory.

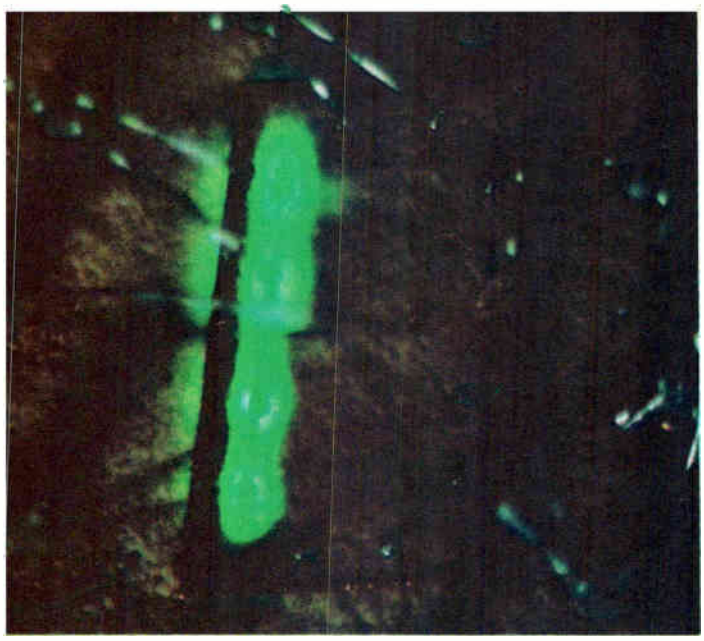
Greater versatility for MOS devices
page 112

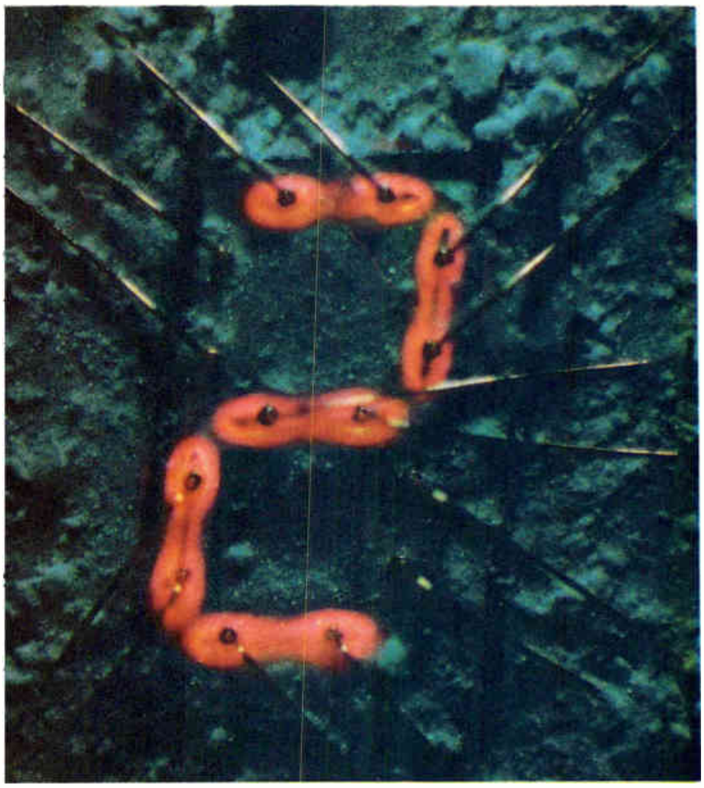
High density and ease of fabrication have led more and more integrated-circuit designers to metal oxide semiconductors. Now a new class of MOS devices has been developed that offers a density of up to 200,000 elements per square inch. Called charge-coupled devices, the new chips hold out the promise of junctionless devices for memories and imaging: since circuit functions are performed directly in the semiconductor itself, the devices do not require p- or n-type diffusions for processing of information.

Coming

Flat-screen display

Flat-screen display schemes have encountered some difficulty in obtaining adequate brightness and simpler addressing. Now a new approach uses a sort of light amplifier and a glow discharge technique that are integral to a screen whose overall thickness is only 0.010 inch.





Seeing red, yellow and green in a semiconductor alphanumeric display

GE's *Allen M. Barnett* and *Fred K. Heumann* are fabricating monolithic solid state displays that can emit many hues rather than one, which is the norm; key to multicolored approach is phosphor coating of light-emitting GaAs diodes; this technique holds out the promise of low cost

● A choice of colors in a semiconductor alphanumeric display would permit color coding of data displays and allow for a wider range of individual preference. Unfortunately, light-emitting diodes up to now have been too inefficient at wavelengths other than red. However, an LED structure under development at General Electric Co.'s Research and Development Center at Schenectady, N.Y. may change all that. Depending on the way it's energized, the LED emits red, orange, yellow, or pale green light, and, in a slightly different version, bright green. GE has built numeric characters with the technique, and devices with letter as well as number capability are expected to follow.

But variety of color is only part of the story, according to Allen Barnett and Fred Heumann, two scientists who have worked on the new display. The GE LED is made with gallium arsenide, whose processing techniques are better understood and far more advanced than those for gallium arsenide phosphide or gallium phosphide, the materials used in currently available LED's [*Electronics*, March 2, page 126 and March 30, page 134]. In addition, GaAs is available in larger quantities, larger wafers and at lower cost than the other two materials.

GE has already built its multicolor LED displays in monolithic form. But these devices are primitive—and no different from many commercially available LED's—in that power is supplied through wires individually bonded to each diode in the array. Barnett and Heumann feel that the full potential of the approach won't be realized until contact metalization can be deposited in a batch process, as in integrated circuits.

Fortunately, GE is close to achieving a true planar configuration that would permit this type of metalization. This would lead to a low-price mass market, in the view of GE scientists. Displays of numbers are expected to be designed into home appliances, cars, perhaps even home telephone links to computers by the late 1980's. This would be in addition to the more conventional uses in industrial displays, laboratory instruments, and business machines.

Barnett feels that the major potential for the new technology is in character and information display; he includes simple graphical applications such as curve tracing in the latter category. "Low bulk, low voltage, fantastic reliability is what the semiconductor offers here," he says. He doesn't see color television as a goal in the foreseeable future—the cathode-ray tube is inexpensive and performs well in this application.

Essentially, the display consists of a semiconductor diode surrounded by a layer of phosphor material. The diode emits infrared radiation, and the phosphor converts this into visible radiation.

Heumann points out that GaAs is the most economical light-emitting semiconductor material available, not excepting silicon carbide. The phosphor materials cost less than one cent per character since only milligrams are needed. The cost of materials for the display, in other words, is extremely small.

Despite the advanced state of its technology, GaAs has been largely ignored as a display material because it emits in the infrared. But with the addition of a phosphor to convert the infrared to visible radiation, and with the doping of the GaAs with silicon to make it more efficient, GaAs becomes a usable display material. GE is getting 6% external efficiency from its Si-doped planar structures in converting electrical power into infrared light. For the diode-phosphor combination, the luminous efficiency ranges from 0.07 to 0.35 lumens per watt, depending on the color of the output. GaAsP displays—unquestionably the most popular today—have luminous efficiency of 0.07 to 0.14 lumens per watt, so GaAs-phosphor displays are at least as good as

Two-step technique of light generation – emission of infrared by a gallium arsenide diode and conversion of infrared to visible radiation by a phosphor – permits various display colors

GaAsP and 2½ times better at their best. GaP can be more efficient—luminous efficiencies of 0.6 to 3.6 lumens per watt have been reported—but its poorly developed materials technology is a serious drawback.

A recent development at Bell Telephone Laboratories indicates that GaAs may have an even better position. Bell researchers have reported finding a phosphor (barium yttrium fluoride) that gives an eight times improvement over previous diode-phosphor combinations, for a net luminous efficiency more than 16 times greater than that of GaAsP devices. (The work at Bell Labs is on discrete point-source light emitters, not on complete monolithic characters as at GE.)

In another recent development, RCA has reported achieving blue emission at reasonable efficiency, thus adding another color to the GaAs-phosphor spectrum. [See U.S. Reports in this issue.]

As the phosphor for its green-emitting display, GE uses lanthanum trifluoride doped with erbium as an activator and ytterbium as a sensitizer. The Yb atoms increase the capture cross-section of the material for the i-r photons, and energy absorbed excites green emission from the Er atoms in a two-step process.

For LaF_3, the visible output under i-r stimulation is centered at 5,400 angstroms, which is conveniently near the peak of the eye's response. There is also a small amount of emission in the red.

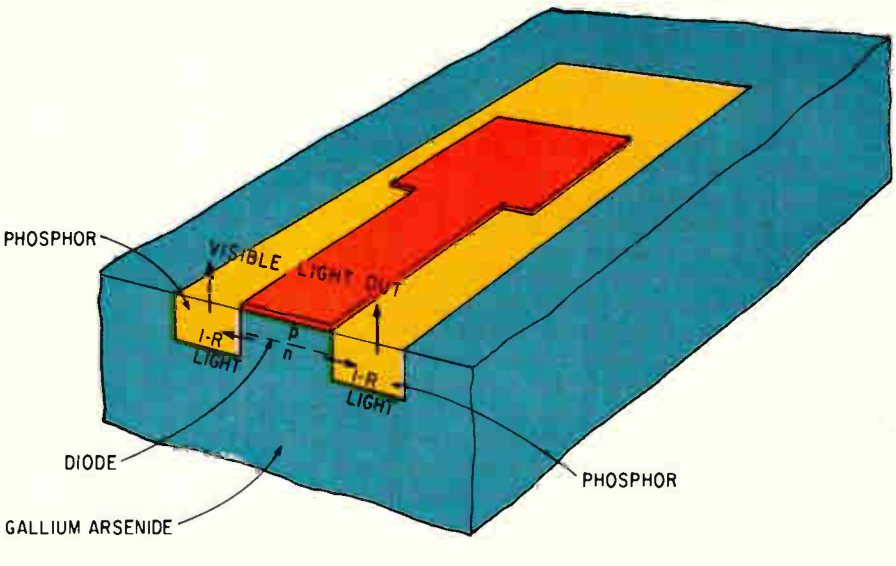
For the tunable red-yellow phosphor, GE relies on yttrium oxychloride, which has peaks in the red at 6,600 Å and in the green at 5,400 Å, and an insignificant emission in the blue. By varying the pulse width, the relative amounts of red and green emission can be regulated to produce outputs ranging from red through orange and yellow to pale green.

This tuning can be accomplished because the rise times for the two peaks are markedly different: the red rises more slowly than the yellow. Thus, the emission is essentially red with a steady current, bright yellow with 2 millisecond pulses, and pale green with 100 microsecond pulses. The brightness is about 50 foot-lamberts at an average current of 50 milliamperes. The peak pulse current for the yellow emission is 625 ma at a 40 megahertz pulse repetition rate. At the same frequency, the pale green emission requires 12.5 amperes peak current, which is impractical for most applications.

Visible-light-emitting diodes based on infrared-to-visible converting phosphors have had an interesting history. Study of these phosphors started in 1959. Initially, the conversion efficiencies were low, but in 1966, three groups of investigators discovered that the addition of a sensitizer to the phosphor resulted in a great improvement. And in 1968, R.A. Hewes and J.F. Sarver of GE's Lighting Research Laboratory reported an efficient infrared-to-visible converting phosphor consisting of LaF_3 activated with erbium and sensitized with ytterbium.[2] This phosphor absorbs at 9,750 angstroms and emits at 5,400.

Ralph Potter at the same laboratory noticed that the absorption peak roughly corresponded to the emission peak of GaAs lasers and light emitters. The phosphor was then sent to Simeon Galginaitis at GE's R&D center, who applied it to a Si-doped GaAs diode with emission corresponding roughly to the phosphor's absorption band. The first results were disappointing, but after Galginaitis and Heumann worked on the efficiency of the infrared emission, they were able to produce the first visible-light-emitting diode based on a GaAs-phosphor system.[3] [Reference 3 contains a complete bibliography of the phosphor development.]

This work was followed by an investigation at Bell Labs which eventually resulted in the factor-of-eight improvement in efficiency of green light emission with



Construction. Moat around GaAs diode contains phosphor which absorbs infrared light and converts it to visible light. Seven such moat-diode segments are formed on a GaAs chip to make a single alphanumeric character.

$BaYF_5$ phosphor.[4] Bell Labs also developed a green-to-red tunable phosphor using Y_3OCl_7. Unlike the GE tunable phosphor, this Bell Labs phosphor is changed from green to red by increasing the current.

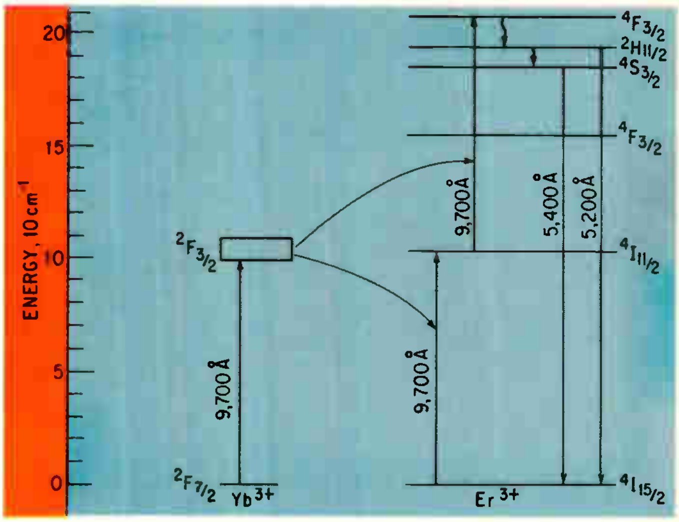
The net result of the work has been numeric character displays, monolithic and multicolor. But Barnett and Heumann feel they've only scratched the surface.

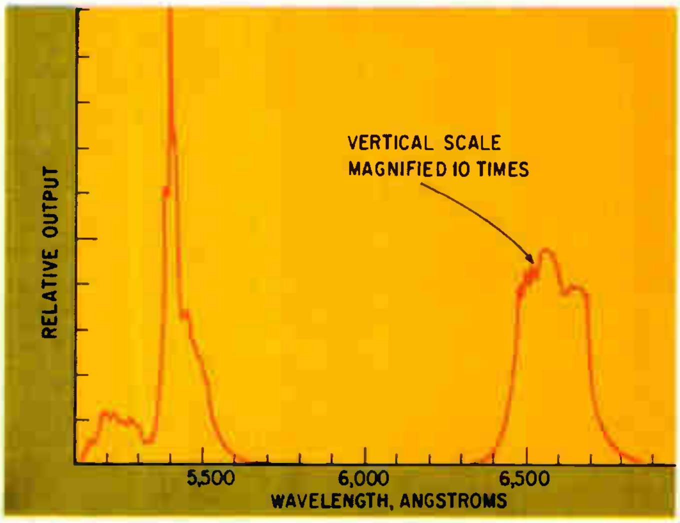
The present form of the display is a 1/7-inch-high seven-segment figure-eight arrangement. Each segment is dumbell shaped and surrounded by the phosphor material. The GE researchers settled on dumbell-shaped segments after experimenting with all manner of shapes —serpentine, square, rectangular, and round. They found that their final choice gave the most uniform light emission at the least current.

The characters are made, 60 at a time, on a wafer of the GaAs. The base material is a tin- or Si-doped GaAs wafer with n-type resistivity. On this is grown epitaxially an n layer and then a p-type layer of Si-doped GaAs, thus forming a p-n junction.[5] (Silicon can make the material n or p depending on conditions.)

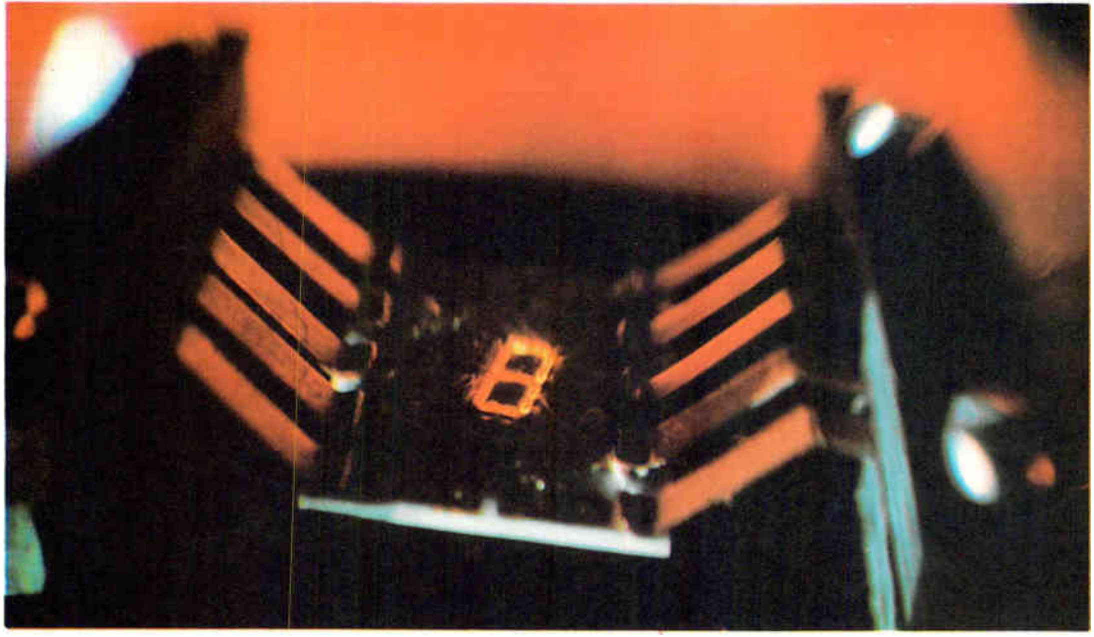
The next step is to lap the p surface until the p-layer thickness is reduced to 0.002 inch, then diffuse zinc into it to reduce the sheet conductivity of the surface. Next, a 4,000 Å-thick layer of gold is sputtered on, and a 2,000 Å layer of nickel is electroplated on that. These metals are alloyed into the GaAs to form

Two-step. Energy diagram shows how dopants in lanthanum fluoride phosphor convert incident infrared light to visible. Ytterbium (Yb) acts as a sensitizer; it aids in absorbing infrared radiation from the GaAs diode at 9,700 angstroms. This trapped energy is transferred to erbium (Er) at two levels. When the upper Er level has been excited, the atoms relax and give off green light at 5,200 and 5,400 angstroms. Other phosphors operate by a similar mechanism.

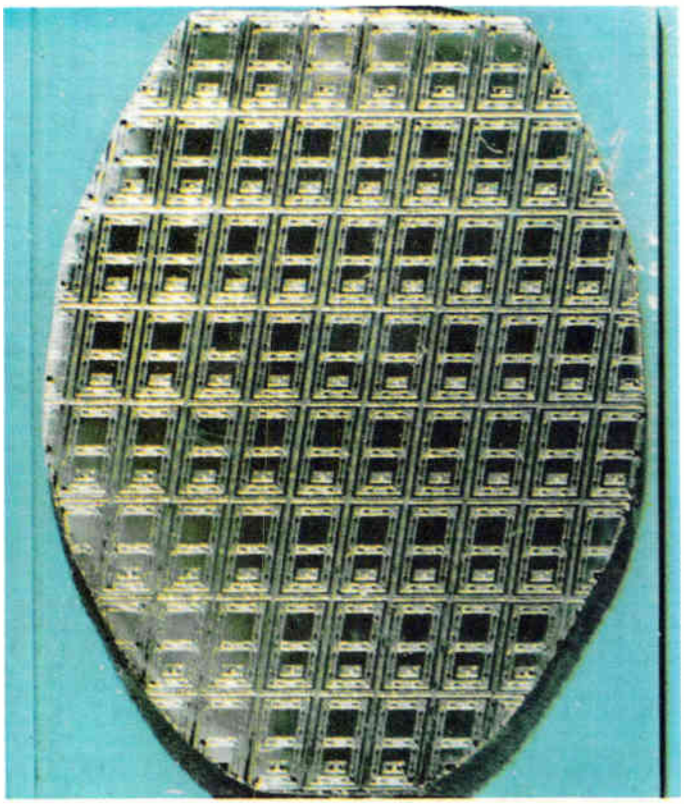




Peaks. Most of the output from lanthanum fluoride is at 5,400 angstroms, corresponding to the color green. There is an insignificant amount in the red at 6,600 angstroms.



Color combination. By applying different pulse widths to different segments, a character can light up in different colors simultaneously.



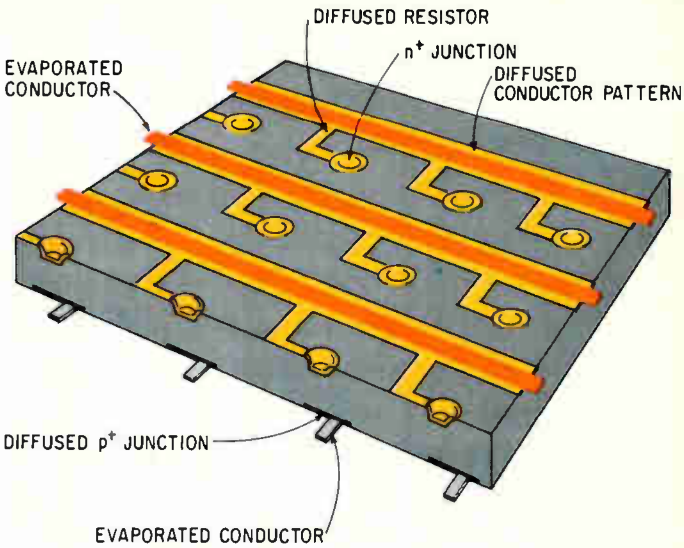
Monolith. GaAs wafer yields 60 chips containing 1/7 inch-high characters. Dumbell shape of individual diode segments is evident in this view.

electrical contacts.

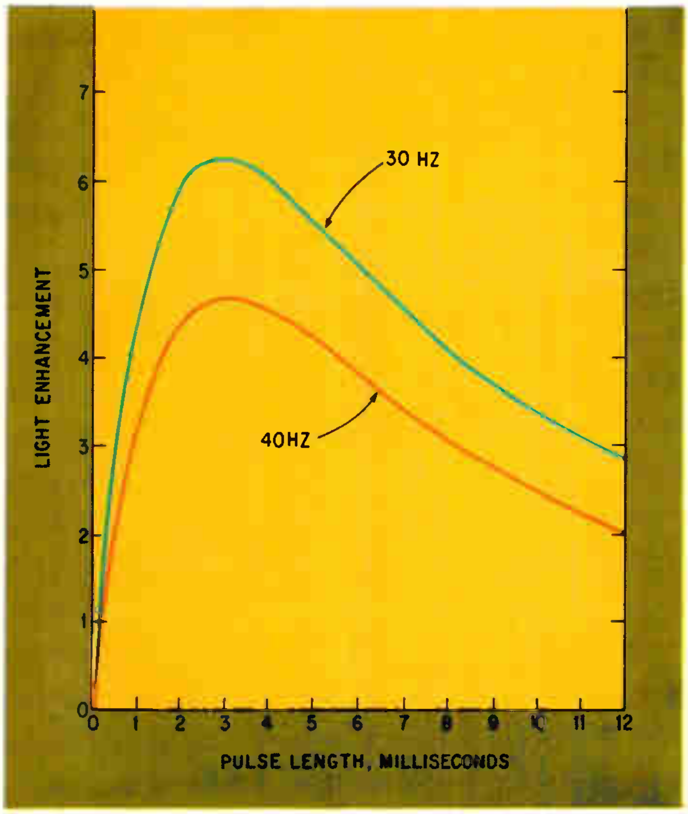
Photolithography comes next: the wafer is coated with photoresist and exposed to a mask containing the desired pattern for the light emitter and phosphor moat. Within the pattern, the photoresist, nickel, gold, and 60 microns of the GaAs are etched away. After wire bonding, the phosphor is applied.

Barnett describes the LED structure as a buried mesa; the phosphor is surrounded by GaAs walls, and these trap the infrared light within the phosphor, intensifying and sharpening the appearance of the alphanumeric character. Barnett and Heumann have experimented with exposed-mesa LED structures and found that the character had a smeared appearance.

Operating the display in a pulsed mode takes advantage of the fact that light output increases with the square of input current. Therefore, by driving the diode with a high intermittent current, the net output is greater than if it were driven by an equivalent nonvarying current. Barnett and Heumann have achieved best results with 2 to 2½ millisecond pulses repeated at a 40 hertz rate. At 50-millamperes average current per display element and 1.3 volts, these pulses give 100 foot-lamberts of light—four times greater than if a constant 50 ma were used. This average current is approximately the same as required to drive a GaAsP display, but the voltage is lower, Barnett claims. The



Experimental. Array of infrared-emitting diodes was built to demonstrate the feasibility of complex display matrixes in GaAs.[1] Diodes are in a 9 by 9 matrix, addressable by rows and columns. Spacing is 0.50 inch between diodes. Each diode has memory; that is, once it has been addressed, it stays on. The phosphor can't be used with this device to convert the infrared light to visible because the efficiency is too low. For successful excitation of the phosphor, the efficient emission of Si-doped GaAs is needed.



Enhancement. Pulsed operation provides a brighter display than d-c operation for the same average current. For 2 millisecond pulses at 40 hertz, the improvement is fourfold. At 30 hz the improvement would be even greater, but the display would have a noticeable flicker.

light output relative to constant excitation would be even greater if a slow 30 hz repetition rate were used, but the display would flicker perceptibly.

With the yttrium oxychloride display, the pulse width affects the color of the light output. At d-c, the output is red. When the same display is fed 1 msec pulses at the same average power, the output is yellow. And when some segments in a character are driven with d-c and others with pulses, the viewer sees different colors in the same alphanumeric. The 40 hz pulse repetition rate is just about ideal, but the display can be operated at much higher rates with only minor effects on performance.

The relatively slow response time of the LaF_3 phosphor could possibly pose a problem in strobing techniques now advocated for multicharacter alphanumeric displays. These techniques can require rather high pulse rates. [*Electronics*, March 2, pp. 120, 126, and 132]. The other phosphors may be fast enough to present no difficulty. However, for a single line of seven-segment characters the response of LaF_3 is entirely adequate, regardless of the number of characters in the line. Similar segments on each character would be energized simultaneously so that at the 40 hz repetition rate, the maximum pulse width would be about 3.7 msec. This is quite compatible with the 2.5 msec pulse width that works best for LaF_3.

In other character configurations, such as a matrix of light-emitting dots, higher scanning frequencies may be necessary. It may be possible in such cases to use combinations of current pulses of shorter duration but of greater energy. ●

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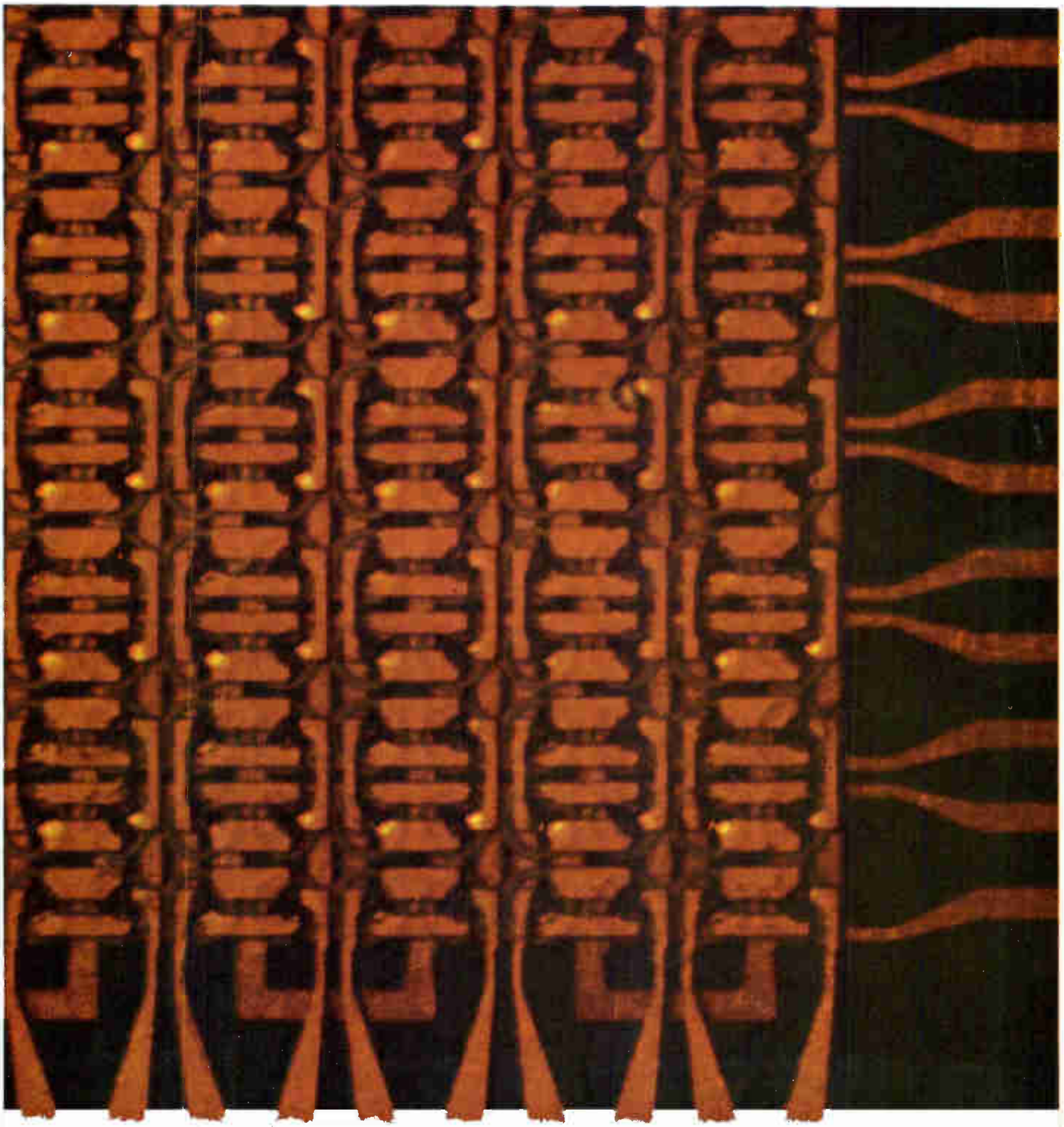
Potential for batch fabrication exists with etched permalloy memories, says *Donald F. O'Brien* of Laboratory for Electronics; permalloy toroids and copper conductors turned out by the thousands make up the memory plane

Etching memories in batches

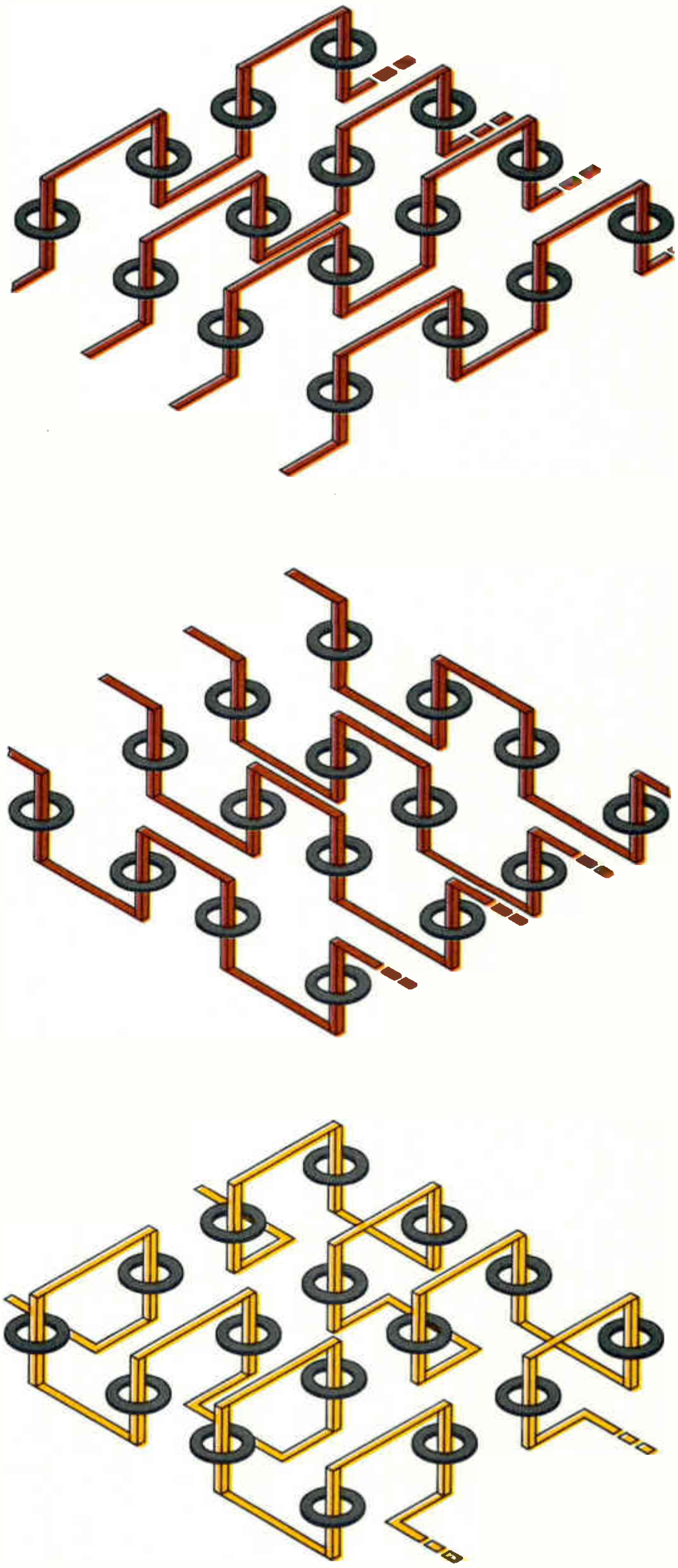


● What batch fabrication does for semiconductors, it can do for memories—improve yield, simplify handling and testing, and lead to extensive miniaturization. Specifically, in the case of etched permalloy memories, the fabrication step, when executed at the level of complete planes rather than at the level of individual elements, produces several thousand bits of memory at a clip.

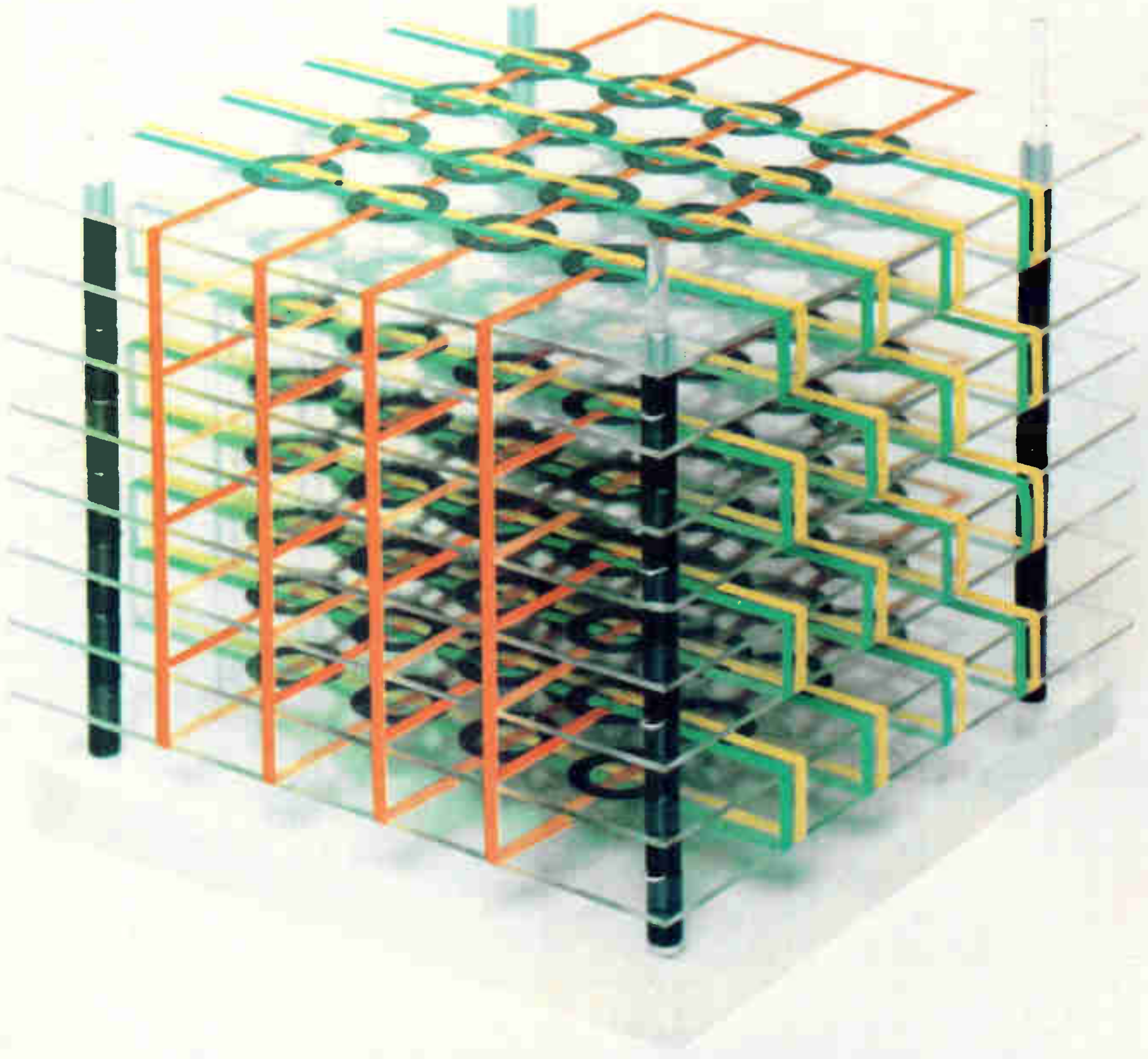
In addition to this prime advantage, etched-permalloy technology carries with it certain particular good points that arise from the materials used, the memory's physical structure, and the way it's put together. Permalloy's magnetic properties are well known, and closed flux structures can be formed, thereby avoiding air gaps and insuring high output levels. Also, the memory lends itself to the formation of proven organizations, such as the 3-D layout for ferrite-core stacks. The permalloy structure is a monolithic structure and needs no external support. Furthermore, it is made in much the same way as multilayer printed-circuit boards.

In operation, the memory is economical and it is mechanically rugged. It holds up over the full military temperature range in the presence of radiation. Other features include very little power dissipation, and densely packed and nonvolatile data. In addition, employing the memory elements as nonlinear mixers of two frequencies delivers a nondestructive readout capability;

Batched. In this enlarged photograph, the individual permalloy toroids are visible, threaded by copper conductors that act as drive and sense wires. The permalloy and copper were etched from continuous layers deposited on an epoxy board (dark brown background).



Zigzag. These drawings show the convolutions of the individual copper conductors in an etched permalloy plane.



Folded. This linear-select mockup illustrates the interconnections in an etched-permalloy stack, arranged for maximum signal output and minimum noise.

Changing of the guard

While this manuscript was in preparation, Laboratory for Electronics Inc., sold its proprietary interest in the etched permalloy technology to Cambridge Memories Inc., Newtonville, Mass. The latter organization is developing the technology further.

This is the 18th installment, and the 40th article, in *Electronics'* continuing series on memory technology, which began in the Oct. 28, 1968, issue.

the phase of the output corresponds to the stored data.

Building the memory basically involves the successive depositions of copper and permalloy on a polymeric supporting medium, with intermediate steps that etch toroidal storage elements from the permalloy, and drive and sense conductors from the copper. The finished planes can then be assembled into stacks, using another batch-fabrication process developed by the former Electronics division of Laboratory for Electronics Inc. The technique was applied in the production of a random-access mass memory and a low-power avionics memory. Both have proven to be feasible.

However, the memory's principal limitations are slow speed and small output signals. Twice as long as those of ferrite cores, the memory's cycles can be shortened only by going to a considerably more expensive form of permalloy and more complex and expensive drive circuits. But, at the same time, because of its lower speed, the memory dissipates only about a tenth of the power of a ferrite-core array and requires much smaller drive currents. As for its small outputs, special sense-amplifier circuits can detect them, or, in the case of 2-D organization, an increased drive current can produce a larger output.

At the outset, five different patterns are drawn at 125 times actual size; they must register perfectly. Representing only a small portion of the plane, the artwork is reproduced photographically by a step-and-repeat process while being reduced to its finished size. The stringent accuracy—±0.0002 inch accuracy across a 12-inch square, horizontally and vertically—maintained during reduction forced LFE to construct a special camera that at the time was well ahead of the state of the art. Today, comparable cameras are in common use by integrated-circuit mask makers.

After an inspection verifies accuracy and registration, the pattern of the first conductor level is etched on an ordinary copper-clad epoxy board. In the photo on page 94, the darkest brown is the underlying epoxy; the next-darkest pattern is the conductors made in this first etch.

Additional applications of epoxy cover the copper pattern. A layer of photoresist is added, exposed, and etched to make a large number of holes in groups of three. Each group lies directly over the ends of the etched conductors.

Now, a thin sheet of permalloy containing 1% molybdenum, added to boost its magnetic properties, is laid on the epoxy layer, which insulates the permalloy from the etched copper. Etching the permalloy leaves a pattern of toroids, 23 mils outside diameter and 17 mils inside diameter, visible as grayish-brown circles in the photo. Each toroid surrounds a group of three holes.

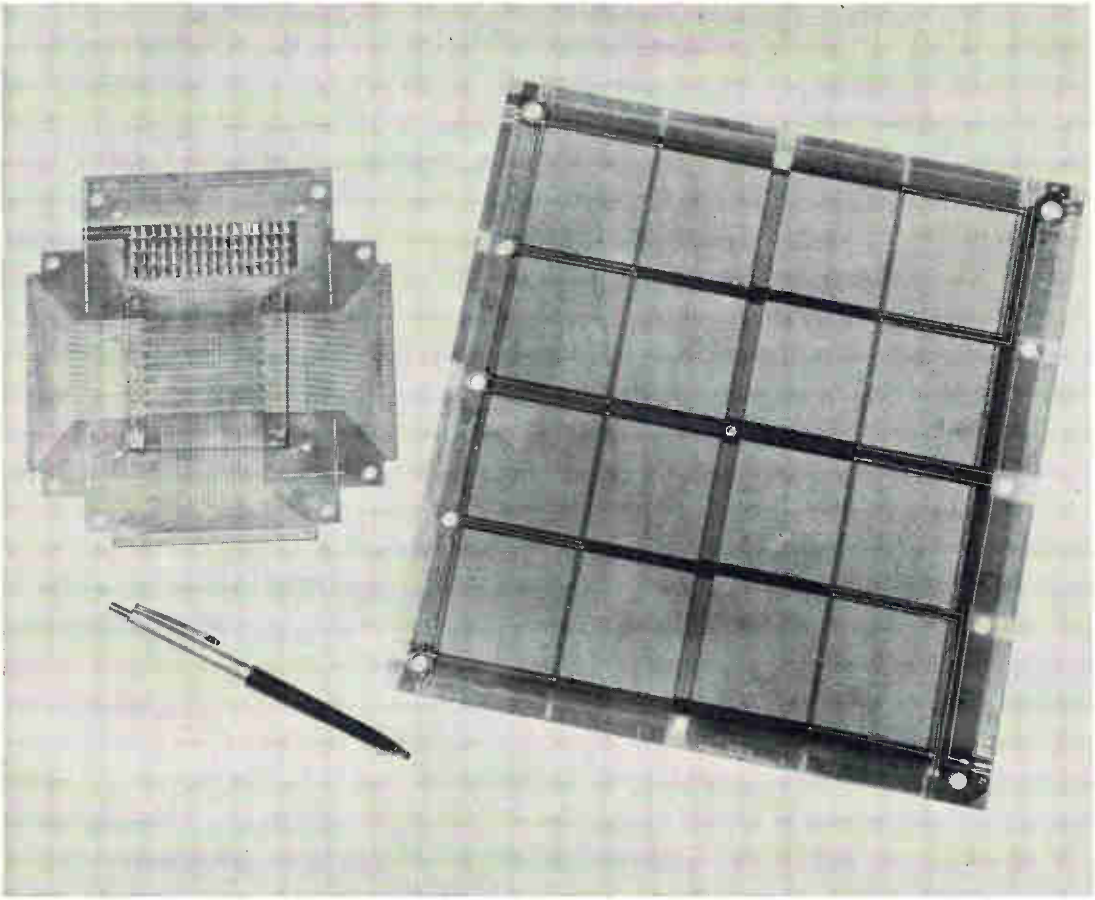
Next, the toroid layer is filled in with epoxy; this surface then receives a coating of photoresist. The holes are etched for the second time through several layers of epoxy and photoresist to the copper. These holes are then filled to the top with copper by successive steps of electroless deposition and electroplating. Thus, the path for electrical contact runs through copper "mesas" to a final solid layer of copper. This top layer is bonded, with plenty of heat and pressure, to insure contact with all mesas—nearly 250,000 on the largest planes. Etching this layer of copper produces the top layer of conductors—the lightest color in the photo.

The copper conductors of the completed plane are checked for continuity and short circuits. The usual magnetic tests performed on any magnetic memory verify the plane's ability to accept data written into it, to resist disturbances by noise and half-select current pulses, and to read out the data accurately upon request. Only a few significant tests are carried out during fabrication: registration is checked visually, and the permalloy is checked for magnetic properties before deposition.

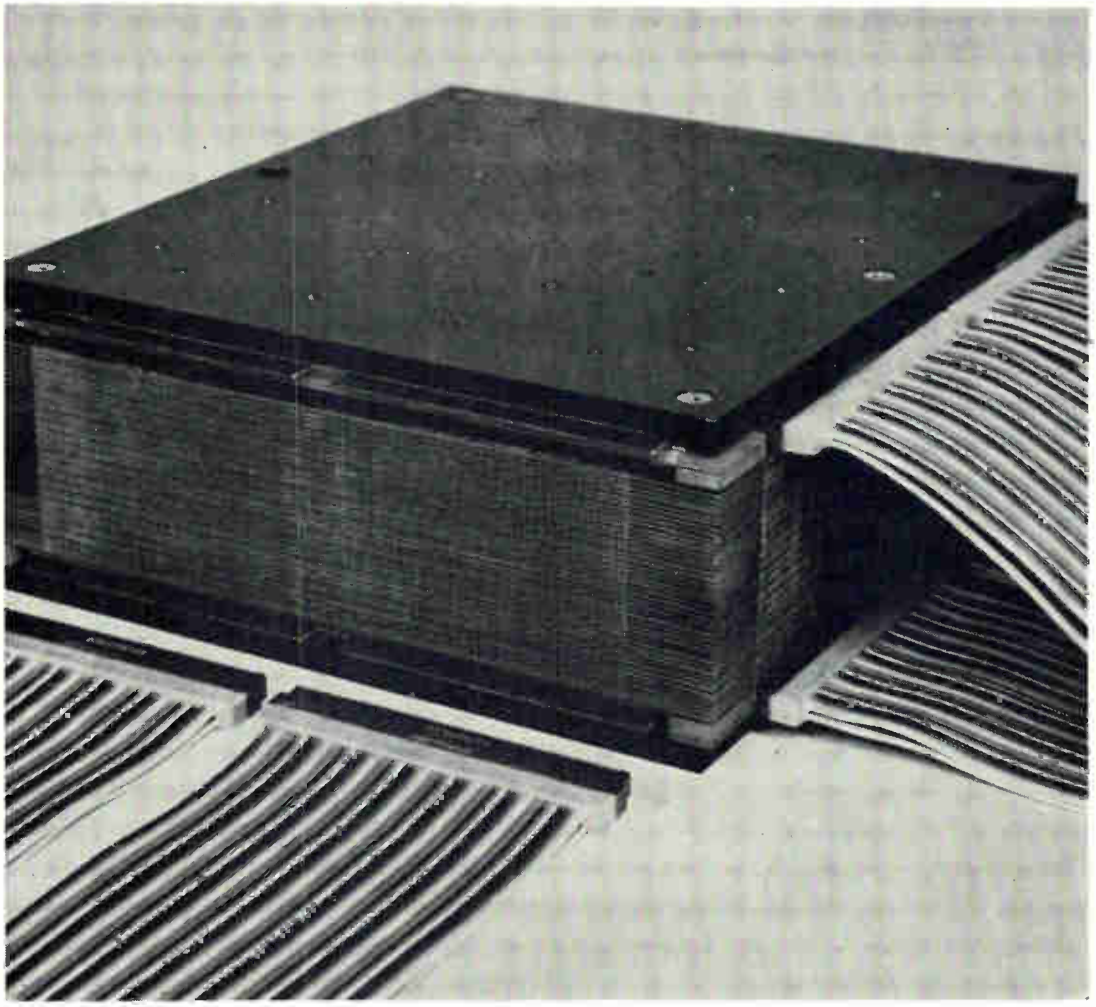
Actually, the process involves over 40 steps whose end product is an array of permalloy toroids "threaded" with three sets of conductors—all visible in the photo and separately diagramed on page 95. One set passes up through the first toroid in a north-south column. A second set passes down through the first toroid in an east-west row. These two correspond respectively to the x and y selection lines. The third set, a combined sense and inhibit line for 3-D operation, serves two rows at once as it passes from left to right across the array, as shown in the photo.

Two typical examples of completed planes are shown on the top of page 98. The smaller of these contains 2,048 toroids wired in a linear-select organization for a low-power avionics application. Diodes, in the solder pads visible in the photo, prevent sneak currents from generating false outputs from unselected words.

The larger plane in the photo contains about 83,000



Large and small. Two typical etched-permalloy planes contain 2,048 toroids (left) and nearly 83,000 (right) for linear-select organizations. Larger plane includes a substantial number of redundant toroids.



Stacked. Batch-fabrication also applies to stacks of etched permalloy planes. Specially drawn wire fits notches precut in the sides of the stack, thus interconnecting corresponding etched conductors.

toroids in a square array, 288 on a side. The photo on page 94 is an enlargement of a portion of this plane. Several redundant lines in each direction can be pressed into service, should any toroids or any connections between mesas and etched conductors turn out to be bad.

Interconnecting these planes into stacks also takes advantage of a batch-fabrication process. First, all the planes are placed in contact with one another in the same registration as they will be in the completed stack. Then a diamond wheel cuts notches, 12 mils deep, in the ends of the conductors. Fifteen-mil spacers are inserted between the planes, and specially drawn wire, cut to lengths equal to the height of the stack, is inserted in the notches. The wire's cross-section fits the notches exactly. Finally, the four edges of the entire stack are solder-dipped. This completes the assembly of stacked permalloy planes, except for the attachment of connectors to the soldered wires for cables that fed the drive and sense circuits.

Two feasibility models of etched permalloy memories have been built. One of these is a low-power avionics version for Wright-Patterson Air Force Base, under contract AF 33(615)-2838. The other is a mass memory for the Rome Air Development Center built under contract AF 30(602)-3826.

In the low-power avionics version, 1,024 words of 32 bits each are stored; the cycle time is 2 microseconds. Its organization is linear select, or 2-D, in a folded arrangement shown on page 96. In this mockup, a single horizontal orange strap between the front and rear edges contains a single four-bit word, isolated with the aid of diodes not shown here. The toroids switch like ferrite cores. Data stored in the toroid is read out through the green and yellow sense lines—one pair of sense lines per bit—and detected with differential amplifiers. Two sense lines for each bit pass in opposite directions through the toroid to reinforce the signal detected by the amplifier, while canceling the noise.

The output signal of etched permalloy, especially in the 2-D organization, is only a millivolt or so, compared to 10 to 15 mv for plated wires and as much as 80 mv for ferrite cores. This problem can be overcome by employing a read overdrive in the 2-D organization, at the expense of part of the technology's low-power advantage; or by using more sophisticated sense amplifier designs that can reliably detect such small signals, in either 2-D or 3-D organization. There's still a third possibility for 3-D that was tried out in the mass memory version, which contains 1.3 million bits and can read out any word nondestructively in 20 usec.

For nondestructive readout this memory uses each core as a nonlinear mixer; a-c currents of 1 megahertz and 600 kilohertz are sent into the selected x and y lines respectively, and the sum frequency, 1.6 Mhz, is detected on the sense line. The phase of the sum frequency, determined over 10 or more cycles of the a-c signal, denotes the state of the core. This reading technique makes small output signals easier to detect, permits speeds closer to those attainable with ferrite cores, and allows nondestructive readout as well. This idea was first proposed in 1954 by Bernard Widrow, then at the Lincoln Laboratory of MIT. However, in conventional memories the phase of the a-c readout can't be reliably determined because the coupling capacitance between drive lines varies too much. The technique works in the etched permalloy stack because the etching technique controls the coupling capacitance much more closely.

Problems still remaining in this technology include simplifying the organization, refining the design and fabrication for large-scale production, developing reliable miniaturized connectors, and refining the drive and sense circuits.

In the mass memory built for the Air Force, each x and y line had a switch at each end; two switches had to close before a line could be selected. Ordinarily every unselected switch has a small amount of leakage, and a substantial amount of coupling occurs between drives lines when the two-frequency a-c drive is used. Using two switches reduced the leakage to a point where spurious signals didn't appear on the sense line. Experiments indicated that a conventional one-switch selection scheme could be developed, with the line ends opposite the switches connected to a common bus.

The density and smallness of etched permalloy memories aggravate even further the always difficult task of designing connectors with contacts that are sufficiently close together and have sufficiently low resistance and high reliability. And of course, as in any technology, small design changes are often necessary when a product goes into production, and there's always room for peripheral circuit improvement. ●

Circuit design

Designer's casebook

Designer's casebook is a regular feature in Electronics. Readers are invited to submit novel circuit ideas and unusual solutions to design problems. Descriptions should be clear. We'll pay $50 for each item published.

Comparator increases rate meter's response

By Donald Wasserman and Glenn Parker
Perkin-Elmer Corp., Norwalk, Conn.

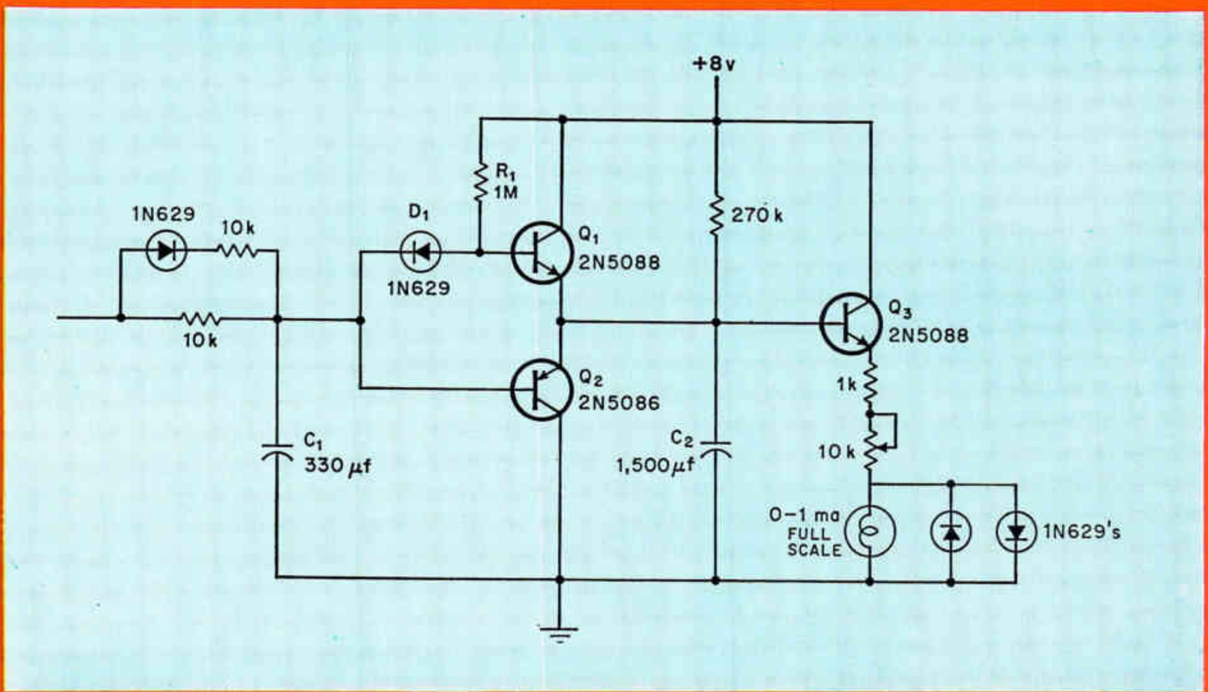
Some low-frequency rate meters, such as those used for pulse counting, produce an output voltage proportional to the repetition rate of an input pulse train. This proportional output may interfere with a reading if ripple is associated with the pulses. A larger time constant to smooth the ripple results in poorer response time. Adding a simple comparator circuit to the integrator improves the measurement response time of the rate meter.

Transistors Q_1 and Q_2 make up the comparator, comparing the voltage developed across C_1 to that across C_2. The voltage developed across C_1 results from the pulses arriving at the input from the output of the preceding monostable multivibrator stage (not shown here). Essentially, capacitor C_1 responds fast, while C_2 filters the ripple.

If, for example, the input repetition rate should slow down, the voltage across C_1 will decrease, turning Q_2 on. Capacitor C_2 then discharges quickly through the low-impedance path of Q_2 to ground, until the voltage across C_2 is about equal to that of C_1. The output emitter follower, Q_3, follows the change in voltage across C_2 and delivers the meter readout.

Similarly, if the input rate should speed up, the voltage on C_1 would rise, turning Q_1 on, providing charging current to capacitor C_2 through the low-impedance path of Q_1, until the voltage across C_2 is again about equal to that on C_1.

Diode D_1 helps reduce the voltage-comparison dead band between C_1 and C_2. And since high-beta transistors are used, R_1 can be made large enough to render negligible the current it contributes to C_1 through D_1.



Balancing act. If the input rate should speed up or slow down, capacitor C_2 will follow C_1's voltage by charging or discharging rapidly through Q_1 and Q_2. The output emitter follower delivers a voltage proportional to the repetition rate of the input pulse train.

Monostable protected against 60-hertz pickup

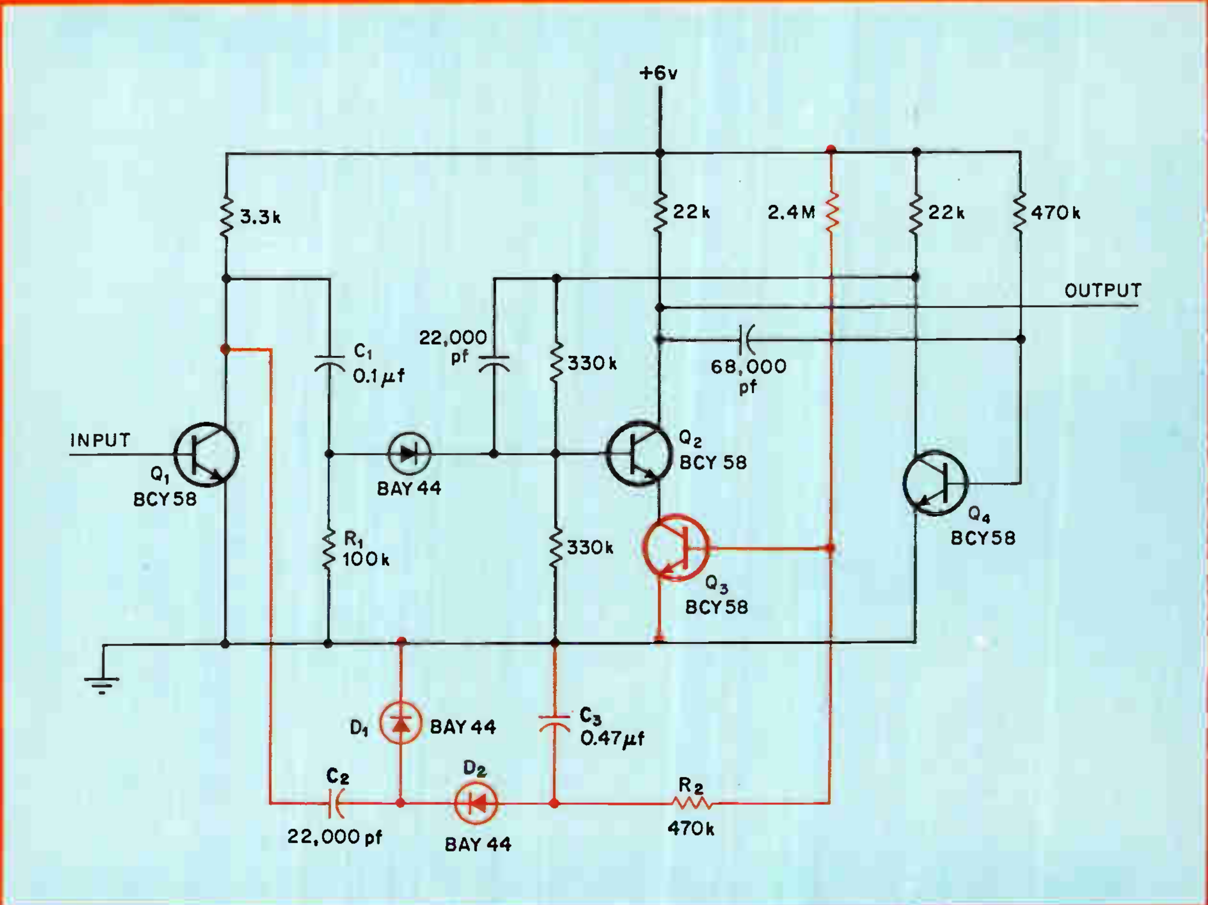
By Vladimir Bicik
Prague, Czechoslovakia

Often, a 60-hertz pickup from faulty system grounding leads to falsely triggered monostable multivibrators. Building an extra transistor and a frequency-to-voltage converter into the circuit protects against such events. These additions effectively lock out frequencies higher than the triggering signal.

One important application—medical electronics—relies on impulses from the monostable to indicate heart activity. Here, the monostable output inhibits a cardiac pacemaker when the heart is operating on its own. Interference could be interpreted by the pacemaker as a sign of heart action and turn off when it is actually needed.

Transistor Q_1 detects and amplifies signals arriving from the heart. The signals are differentiated by R_1-C_1 and fed to the monostable Q_2-Q_4.

The highest frequency signal from the heart will be in the range of 12 to 150 beats per minute or 2 to 2.5 hertz. A voltage-doubler circuit, comprising C_2, C_3, D_1, and D_2, senses the input pulses and converts them to a voltage, which develops across capacitor C_3. As long as the frequency is in the range of 2 to 2.5 hz, little accumulated voltage appears across C_3, since the voltage has time to discharge through R_2 before the next pulse appears. Should a 60-hz signal be picked up and amplified by Q_1, this increased frequency would begin to charge C_3 and drive its voltage more and more negative with respect to ground. The capacitor will not be capable of discharging through R_2, and thus Q_3 will quickly cutoff. When Q_3 cuts off, the monostable circuit becomes inhibited, signaling the pacemaker to begin functioning.



Heart action. This monostable is inhibited from producing output pulses should 60-hertz interference be picked up by input amplifier Q_1. The voltage doubler (shown in red) would charge capacitor C_3 until its negative voltage cuts off Q_3. When Q_3 shuts off, the monostable circuit, Q_2-Q_4, cuts off.

One-shot generates wide range of periods

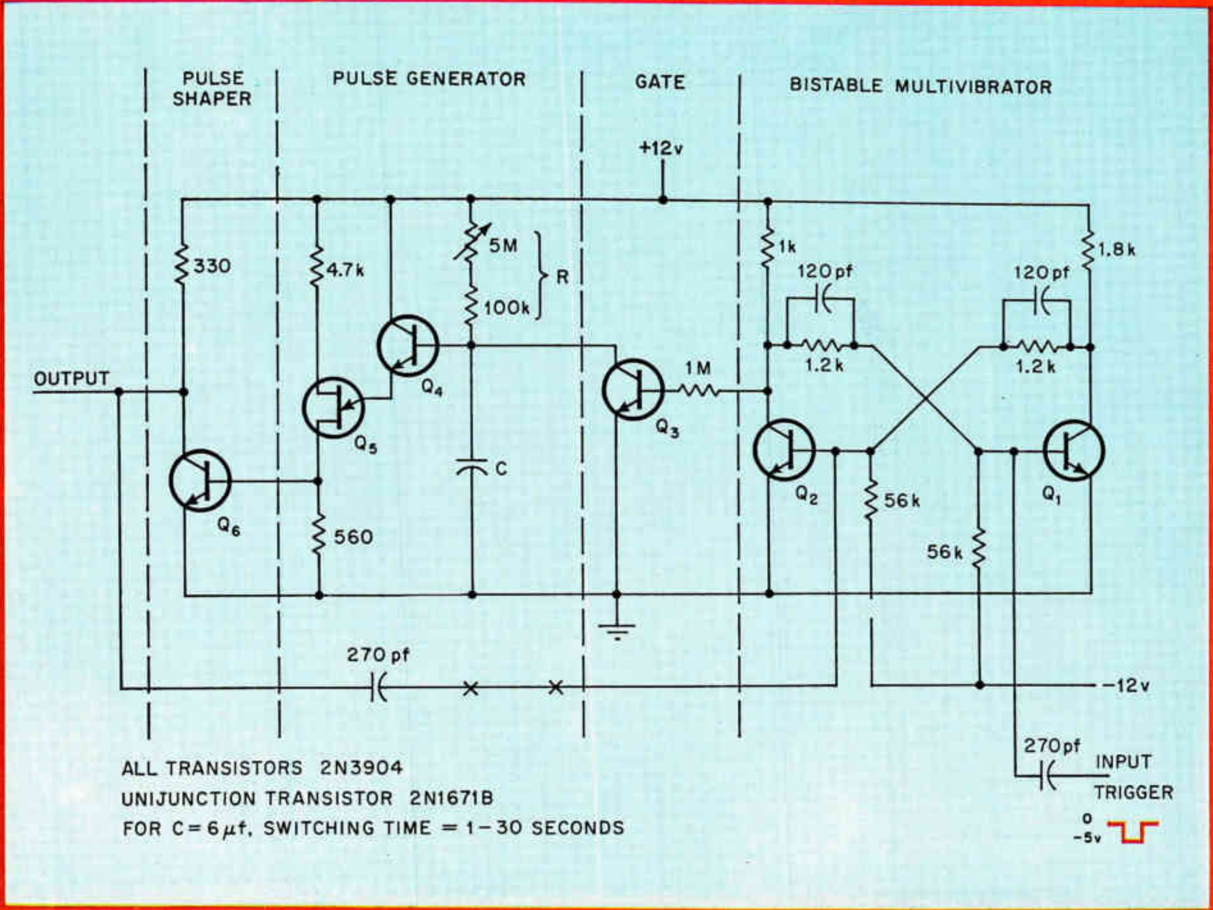
By Seymour Bell
University of Michigan, Ann Arbor

Gating a pulse generator with a bistable multivibrator produces a large variation in the time constants, and thus in the pulse width, of a monostable multivibrator. The combined circuit generates pulse widths of less than one tenth to greater than 100 seconds.

Essentially, the circuit consists of the bistable multivibrator, a transistor gate, the pulse generator, and a pulse shaper. In the bistable's normal state, transistor Q_1 is on and Q_2 off. A positive voltage thus appears at the base of the transistor gate, Q_3, forcing it on. While Q_3 is on, the pulse generator's timing capacitor C short circuits keeping the pulse generator off.

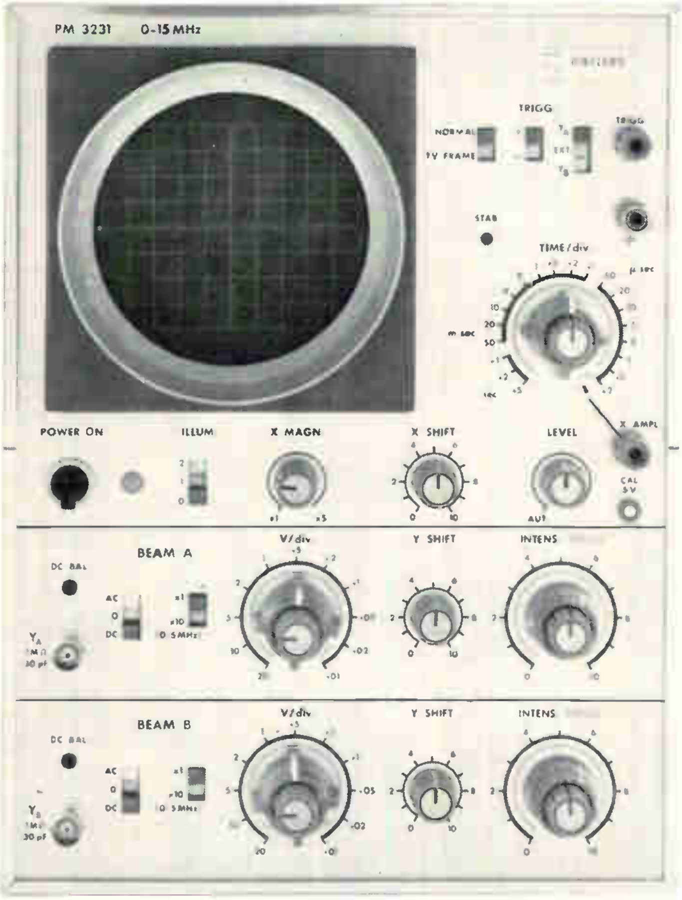
A negative trigger pulse applied to the input of the bistable multivibrator starts the action of the monostable circuit. Transistor Q_1 switches off, turning Q_2 on, which, in turn, switches Q_3 off. When Q_3 turns off, the timing capacitor starts charging through the resistor network, R, towards the 12-volt supply. The unijunction transistor fires when its critical voltage is reached. The pulse out of the unijunction is shaped by Q_6 and fed back to the bistable, which then returns to its normal state and awaits the next trigger pulse. The action of the bistable shuts off the pulse generator.

The pulse generator determines the time constant of the overall circuit. The upper limit of the time constant is determined by the combined leakage of Q_3 and timing capacitor C, and by the gain of Q_4. The time constant can be multiplied by a factor of 2 for each toggling flip-flop inserted in series between the points marked X—the output of the pulse shaper and the input to the bistable.



Variable. The wide range of time constants from the monostable circuit results from the longer period provided by the unijunction pulse generator. A negative input trigger flips the bistable circuit, which turns on the pulse generator. The output pulse is then fed back and turns off the bistable.

New 15 MHz scope: two guns, two delay lines.



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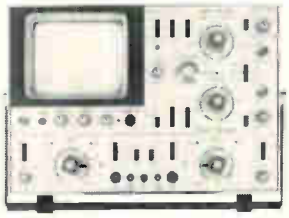

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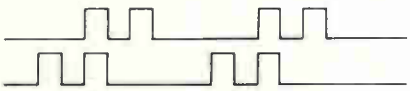

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Making small ROM's do math quickly, cheaply and easily

Albert Hemel of Communication Products Corp. shows how combining lookup-table and equivalent-function techniques with ROM's averts the need for huge single-memory capacity

● A team of techniques, some old and some new, can become the winning combination for making inexpensive and widely available ready-only memories perform mathematical functions. The three members of this team are the familiar lookup-table approach that contains all possible combinations of a given mathematical function or arithmetic operation; the inexpensive read-only memories made possible by large-scale integration technology; and the equivalent-function approach wherein a large number is represented by the sum of several smaller numbers prior to implementation of the mathematical process.

The lookup table is basic to the new technique. However, instead of trying to store the complete table in a single memory, which in some cases would require a capacity exceeding 1 million bits, several smaller, off-the-shelf ROM's are used. The combination replaces the usual mass of gates and flip-flops ordinarily used to perform mathematical functions. Furthermore, the combination is fast—the lookup table-ROM approach involves only the delay through the memory and its associated gates. The method can be used for addition, subtraction, multiplication, and division as well as for computing exponential powers and square roots.

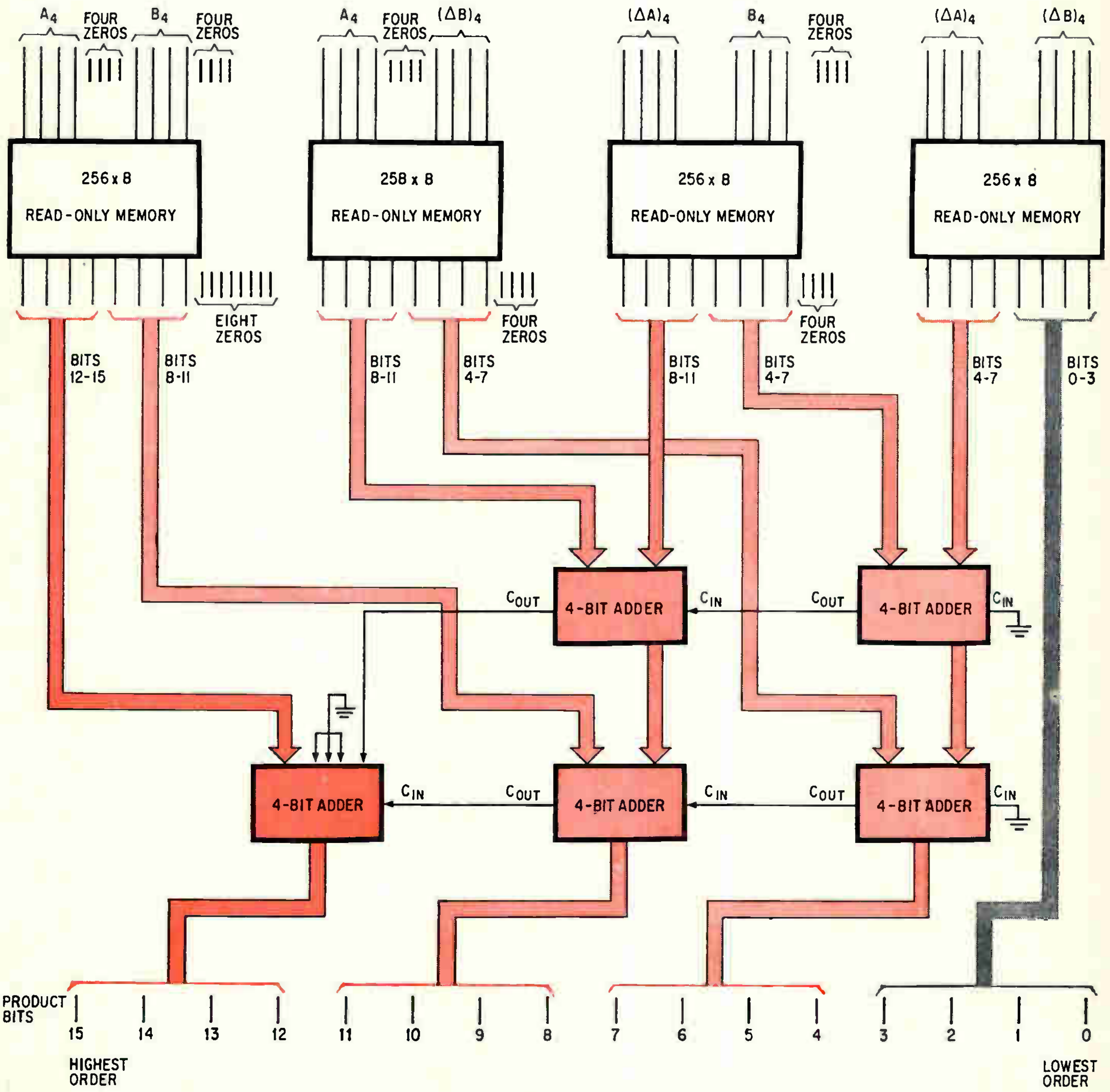
Multiplication is one of the simplest operations that can be carried out with a read-only memory. Basically, multiplication is repeated addition; that's exactly what a desk calculator does. One of the numbers to be multiplied—the multiplicand—is added to itself as many times as the other number—the multiplier—specifies. Automatic desk calculators can take certain shortcuts; the simplest is multiplying by 10 merely by shifting the multiplicand to the right one digit position. To multiply by 27, for example, instead of adding the multiplicand 27 times, the machine adds it 7 times, shifts it right, and adds it twice more. To multiply by 207 the process would be the same except that the multiplicand would be shifted two places to the right; no addition would occur after the first shift because of the 0 in the multiplier.

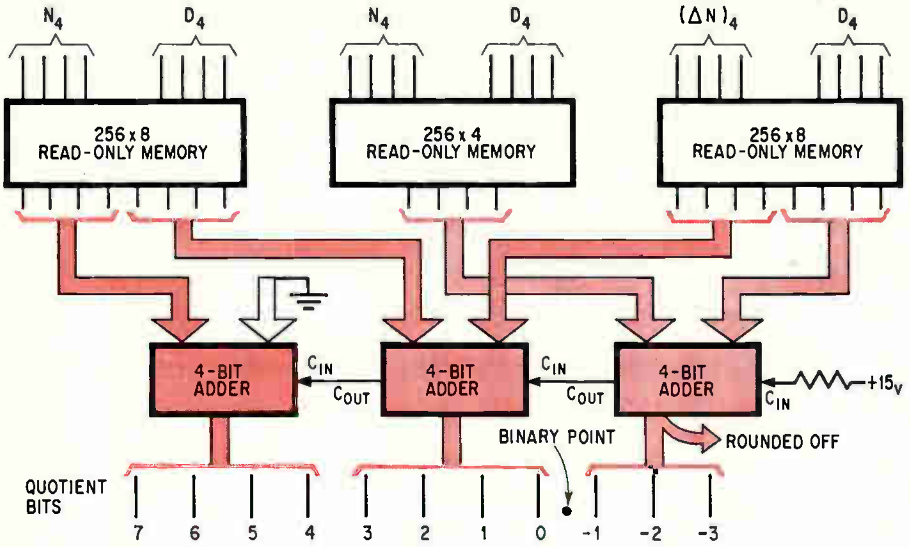
Conventional logic arrays multiply in the same way, with one important difference: since they work with numbers in binary notation, the multiplicand is never added more than once following each shift. All the multiplier's digits are either 1 or 0; an addition occurs for a 1. But another shift is made immediately for a 0. This shifting-and-adding sequence is time consuming.

In any multiplication, whether decimal or binary, the number of digits in the product equals either the sum of the number of digits in multiplier and multiplicand, or that sum less one.

Therefore in a straightforward lookup table the number of bits per word must equal twice the above sum. Suppose the table contains all possible products of two four-bit numbers. Four input lines would be required for each

Multiplier. Four read-only memories and five monolithic four-bit adders can multiply two eight-bit numbers cheaper than can conventional sequential logic. Lighter and heavier tints refer, respectively, to less and more significant bits in the result.


A4
FOUR ZEROS
B4
FOUR ZEROS
256 x 8
READ-ONLY MEMORY
EIGHT ZEROS
BITS 12-15
BITS 8-11
A4
FOUR ZEROS
(ΔB)4
258 x 8
READ-ONLY MEMORY
FOUR ZEROS
BITS 8-11
BITS 4-7
(ΔA)4
B4
FOUR ZEROS
256 x 8
READ-ONLY MEMORY
FOUR ZEROS
BITS 8-11
BITS 4-7
(ΔA)4
(ΔB)4
256 x 8
READ-ONLY MEMORY
BITS 4-7
BITS 0-3
4-BIT ADDER
COUT
CIN
4-BIT ADDER
COUT
CIN
4-BIT ADDER
CIN
COUT
4-BIT ADDER
CIN
COUT
4-BIT ADDER
CIN
PRODUCT BITS
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
HIGHEST ORDER
LOWEST ORDER



Divider. Three ROM's and three four-bit adders quickly and efficiently find the quotient of an eight-bit dividend and a four-bit divisor with accuracy out to 11 places.

number to be multiplied, or eight in all. These eight lines can carry $2^8 = 256$ different combinations of binary signals; each combination represents the address of one word in the memory. The memory's capacity would be 2,048 bits; since the product of two four-bit numbers can be as long as eight bits, the bit count in the memory would be $256 \times 8 = 2{,}048$.

This straightforward lookup table is as good as any method for performing a simple four-bit multiplication. But if the numbers are longer than four bits, the size of the memory grows very quickly. Thus, for two five-bit numbers, the word count is 1,024 and the output must be 10 bits long; total bit count is $1{,}024 \times 10 = 10{,}240$. For two six-bit numbers the total is $4{,}096 \times 12 = 49{,}152$. And for eight-bit numbers it is $65{,}536 \times 16$—more than a million bits.

No single memory with a million-bit capacity is available now, nor is one expected soon. If many small memories are interconnected to achieve this size, the cost becomes prohibitive.

But an equivalent lookup-table multiplier that works just as well as the big table can be built with much smaller memories. To design such a multiplier, represent each of the factors to be multiplied, A_8 and B_8, as the sum of two smaller numbers: one is simply the last four bits of the given number, the other is the first four bits followed by four 0's. Thus:

$$A_8 = A_4 + (\Delta A)_4$$
$$A_4 = \text{XXXX0000}$$
$$(\Delta A)_4 = \text{XXXX}$$

Each X represents a binary 0 or 1. The other factor, B_8, is subdivided the same way.

With these numbers the original multiplication can be reconstructed as the sum of several four-bit multiplications:

$$A_8B_8 = [A_4 + (\Delta A)_4][B_4 + (\Delta B)_4]$$
$$= [A_4B_4] + [A_4(\Delta B)_4] + [(\Delta B)_4B_4] + [(\Delta A)_4(\Delta B)_4]$$

These four products and their sum can be implemented in four 2,048-bit ROM's and five four-bit adders—all standard off-the-shelf items. They are manufactured by several companies, such as American Microsystems, Texas Instruments, Electronic Arrays Inc., Fairchild Semiconductor, and National Semiconductor. The multiplier shown on page 105 uses National's 256-by-8-bit MM 523, and also the Texas Instruments SN 7483 four-bit adders. Furthermore, the result appears at the outputs of the adders within one microsecond after the signals arrive at the memories' inputs.

These metal oxide semiconductor memories are used with adders built with transistor-transistor logic. This combination requires a 7.5 kilohm resistor to be connected between each memory output and a —12-volt supply. And, if TTL circuits are to drive the memories, each memory input should be connected through a pullup resistor to a +12-volt supply. In this case, every input is used twice, so the pullup resistors' value should be 3.75—half the normal value. Similar considerations to insure that the necessary current is available apply to the other designs described in this article—7.5 k ohms for inputs used only once, 3.75 k for inputs used twice, and 2.5 k for those used three times.

Each of the four memories has eight inputs and eight outputs, as in the simple example described earlier; but here the eight outputs are grouped into two sets of four. Each of these sets corresponds to one of four four-bit groupings in the 16-bit product. If the product bits are numbered 0 to 15, with bit 0 the least significant and the furthest right, the groupings in the product

. . . multiplication and division are performed economically by breaking down the factors into the sums of two smaller numbers . . .

are bits 0-3, 4-7, 8-11, and 12-15.

The trailing 0's are not connected (for the inputs A_4 and B_4) as on page 105. However, they determine which of the four-bit groupings applies to a particular memory's output. The memory whose inputs are the $(\Delta A)_4$ and $(\Delta B)_4$ isn't concerned with any trailing 0's, so its outputs contribute to bit grouping 0-3 and 4-7 in the product. None of the other memories contributes to bits 0-3, so no adder is required for this output.

Four trailing 0's are associated with the inputs, and therefore with the outputs, of the two intermediate memories. These 0's are not connected to the memory, but they correspond to bits 0-3, so that the memories' actual outputs correspond to bits 4-7 and 8-11. The three memories that have at least one delta input produce a total of three contributions to bits 4-7; these three groups are combined in two four-bit adders to produce bits 4-7 of the product.

Finally, the last memory, which has no delta inputs, has eight trailing 0's appended to its outputs—four carried through from each of the two inputs. These correspond to bits 0-7, so that the memory's outputs are associated with bits 8-11 and 12-15. Therefore there are three memories whose outputs correspond to bits 8-11; these three groups are combined in two more four-bit adders to produce bits 8-11 of the product.

The four remaining outputs of the last memory alone would make up bits 12-15 of the product, except for the possibility of a carry bit from the lower-order adders. To incorporate this carry bit into the product, the fifth adder is required; like all the others, it has two four-bit inputs and one carry input. But it doesn't utilize all of its inputs. One of the four-bit inputs takes bits 12-15 from the last memory; the input carry takes the carry output from one of the lower adders. So far, the procedure is conventional. But there's another carry from another lower adder that has to be accounted for, and no other four-bit input. So the carry is connected to the least significant of the unused inputs, and the other three are grounded to hold them to 0. This is a rather profligate use of logic, and would never be economical except where integrated circuits are used. But it's less expensive to throw in another four-bit adder than to work up a special design from the individual IC gates.

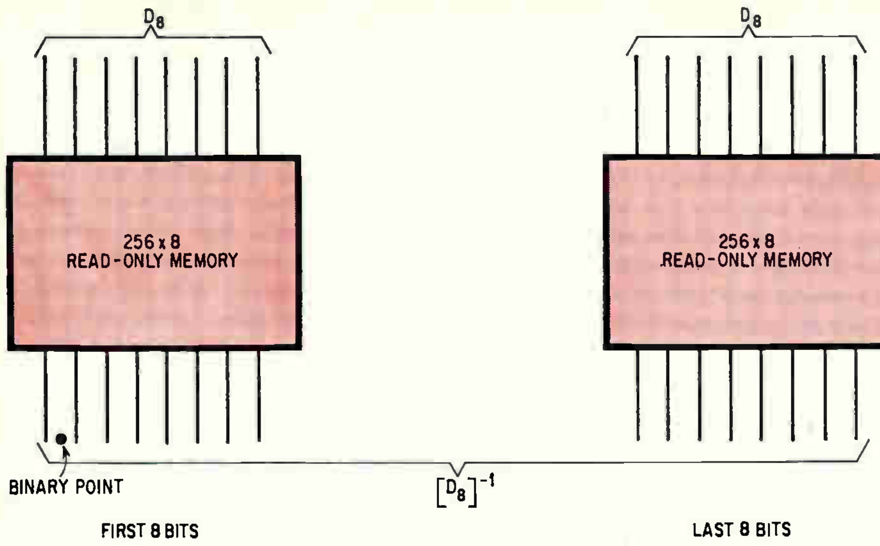
A similar approach can be applied to division. When an eight-bit number, N_8, is to be divided by a four-bit divisor, D_4, the quotient could be thought of as four bits long—division is the inverse of multiplication, and the product of two four-bit numbers has eight bits. But with no restrictions on the divisor's magnitude, a full eight bits must be allowed for the quotient—in case the divisor is 0001, for example. Furthermore, there may be a remainder. To cover this contingency, the following example is set up for an 11-bit quotient, designated Q_{11}; the choice of 11 bits will be explained later. Of these 11 bits, three are to the right of the binary point, which corresponds to the decimal point in decimal notation; these three bits thus represent a binary fraction. Mathematically, the example $Q_{11} = N_8/D_4$ may be expressed as xxxxxxxxxxx = xxxxxxxx/xxxx where the x's again represent either 1's or 0's in binary notation.

In a straightforward lookup table, the divisor and the dividend would require a total of 12 inputs, and the memory would contain $2^{12} = 4{,}096$ words of 11 bits each, or a total of 45,056 bits.

But if the 8-bit numerator is subdivided in the same way as the numbers in the multiplication example, the problem may be restated

$$Q_{11} = \frac{[N_4 + (\Delta N)_4]}{D_4} = \frac{N_4}{D_4} + \frac{(\Delta N)_4}{D_4}$$

where N_4 and $(\Delta N)_4$ are defined in the same way as



Inverter. With a large divisor, it may be easier to multiply the reciprocal than to divide directly. Reciprocals can be easily obtained directly from two ROM's.

the representations they correspond to in the multiplication example. Each of the two subsidiary quotients can be implemented with a 256-word ROM, but there's a catch that isn't found in multiplication.

In general, both quotients may have remainders that cannot be completely specified in a binary fraction 11 bits long—just as the fraction 3/32 cannot be completely specified in three decimal places. When the quotients are added together to make Q_{11}, since both of them may have been rounded off, they may create a cumulative error that makes the last bit position in the sum incorrect. To compensate, therefore, the two subsidiary quotients are implemented with an extra fractional bit—a fourth bit to the right of the binary point instead of three. Then, the lowest-order of these four bits is discarded at the output of the adder to provide the desired 11-bit accuracy.

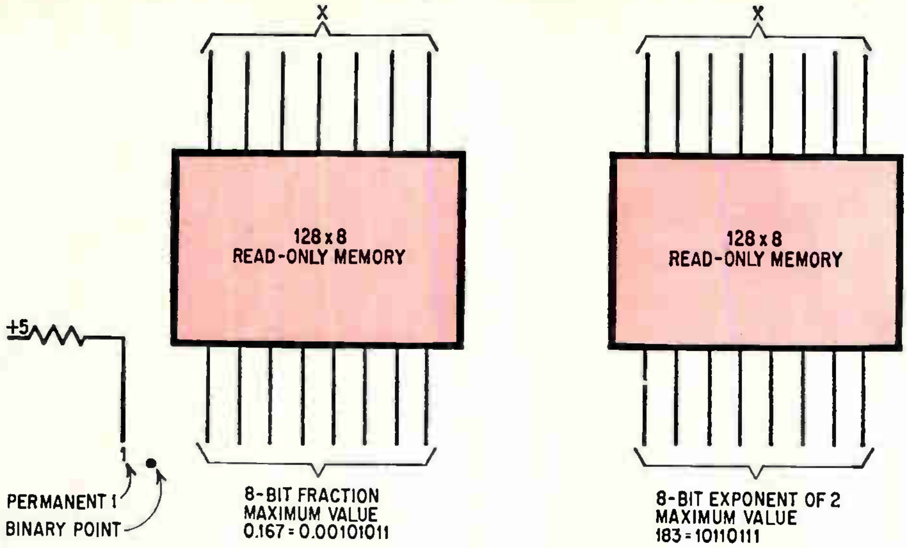
Thus the N_4/D_4 portion of the final quotient can be implemented with a read-only memory of 256 words of 12 bits each. As shown on page 106, this is easily accomplished by using standard memories of eight-bit and four-bit word lengths connected in parallel. Typical ROM's such as National's MM523 can be used for the eight-bit word lengths, and the MM521 for the four-bit word. And just one additional eight-bit memory can be used for the N_4/D_4 portion. Since this N_4 dividend consists of only four bits, the necessary accuracy, four places to the right of the binary point, is attained with only eight bits. The total is 5,120 bits with this technique, compared to 45,056 for the straightforward approach.

The 20 outputs from the three memories are combined in three four-bit adders in much the same way as was done in multiplication. One of the adders handles the four fractional bits and another the four low-order bits to the left of the binary point. A third adder is necessary for the four highest-order bits; it serves the same purpose as the fifth adder did in multiplication—to handle the effect of a carry from the other adders into these bits.

Ordinarily, when several small adders are used for summing large numbers, as in this example, the input carry to the least significant adder is held at zero with a ground connection; such a connection is shown in the diagram for multiplication, and also could be used in the division example. But in division, the lowest order bit is included only to prevent a cumulative rounding error, and is discarded in the final quotient. One convenient rule that can be applied to binary rounding is to add 1 to the lowest-order bit that is retained if the highest-order discarded bit is 1; this corresponds to the decimal rule to add 1 to the last digit if the highest-order discarded digit is five or more. This upward rounding can be insured by connecting the lowest input carry to a positive voltage, or leaving it disconnected, rather than grounding it. Either alternative holds the carry to a 1.

When the denominator is large, multiplying by the divisor's reciprocal may be easier than dividing directly. Finding the reciprocal of a binary number is not the same as complementing; it is the result of dividing the number into unity, and in general it will have a large remainder. Consequently, for accuracy, the reciprocal should have more bits than the original number. The diagram above illustrates in a general way how an eight-bit denominator is inverted using two 256-word-by-eight bit ROM's to produce a reciprocal value that's accurate to 16 binary places. When inverting larger numbers, whose leading bit is always 1, the reciprocal's leading bits are always 0. Then one of the two memories can be made smaller or eliminated altogether.

The four-bit adders used in the multiplication and division schemes, as well as subtractors, may themselves be implemented with read-only memories. The two operations are identical, except that in subtraction, one of



Exponential. Two ROM's can generate values of exponential functions over a wide range. One gives the fractional value, or mantissa—a characteristic of 1 always is used—and the other yields the exponent in a floating-point notation referred to the base 2.

the numbers involved is complemented before beginning the operation—its complement is used as part of the ROM address. However, there is little advantage in using ROM's, since integrated-circuit adders are readily available at low cost. But it's interesting to note some of the peculiarities that occur when addition is performed with this scheme.

It appears that an addition lookup table, containing the sums of pairs of four-bit numbers, would have the same number of entries—the same number of ROM words—as a table containing the products of such pairs. But this is not so. The adder table must allow for an input carry.

Thus a total number of nine input bits is needed for a four-bit adder—four for each 4-bit number and one for the carry. These nine bits address $2^9 = 512$ words, compared to 256 in the multiplication table. The greater number of words is partially offset by the fact that the sum contains no more than five bits, including an output carry. Thus the total number of bits in a ROM serving as a four-bit adder is $512 \times 5 = 2{,}560$, compared with the four-bit multiplier's 2,048 bits.

But just as in multiplication and division, the equivalent-function approach can simplify the adder design. For example, if a four-bit addition is considered as two two-bit additions, each with its own input carry, then the total number of input bits to each adder is five. This requires only $2^5 = 32$ words of three bits each, including an output carry, for each adder. The two adders then would require 64 words, and the output carry of one could be connected directly to the other's input carry. These 64 words thus could be packaged in a single unit containing only 192 bits, which is much less than the earlier 2,560 bits.

Raising values to an exponential power also works out quite conveniently with ROM's. Because the exponential function is one of the more rapidly increasing functions—exceeded among common functions only by the factorial—the outputs of a ROM containing values of the exponential should be expressed in floating-point notation—for example, ϵ^{10} expressed in floating-point notation is 2.2026×10^4, instead of 22,026.

However, floating-point notation need not be in the conventional power-of-10 format. In binary notation, powers of two are more convenient; the above example in binary is thus

$$\epsilon^{1010} = 101011000001010$$
$$= 1.01011000001010 \times 2^{14}$$
$$= 1.01011000 \times 2^{1110}$$

Here the exponent of ϵ is 10 in binary form; its value is expressed in binary form as a 15-bit number. This is finally expressed in base-2 floating-point notation as 1 followed by a 14-bit binary fraction, multiplied by 2^{14}. This fraction is shown above with the exponent in both a decimal and true binary floating-point format. In the latter, the fraction is rounded off to eight binary places.

Base-2 floating-point notation has two major advantages: it need not be reconverted into binary form for use in a system containing the function table, and its most significant bit is always 1. The latter permits this bit to be "free"—wired permanently outside the memory, rather than stored in it.

An exponential-function table containing values of ϵ^x, where x is accurate to seven bits, can be stored in two ROM's, each containing 128 words of eight bits each, as shown above. One of the memories, which could be National's MM 522 or equivalent, would produce the fractional part of the exponential value accurate to eight bits; the other would produce the exponent part of the function expressed in floating-point form. The input ranges from ϵ^0 to ϵ^{127} and the output from 1 to 1.167 $\times$

2^{183} or, in binary, to $1.00101011 \times 2^{10110111}$.

Such numbers aren't often encountered in practical applications. A more useful implementation might permit the 128 input values to range for example, from 0 to 63.5 in 0.5 steps; or to 31.75 in 0.25 steps; or to 7.9375 in 0.0625 steps, with successively higher resolution, depending on the position of the binary point. These correspond respectively to maximum output values of 1.528×2^{91}, 1.748×2^{45}, 1.870×2^{22}, and 1.368×2^{11}. In binary notation these are, respectively

$$1.10000111 \times 2^{1011011}$$

$$1.10111111 \times 2^{101101}$$

$$1.11011110 \times 2^{10110}$$

$$1.01011110 \times 2^{1011}$$

Any one of these versions would use the 128-word-by-eight-bit ROM for the binary fraction and a 128-word memory with a word length of four to seven bits for the exponent.

If an exponential function with both a wide range and high resolution is required, seven bits may not be sufficient for the input. This presents the same problem encountered in setting up a multiplication table for the product of two eight-bit numbers—it requires a much larger ROM than is practical.

But the solution to this problem is similar to that for multiplication—the exponent is divided into two parts

$$\epsilon^{x} = \epsilon^{(y + \Delta y)} = (\epsilon^{y})(\epsilon^{\Delta y})$$

where, in the same manner as before, y contains all the higher-order bits of x followed by a string of 0's, and Δy contains the low-order bits of x. The two individual exponential functions are generated with two ROM's each. When the two exponential functions found in this way are combined, their bases, including the permanent high-order 1, are multiplied, and their exponents are added.

An exponential function of a constant other than ϵ can be obtained in the same way; it requires only that the read-only memories be programed with the proper values. But if the base of the exponential function is itself a variable, a very simple process is available for calculating its value. The process is based on the equivalence

$$A^{x} = 2^{x(\log_2 A)}$$

This equivalence holds true, of course, for any logarithmic base, including ϵ and 10; but 2 is used because it permits multiplication by a power of two by merely shifting the binary point, analogous to multiplication by a power of 10 in decimal notation.

The process requires that six ROM's be used—one to provide $\log_2 A$, four to multiply this log by x, and one to provide one of two subdivisions of $x(\log_2 A)$. These two subdivisions, in general, can be an integer part N and a fraction part F. With these subdivisions, the above equivalence equation becomes

$$A^{x} = 2^{x(\log_2 A)} = 2^{(N + F)} = (2^{N})(2^{F})$$

In this product, the number 2^{F} can be obtained from the sixth ROM, and the factor 2^{N} represents a shift of the binary point N places to the right.

For example, suppose A = 7 and x = 3. The value of $7^3 = 343$, but in terms of the equivalence, the steps are

$$7^3 = 2^{3(\log_2 7)} = 2^{3(2.807)} = 2^{8.421} = 2^{8})(2^{0.421})$$

These are expressed in decimal notation for clarity; but in practice, of course, they would be in binary. The factor $2^{0.421} = 2^{0.0110110} = 1.01010111$; the factor 2^8 calls for the binary point to shift 8 places to the right, giving 101010111, which is equivalent to 343 in decimal notation.

For extracting square roots or higher roots, these combinational techniques won't work; there is no easy way to subdivide a large number into two parts, find the square root of each part, and then recombine the results. There are two complicated ways to go about it; one based on the binomial theorem; the other based on the Taylor series. But both are of limited value in practical applications.

However, the reverse process of finding the square or other fixed power of a number is quite easy with the ROM technique. The squares of all eight-bit numbers contain a maximum of 16 bits, which can be stored in a ROM of 256 words by 16 bits, yielding a total bit count of 4,096.

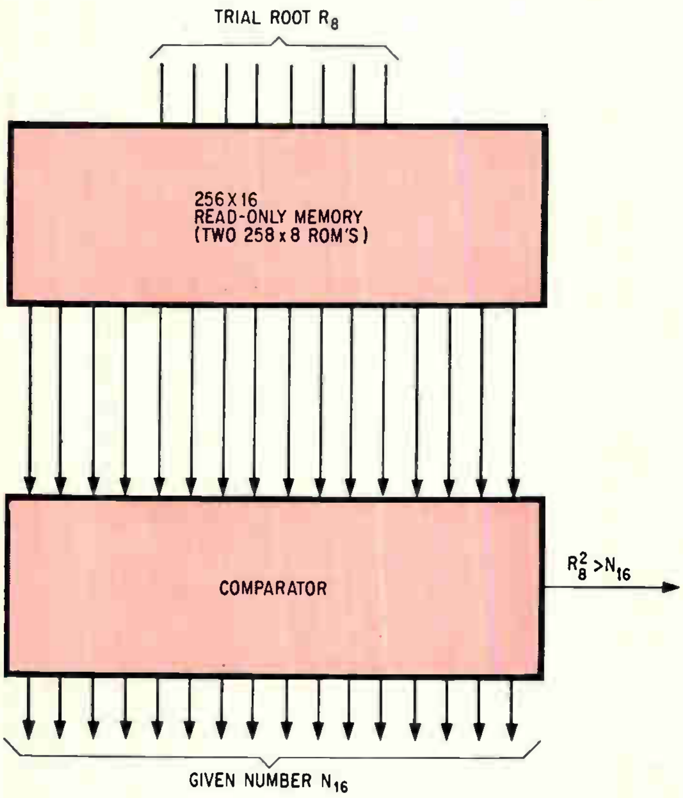
The ease of the method points the way to an iterative search technique for calculating square roots by trial and correction. The iterative search for the eight bit root, R_8, of a given 16-bit number, N_{16}, begins with using a trial root of $R_8 = 0$ as the address to the ROM storing all the squares. This trial root is then successively increased until the memory produces a number equal to or greater than the given number N_{16}; that trial root is the true root.

This process is fastest, on the average, if the most significant bit of the trial root is changed first from 0 to 1. If the output of the memory then exceeds the given number N_{16}, the most significant bit returns to 0; otherwise, it remains at 1. The same procedure then is used with the other bits of R_8. The circuits to control this sequence of trial roots and to compare the memory's successive outputs with the given number N_{16} can be made from standard IC flip-flops and comparators.

A rounding error often will occur if the ROM stores the squares of the trial roots R_8. Suppose, for example, the number whose root to be found is 280—in 16-position binary, this is 0000 0001 0001 1000. The successive eight-bit trial roots for this 16-bit number are 1000 0000; 0100 0000; 0010 0000; 0001 0000; 0001 1000; 0001 0100; 0001 0010; 0001 0001; in decimal they would be stated 128, 64, 32, 16, 24, 20, 18, 17. The squares of each of the first three trial roots are greater than 280; but the square of 16 is only 256. So the 1 is retained in the fourth position and 1's are tried in successively less significant positions until the last, corresponding to 17. This result is correct in this case, because the actual square root of 280 is 16.7332, correctly rounded off to 17. But if the number whose root was to calculated were 270, the same successive trial roots would be used. The result, however, would be incorrectly rounded off because the actual square root of 270 is 16.4317. This should be rounded off to 16.

To avoid this rounding error, the ROM can be programed to store $(R_8 - \frac{1}{2})^2$ instead of R_8^2. These two numbers differ by $(R_8 - \frac{1}{4})$ but the former differs from $(R_8 - 1)^2$ by $(R_8 - \frac{3}{4})$. Thus the memory's output will always be closer to the true square of R_8 than to the square of $(R_8 - 1)$. Using the same method of successive approximations, with an $(R_8 - \frac{1}{2})^2$ ROM, as was described above for an R_8^2 ROM, $(280)^{\frac{1}{2}}$ will be found to be 17 and $(270)^{\frac{1}{2}}$ will be 16.

An alternative procedure that would work just as well would be to begin with the largest possible trial root, 1111111, and change successive bits to 0 beginning at the most significant bit until the memory's output is less than the given number. With this alternative procedure, the memory should store $(R_8 + \frac{1}{2})^2$ to prevent the rounding error. ●



Extractor. This scheme for obtaining square roots depends primarily on squaring a series of trial roots using a small ROM until a number is found that comes sufficiently close to the original number.

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New MOS technique points way to junctionless devices

Semiconductor's substrate handles data for memory and display; simple device construction promises increased capacity, reduced size and eventual low cost, reports Electronics' *Laurence Altman*

● Increased circuit complexity and simplified fabrication techniques are the goals pursued by designers of integrated circuits. And in line with these goals, the design trend in recent years has been toward metal oxide semiconductor construction because it requires fewer fabrication steps and permits more elements on a chip than does bipolar technology. Now a new MOS class of devices, developed by Bell Laboratories in Murray Hill, N.J., offers even higher density than conventional MOS—up to 200,000 elements per square inch. Called charge-coupled devices (CCD), they are simpler to fabricate than conventional MOS; they do not require p- or n-type diffusions to process information since circuit functions are performed directly in the semiconductor itself.

CCD's can provide memory, logic, delay line, and imaging functions. The inventors, W.S. Boyle and G.E. Smith, say CCD technology is so new that it's difficult to predict its impact. But the device's higher bit density, more reliable operation, and potentially lower cost could change the face of MOS technology.

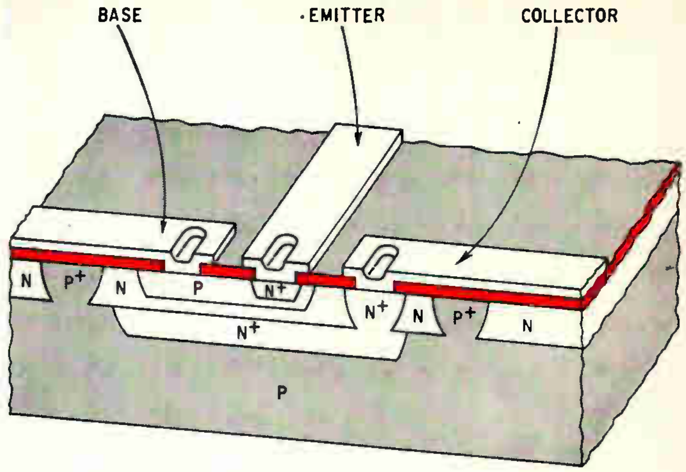
Stated most directly, the charge-coupled devices create and store minority carriers or their absence in potential wells—spacially defined regions where depletion is momentarily deepened—at the interface of a homogeneous semiconductor and oxide insulator. Once stored, the charges coupled to the potential well can be moved over the surface of the semiconductor simply by moving the potential well. The process of injecting a charge into a semiconductor, transferring it via potential wells along the surface of the semiconductor, and then detecting it or its absence at some other location at some later time forms the basis of the circuit operations. And this entire operation could be done without windows in the semiconductor—no p-n junctions, no difficult diffusions, and fewer etchings. Any suitable semiconductor-insulator system will work.

The device operates as an array of MOS capacitors by passing an injected charge from one capacitor to another. A d-c biasing potential is applied to the metal electrode of the MOS capacitor, forming a uniform depletion layer at the semiconductor-insulator interface. A storage voltage greater than the bias voltage is then applied to the electrode of the capacitor to form a potential well at that location. When minority carriers or holes are introduced into the silicon substrate—say, from a light image incident on the bottom of the substrate—these holes will collect in this potential well at the semiconductor surface. This charge may be transfered to an adjacent capacitor by applying a transfer voltage such that a still deeper potential well is formed at that location. After the transfer, the voltage on the first capacitor is returned to the d-c biasing potential and the voltage on the second reduced to the storage voltage. This process can now be repeated to move the charge over the surface of the device.

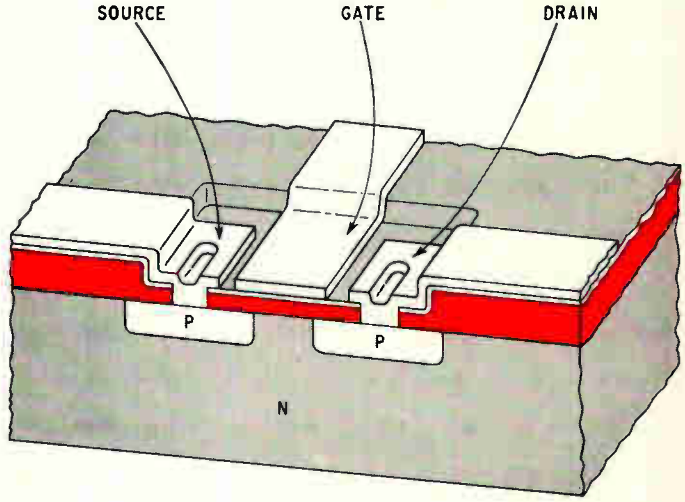
Detection can be accomplished without junctions in a number of ways, for example, by sensing the capacitance change due to the presence or absence of charge.

Moving carriers on the surface of a semiconductor leads immediately to shift register applications. Since the time for transfer of charge is less than a microsecond, shift registers at better than megahertz rates are possible. In addition, storage is possible because once a potential well is formed there is a fairly long time constant (in seconds) before it fills up with minority carriers that are thermally generated in the semiconductor substrate.

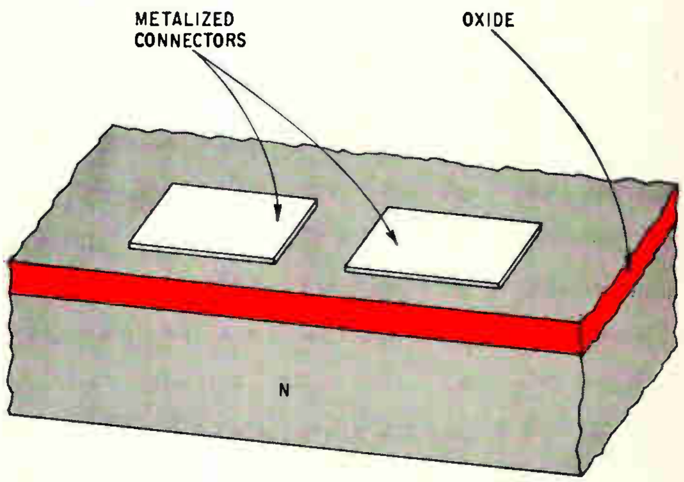
Imaging devices can be made by depositing a two-dimensional array of electrodes on the oxide insulator. Under suitable voltages this array forms a corresponding array of potential wells. When an image is projected on the underside of the semiconductor—the target area—the holes created by the light will diffuse toward the electrode side of the device. There, they can be stored in the potential wells created by the negatively charged electrodes. The image can then be read out by the shift-register action. This aspect of the technology is currently being pursued by a group of Bell Laboratory scientists including G. F. Amelio and M. F. Tompset who are actively exploring the potential of CCD devices for video applications.



BIPOLAR ELEMENT

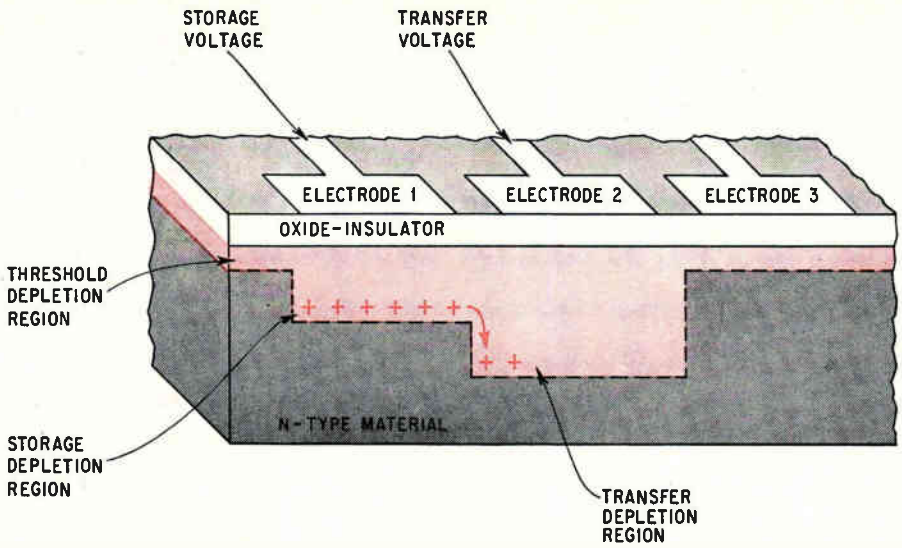


MOS ELEMENT



CCD ELEMENT

It's simple. Devices should be cheaper with CCD construction. A bipolar transistor requires about 16 diffusions, photoetchings and oxidations. MOS elements provide some simplification, requiring about eight steps. CCD's on the other hand should need less processing than standard MOS.



Essentially a three-layered structure, CCD construction, based on standard MOS techniques, is remarkably simple. Oxidizing the surface of a semiconductor wafer forms a thin insulator, on which is deposited a metal pattern of conductors and electrodes. A thicker oxide layer may be required under the conductor to prevent depletion layers from forming under the beam lead connections running to the electrode pattern.

Compare this to standard bipolar and MOS technology. A bipolar transistor circuit used in a shift register needs about 16 fabricating steps, including several critical p- and n-type diffusions. An insulated-gate field effect transistor (IG FET) for the same memory, constructed by MOS techniques, takes at least eight processing steps, two of which are critical impurity diffusions. And this is in addition to source, gate and drain contacts. Thus, by comparison with the steps required for bipolar and conventional MOS devices, the simple CCD structure could reduce fabrication by a factor of 2 and 4 respectively, leading to lower fabrication cost per unit area.

But lower construction costs are not the whole story—with CCD's there's a dramatic reduction in size compared to transistor shift registers. This leads to a significant increase in information handling capability (bit density) for a given chip size. A typical IG FET dynamic shift register requires 20 square mils per bit—six FET's are generally needed to process one bit of information. In comparison, using the same photolithographic specifications, the new CCD's could require as little as 2.5 square mils of substrate real estate to process one bit. This factor of almost 10 will show up as a considerable cost saving if CCD's are used in place of FET's.

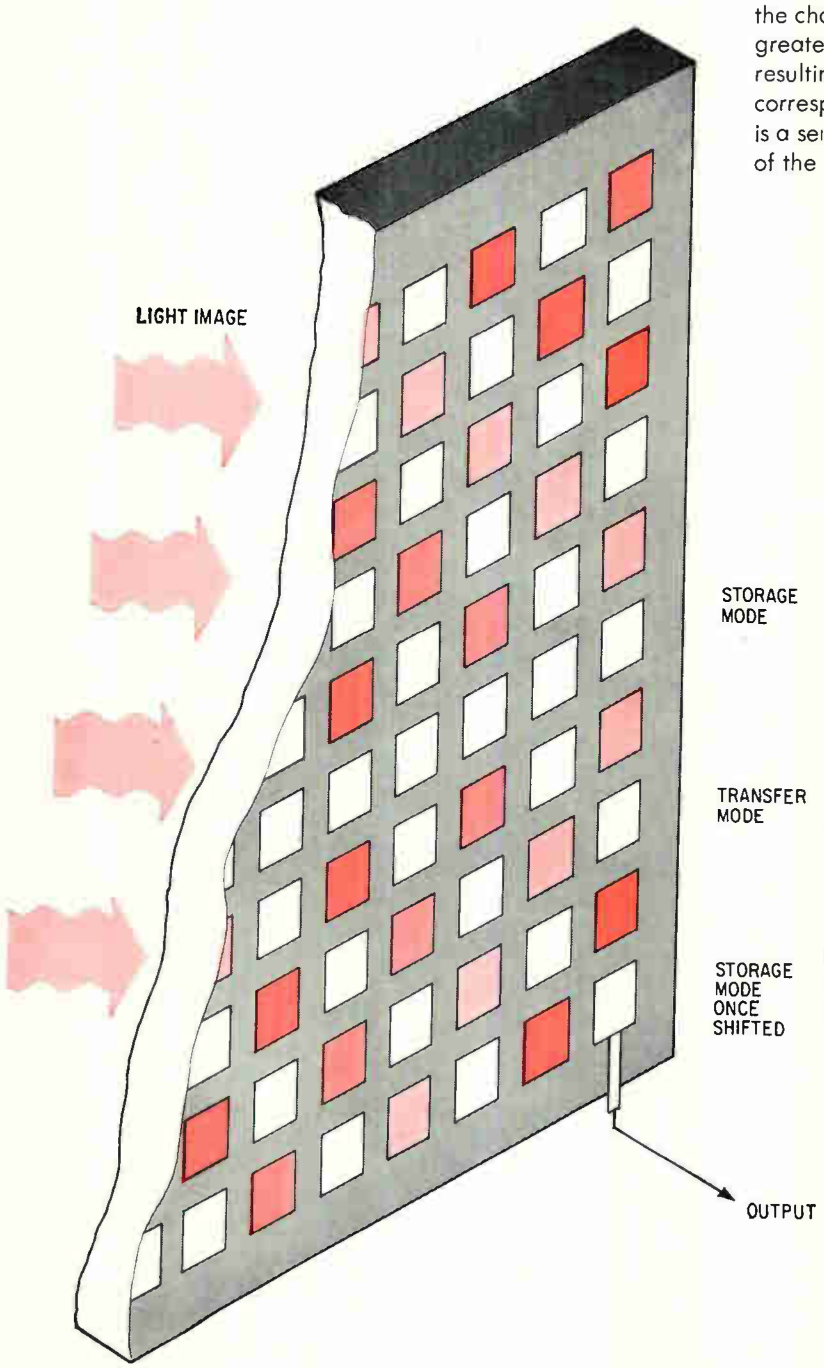
Alternately, a given chip can process ten times the information using CCD methods. When one realizes that on a one-square-inch chip of silicon at least 200,000 bits of information can be handled, with room left over for associated circuitry, the potential of this new technology becomes apparent just for memory applications alone.

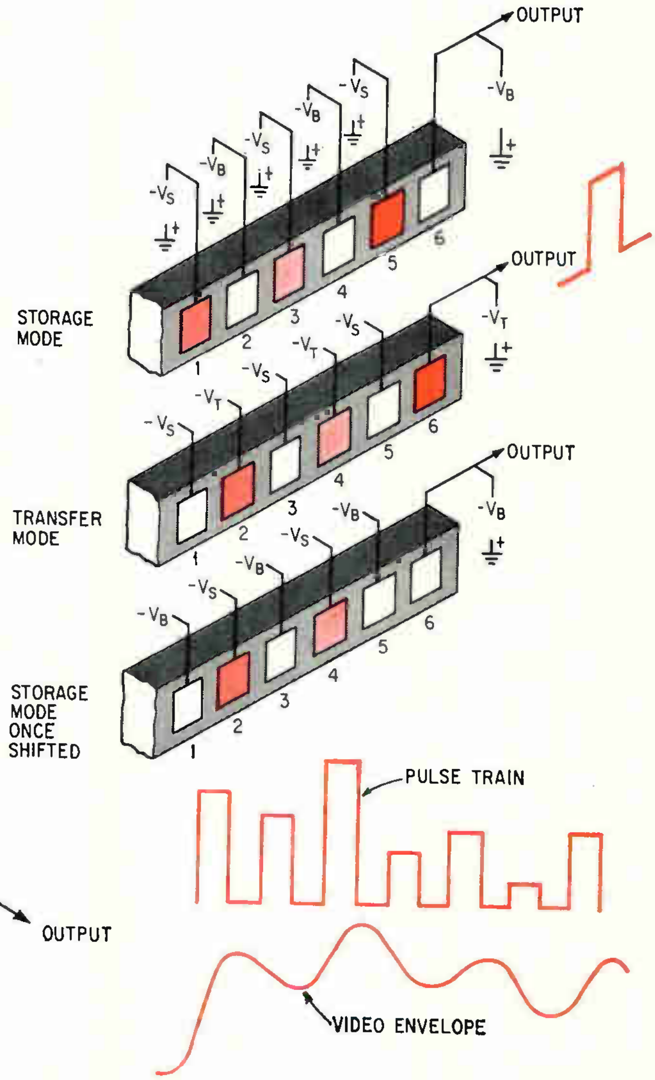
But the ramifications of this new MOS technique go deeper than the immediate advantages of size, cost, and capacity. There also is a great advantage in the flexibility of material that could be used. Up to now, many materials other than silicon that exhibit special desirable properties have been largely ignored because p- or n-type diffusions were difficult with them. Now these materials could be considered in charge-coupled devices. Materials with high bandgap energies and high mobility, and which are compatible with other insulating layers, could be utilized for their special properties. Thus far only silicon has been tried by Bell in their experimental devices. But if, for example, a longer storage time were desirable, a larger bandgap material could be used in order to reduce the thermally generated currents which flow into the depletion region.

Bell's early work with their CCD's—n-type silicon-silicon dioxide structures—uses typical MOS device parameters. The oxide thickness was 1200 Angstroms and the substrate had a resistivity of 10 ohms-centimeters. With CCD's, efficient transportation of charge along the oxide-silicon interface requires an interface free of defects to avoid undesirable surface states. But these interface criteria are roughly the same as those required by IG FET's and thus are reasonably well characterized.

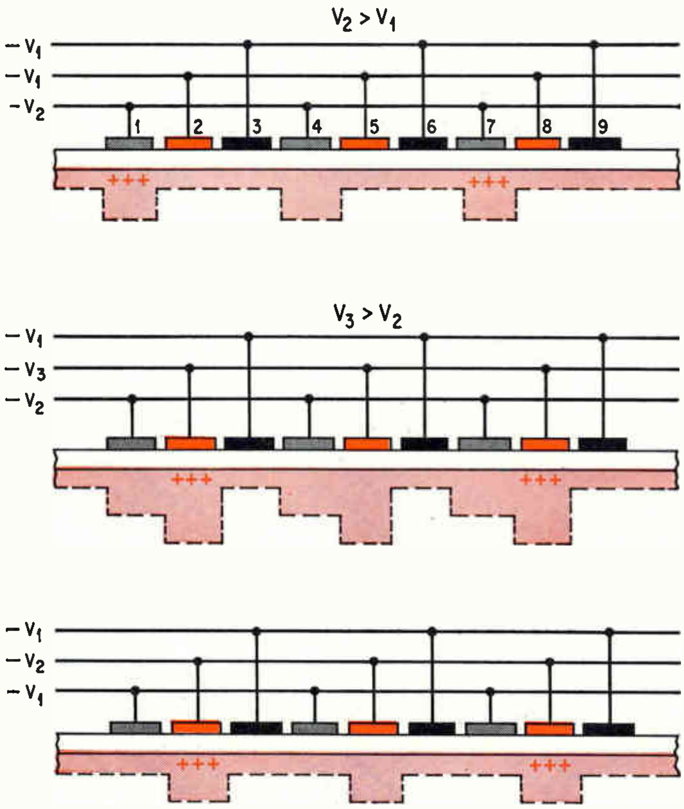
The operation of the device can be illustrated by considing just two electrodes on the oxide. A negative bias voltage applied across the n-type substrate must be greater than the threshold voltage required to form a uniform depletion region at the substrate-insulator

The movement. Charges are moved between electrodes 1 and 2 by applying a transfer voltage larger than the storage voltage to the receiving electrode. Both storage and transfer voltages must be larger than the threshold voltage necessary to cause depletion.





Good display. A two-dimensional array of electrodes on a CCD structure forms a configuration suitable for imaging. In the storage mode, the quantity of charge accumulating at each storage electrode (shown in varying shades of tint) corresponds to the intensity of the image incident on the substrate. The storage voltage, V_s, greater than bias voltage, V_b, forms the potential wells that trap the charge. In the transfer mode, a transfer voltage, V_t greater than V_s shifts the charge one space, resulting in a pulse at the output whose amplitude corresponds to the quantity of the charge. Hence, the output is a series of pulses whose envelope is the video analog of the image.



Phase three. Storage conditions are set up (top) by applying a storage voltage, $-V_2$ to every fourth of a series of electrodes. The potential wells that form at these points hold the charge. The charge or its absence is transferred to adjacent electrodes (middle) by applying a transfer voltage, V_3, to those electrodes. With the charges transferred, (bottom) initial conditions are once again restored.

interface. Applying a more negative voltage (storage voltage) to electrode 1 creates a still larger negative region in the substrate directly under that electrode. This deeper depletion region at that point spatially defines the potential well. This is the storage mode of the device; it can now receive and store charges (minority carriers) created in the semiconductor from a suitable source. Since minority carriers in n-type silicon are holes—which are positively charged—and since the electrode is negative with respect to the substrate, these positively-charged holes are attracted towards the negative electrode and held in the potential well under that electrode.

The transfer mode—the next operation—creates a condition that moves the charge to the second adjacent electrode. This movement is accomplished by applying a still more negative voltage (the transfer voltage) to electrode 2, digging a still deeper potential well under that electrode. Now the holes being stored under electrode 1, attracted to the deeper well, transfer to the new electrode.

Initial storage conditions are regained by removing the storage voltage on electrode 1 and reducing the transfer voltage on electrode 2 to the storage voltage. Once the charges are stored under electrode 2, the transfer process can be repeated on another adjacent electrode until the charges are moved across the substrate. Thus, with just two voltages, charges can be transfered from point to point across the device.

In actual tranfer operation, voltages would be applied to an equally spaced array of conductors. To minimize connections, every third electrode is connected to a common conductor as shown in the composite figure on the left. Initially, a storage voltage, $-V_2$, is applied to one series of electrodes, say 1, 4, 7, etc., (top), and a smaller bias voltage, $-V_1$, is applied to the other electrodes. The only restriction here is that all applied voltages be greater than the threshold voltage required for depletion.

The voltage $-V_2$ forms potential wells under electrodes 1, 4, 7, etc. Thus charges injected into the semiconductor are attracted to those regions. Consider that the injection is accomplished in such a manner that charges are placed under electrodes 1 and 7 and none under electrode 4.

In the next stage of operation a transfer voltage, $-V_3$ ($V_3 > V_2$) is applied to the next series of electrodes 2, 5, 8, etc., (middle). Because the potential wells will be greater under those electrodes, charges under electrodes 1 and 7 and the absence of charge under electrode 4 will shift one place. Then initial storage conditions are re-established (bottom) by reducing $-V_3$ to the storage potential $-V_2$, and by reducing the voltage on the other electrodes to $-V_1$. In this manner charges or their absence can be transferred along the device and circuit functions performed.

In any operational sequence the transfer voltages must be applied and manipulated in a time shorter than the storage time of a potential well. After that time minority carriers thermally generated in the semiconductor will begin to move into the wells. This storage time is approximately the ratio of charge, Q, to the thermally generated current, I_d, required to supply the equilibrium charge density Q, or $t_o = Q/I_d$. The thermal current, which results from generation-recombination centers in the depletion region at the semiconductor-insulator interface, is small enough in most semiconductors so that t_o is large and no time restriction results in practice. In fact, storage times in the order of seconds can be achieved, whereas transfer-voltage clock rates are in megahertz for typical applications.

After transfer, detection of the charge or its absence must be made. Two methods are available: change of capacitance as a function of stored charge, and change of electrode-surface potential with charge.

In the devices built and tested by Bell, both detection methods—capacitance and potential—offered equally attractive results. As detailed in two papers appearing in the April, 1970 Bell System Technical Journal, these parameters, as well as depletion-layer changes, were measured as a function of the fraction of charge transfered to the total charge available. For 100% transfer, the capacitance changed at each electrode by a factor of approximately 3, the potential by a factor of 8, and the depletion depth by a factor of 5. Since these quantities are strong functions of charge transfer, the most convenient one could be used. In these tests, transfer voltages (gate voltages) of approximately 10 volts were used, a level readily attainable from silicon technology.

A knowledge of the surface potential is also required to design a structure that insures complete transfer of charge, since as charge flow from one electrode to another, the potential drops on the receiving electrode and rises on the other. To insure that charge will not flow back, the applied voltages on any two adjacent electrodes must therefore be chosen so that the potential of the one giving up the charge must always be lower than the electrode receiving the charge.

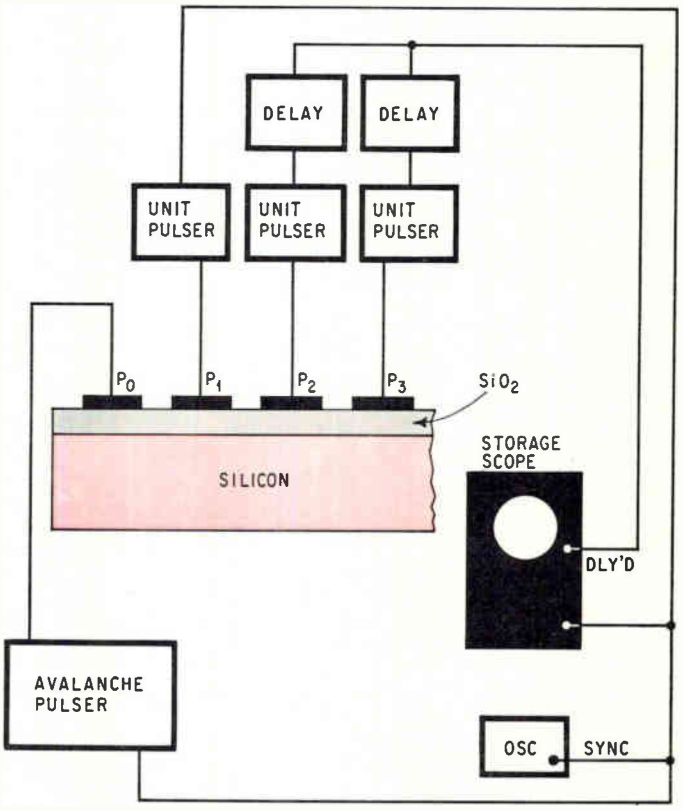
But regardless of the method used to detect the charge at each electrode, two interrelated quantities—the transfer time and transfer efficiency—are crucial in the operation of the device. The transfer time is the time for charge to make the trip between adjacent electrodes, while the efficiency is the fraction of charge transfered. In Bell's tests the charge-transfer efficiency has been found to be as high as 98%, and this quantity is the only limit on the number of transfers before the train of pulses must be regenerated.

This small amount of residual charge will add to subsequent signals and hence degrade the output. The charge is left behind because of trapping surface states whose time constant (time to empty) is comparable to the clock period (time to transfer). At present the entire subject of surface states and its affect on charge transfer are not well understood and must await future exploration. In any case the high efficiency of charge transfer in CCD's minimizes the problem of residual charge.

The circulation of charges between electrodes in an array forms the basis of all applications. A shift register can readily be constructed with the addition of a charge generator at the input and a detector at the output. Several methods of generation are possible: forward biased p-type diffusion in the n-silicon, surface avalanching in an MOS structure, or radiation-induced electron-hole pair creation are examples. Detection circuits could use a reverse biased p-n junction or Schottky barrier diodes.

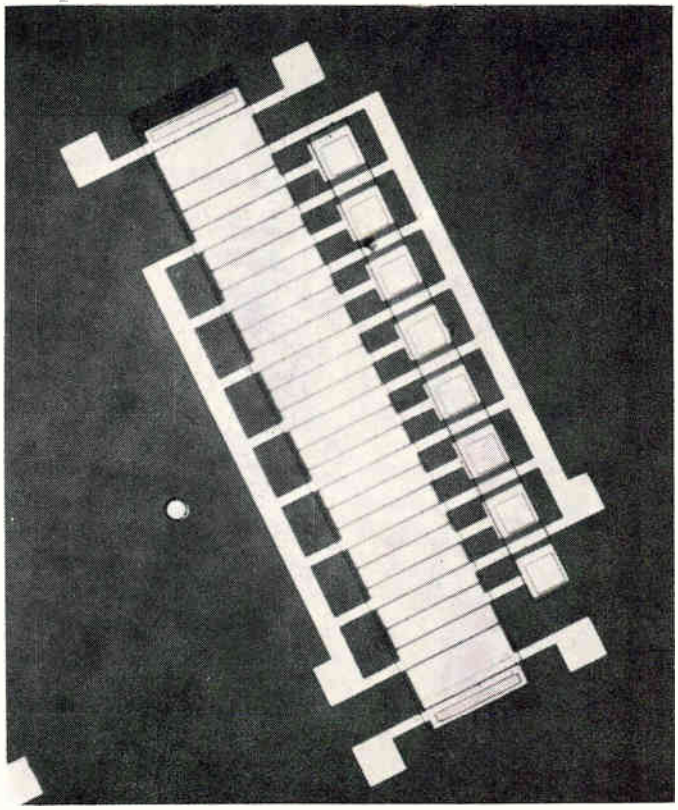
The CCD shift registers can be used in any application where the conventional MOS shift register is now used—in computers, as logic and memory circuits, as

Testing. Bell evaluated CCD's by using an avalanche pulsing capacitor, P_o, which supplies holes to the other electrode capacitors along the line. As each MOS unit capacitor is pulsed by the supply generators, a charging and discharging spike is observed at the oscilloscope, which is proportional to the charge flow.



switching and holding circuits in high-capacity communication systems, as gates for relays in any number of applications. But CCD's are far more versatile than conventional MOS shift registers. Not only is a factor of ten size reduction available, or a factor of ten increase in bit density, but the output signal—a series of pulses whose separation in time corresponds to the spacial separation of the storage electrodes in the array—can readily be put back into the device and recirculated. This storage facility allows the same pulse train to be further manipulated at a later time. For example, it can be compared with another train of pulses for coding, or for delay gate circuits.

Major shifts. Bell's experimental 24-electrode, 8-bit dynamic shift register, using a new simplifier MOS charge-coupled technology, forms the basis of all applications. It can be used to construct a recirculating memory or a variable delay line. When its electrodes are arranged in a two-dimensional array, it can perform image and display functions, thus promising video applications.



This manipulation and recirculation also provides the essential elements of a digital delay line, where total delay times up to the storage-time constant (in seconds) are available. Moreover, the delay time is variable; by changing the clock rate on the transfer voltages, charge can be transfered between electrodes at a higher or lower rate. Thus, one device only fractions of an inch in area could produce variable delay times from microseconds up to hundreds of milliseconds or longer simply by changing the clock frequency. This variable delay-line capability could make the new CCD a strong competitor to the recently developed but more complex acoustic surface-wave technology.

However, depending on the transfer efficiency, there is an upper limit on the length of the line before regeneration is required. But once regenerated, the signal is available to drive another circuit, or it can be recirculated to another line on the same chip, or recirculated and stored in the same line to be used later. This forms the building block from which arbitrarily large shift registers can be made.

Besides shift register devices, Bell is very interested in developing charge-coupled image and display devices. This is particularly attractive to Bell for possible application in Picturephone since the CCD could have strong advantages in size, cost and reliability over silicon-target image tubes.

In CCD's, imaging is accomplished by placing voltages of equal magnitude on all storage electrodes in a two dimensional array. The underside of the silicon serves as the target area. When an image is focused on this surface, light is absorbed in the n-type silicon, creating electron-hole pairs, the number of which depends upon the intensity of the light at that point. Since the holes will be attracted to the nearest potential well, the charge accumulating under each electrode is proportional to the intensity of light falling on the underside of the silicon at that point. This is the storage mode of the image device.

Transfer is made in the normal way, by changing voltages on adjacent electrodes until all the charges are shifted off the silicon substrate. The signal detected at the end of the line is a pulse train whose individual pulse amplitudes are the analog of the light intensity. The time between the pulses corresponds to the electrode configuration on the substrate surface. Thus a monitor synched to this signal will reproduce the image on a time scale. Furthermore, the envelope of the pulse train, which represents the image intensity, is the video response of the signal. And most important, the storage time is much larger than the video frame time, thus making the device feasible. ●

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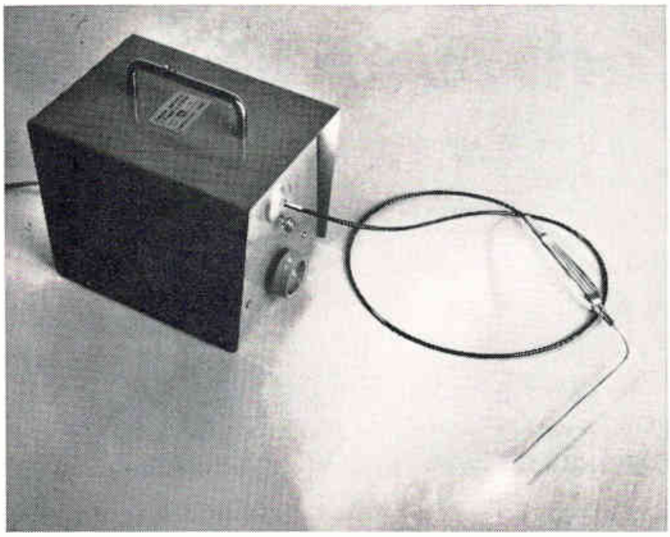

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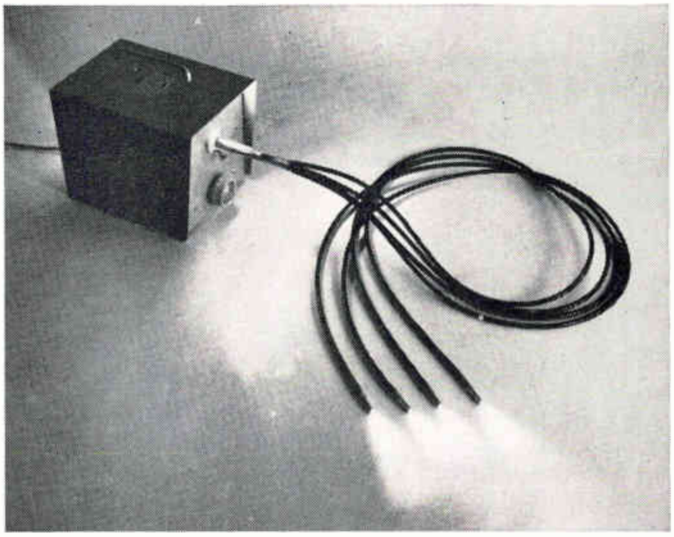

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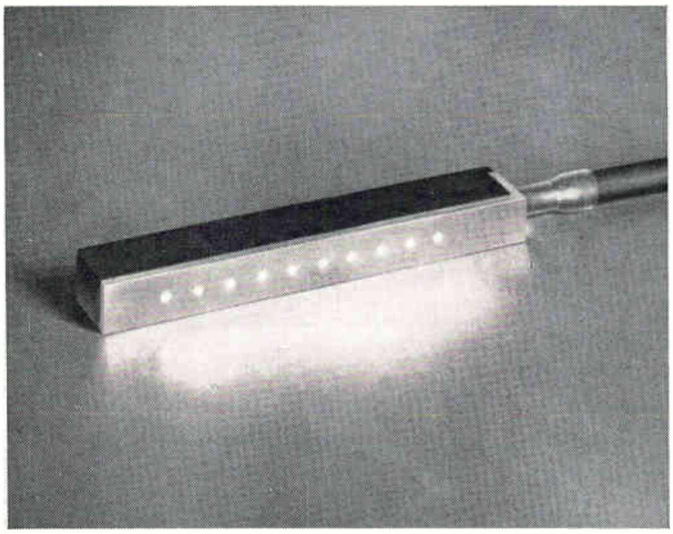

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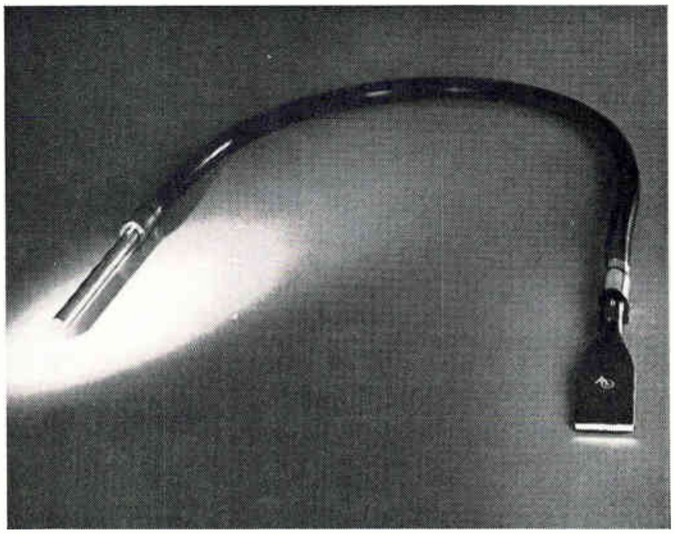

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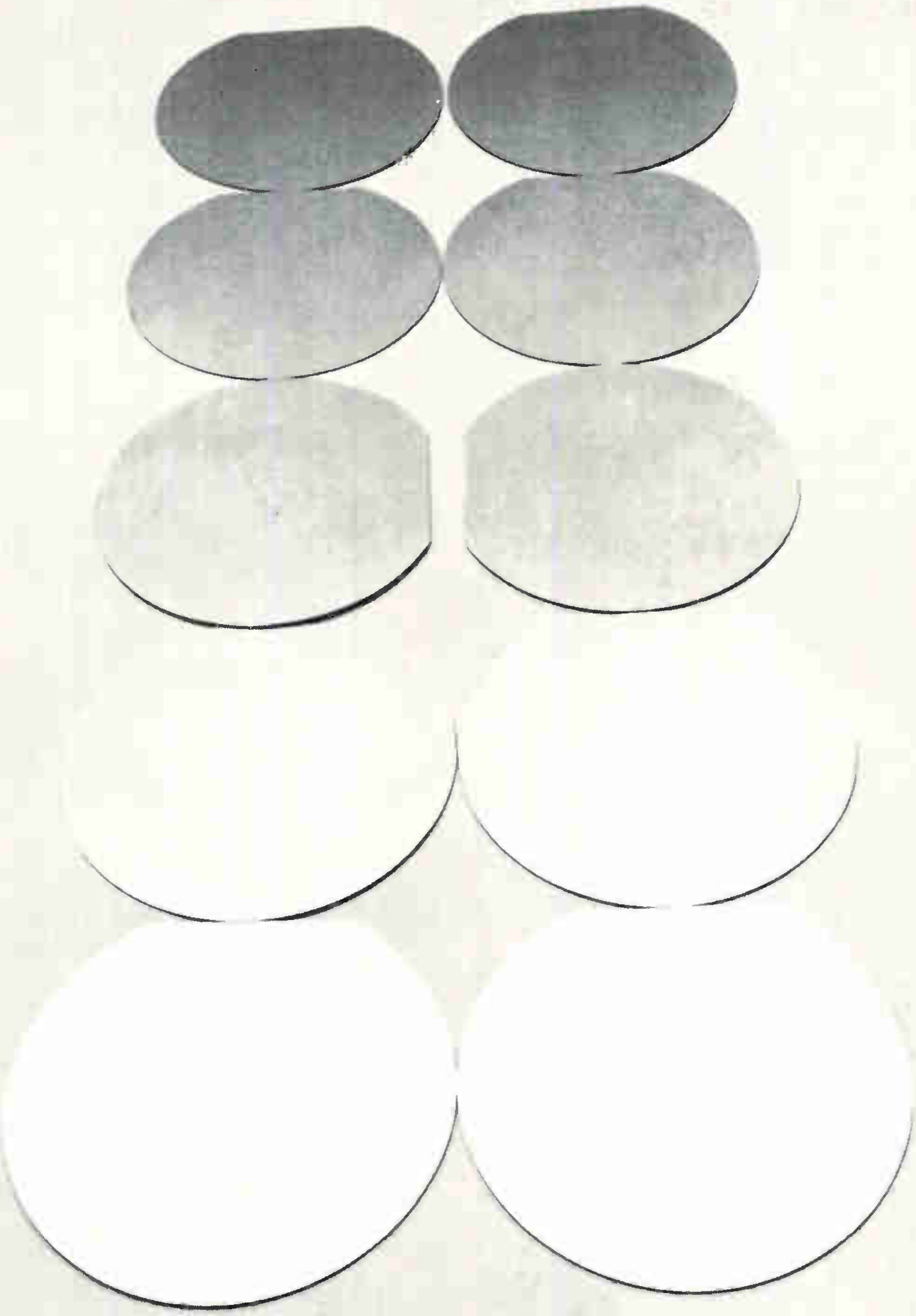

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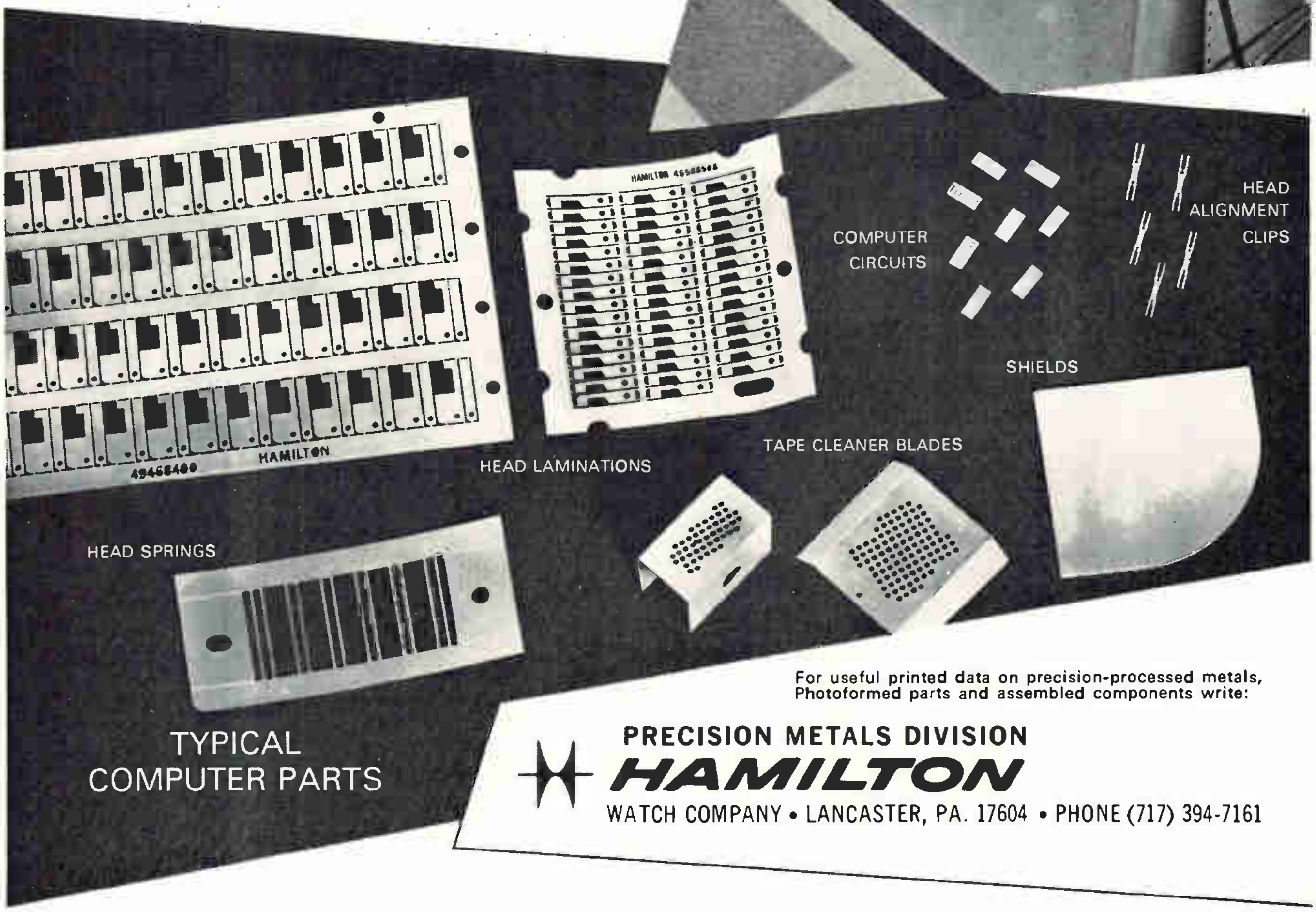

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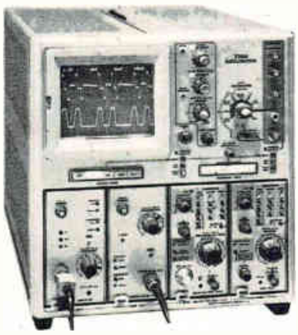

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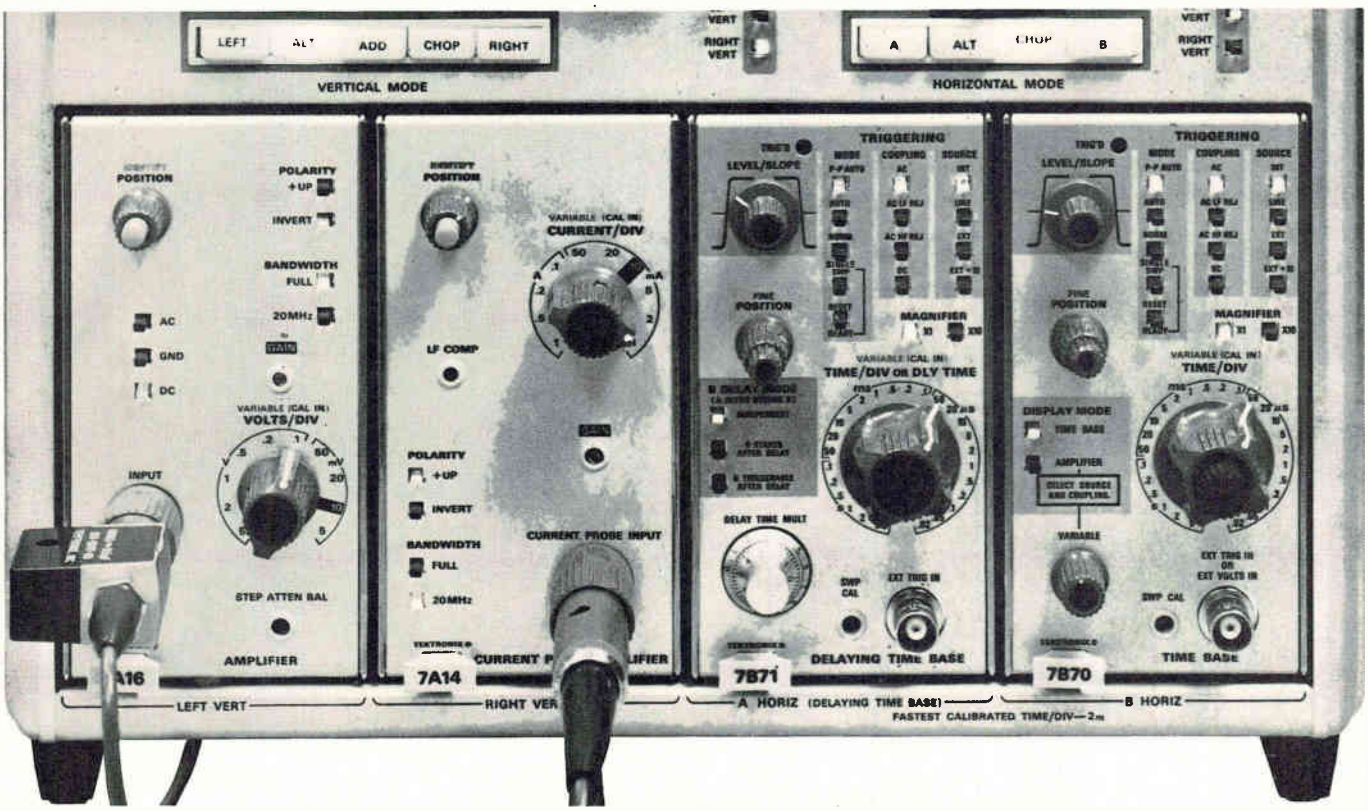

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Plastic IC's get foot in military door

Though tough new set of tests proposed by RADC officials is just a first step, manufacturers hope it will lead to lifting of military ban on plastic packages

By Lawrence Curran

Electronics' staff

Manufacturers of plastic-packaged integrated circuits, who have long been pressing military reliability specialists to accept their devices, have a new bone to chew on. Many of these vendors have been asking the military to settle on standard tests for plastics, contending if they knew what users wanted, they could make IC's to withstand reasonable environments [*Electronics*, May 12, 1969, p. 147].

The bone was tossed last month at the IEEE Reliability Physics Symposium in Las Vegas. There, Joseph Brauer, chief of the solid state applications section in the Rome Air Development Center's reliability branch, proposed a set of tests for plastic-packaged microcircuits (see tables p. 128) that could pave the way for acceptance of plastics by the military services for all but applications demanding the highest reliability [*Electronics*, April 27, p. 33]. These high-reliability, or Class A applications include such hardware as Minuteman ICBM and Apollo spacecraft circuitry.

IC makers have been pushing for acceptance of plastic packages because of their low cost vis-a-vis hermetically sealed units. And in some cases plastic-packaged IC's resist shock and vibration better than their sealed-can counterparts.

But until last month, the military had insisted that plastics couldn't qualify for use in military equipment. RADC, the focal point for considerable vendor-user controversy over plastic reliability in recent years, actually banned plastics. Some impurities inherent in certain plastics or resulting from plastic processing steps can degrade chips. As a result of the package's permeability, these impurities—whether gases and vapors outside the package or chemicals generated within—have adversely affected reverse-current leakage and space-charge buildup. And shrinkage sometimes resulting from curing or solvent evaporation can cause stresses severe enough to fracture IC interconnection wires.

Brauer and his associates at RADC emphasize that the proposal of the tests in itself doesn't constitute military acceptance of plastics. Rather, Brauer says, the qualification and screening procedures they embody mean that "we've proposed that the services lift the statutory ban on plastics and use those that pass the tests." And Brauer quickly adds that even the devices that pass these tests still won't be accepted for Class A applications as they're defined in the recently distributed Mil-M-38510, the general specification for microcircuits that relies heavily on test methods in Mil-Std-883.

Mil-M-38510 doesn't explicitly describe Class A, B, and C applications. But Class A uses are those in which the military considers high reliability "absolutely imperative," Brauer explains. Maintenance on Class A hardware is considered either impossible or prohibitively expensive. For Class B applications in which reliability is deemed "vital," maintenance is possible, but it's either difficult or expensive.

Class C applications are those in which "we're still concerned about reliability," Brauer says, "but a moderate amount of maintenance and downtime can be tolerated."

Selective risk. The tests proposed at the Las Vegas symposium didn't develop overnight; they're the result of months of work by an ad hoc committee within the Department of Defense Research and Engineering that includes representatives from all the services and NASA. Brauer thinks it's time to see if plastics can qualify. "We're now willing to take a risk on a selective basis," he observes.

Most of the test procedures are taken from Mil-Std-883, but some are modifications and others are additions tailored for the failures peculiar to plastics. For example in the Group B lot sampling tests, the salt atmosphere portion (Subgroup 4) with end-point electrical parameters has been extended to 48 hours instead of 24 hours provided in 883. And the test falls into Group C in 883 as originally written, and doesn't include end-point electrical parameters.

RADC experience has shown that silicone resins do well on everything but salt-atmosphere exposure. "Otherwise, silicones might be able to pass these tests soon," Brauer maintains. Epoxies, on the other hand, encounter trouble much sooner than silicones in moisture and pressure-cooker testing, but last for months on salt-spray tests, Brauer points out. Phenolic resins withstand pressure-cooker tests, but fail badly on all other counts, Brauer says.

In the proposed Group B lot-sampling tests, the biased moisture life test with end-point electrical

Proposed tests for plastic-encapsulated microcircuits

Green blocks indicate modification of Mil-Std-883 test procedures; red, new additions. Numbered test methods—2010, 1080, 5005, etc.—refer to 883. 10XX means that a complete number has yet to be assigned to a new test method. "LTPD" stands for Lot Tolerance Percent Defective, and numbers under that heading in the Group B and C tests refer to a table in 883 on how many defective parts are allowed in a lot.

100% screens

	Class B		Class C	
Screen	**Method**	**Conditions**	**Method**	**Conditions**
Internal visual before encapsulation[1]	2010	Test Condition B	2010	Test Condition B
Stabilization bake	1008	24 hrs. minimum, Test Condition C, 150±25°C	1008	24 hrs. minimum, Test Condition C, 150±25°C
Temperature cycling	1010	Test Condition C	1010	Test Condition C
Burn-in test	1015	168 hrs. at 125°C	not required	
Final electrical tests		► Static tests • at 25°C • at maximum, minimum operation temperature[2] ► Functional tests ► Dynamic tests at 25°C		► Static tests • at 25°C • at maximum, minimum operation temperature[2] ► Functional tests at 25°C
Qualification or quality conformance inspection	5005	per applicable document	5005	per applicable document
External visual inspection[3]	2009			

[1] To be accomplished prior to encapsulation with all applicable criteria of Method 2010.
[2] Test is required to establish continuity of microcircuit bonds and connections at specified temperature extremes. Detail specification shall contain sufficient static tests for screening to establish continuity from all used external leads to the die or substrate. An alternative to using static parameter tests for this purpose can be a continuity test (threshold) program which establishes continuity from all used external leads to the internal microcircuit elements.
[3] Unless otherwise specified, external visual inspection need not include measurement of physical dimensions.

Group B tests—sampling of each lot

Test	Methods	Conditions	Class B LTPD	Class C LTPD
Subgroup 1 ► Visual and mechanical	2008	Test Condition B, per documented design and construction	1 device, no failure	1 device, no failure
► Bond strength	2011	Test Conditions B, C, D, or F, as applicable	7	10
Subgroup 2 ► Marking permanency	2008	Test Condition B, paragraph 3.2.1	4 devices, no failures	4 devices, no failures
► Physical dimensions	2008	Test Condition A		
► Lead fatigue	2004	Test Condition B₂	15	20
Subgroup 3 ► Radiography[1]	2012	One view, normal to die or substrate criteria as specified	15	20
► Solderability	2003	temperature, 260±10°C, with age	15	15
Subgroup 4 ► Salt atmosphere	1009	Test Condition B	15	15
► End-point electrical parameter		as specified in procurement document	15	15
Subgroup 5 ► Biased moisture life ► End-point electrical parameter	10XX	85°C at 85% relative humidity with minimum power bias for 1,000 hrs. minimum as specified in procurement document	10	15

Subgroups 1, 2, and 3 may use electrical rejects. Subgroup 4 samples may be used in Subgroup 5 tests.
[1] Radiographic acceptance criteria include precautions against lead frame shift, foreign particles, lead dress, and encapsulant voids.

Group C tests—periodic sampling

Test	Methods	Conditions	Class B LTPD	Class C LTPD
Subgroup 1 ► Steady-state reverse bias ► End-point electrical parameters	1005	Test Condition A, 160 hrs. at 150°C, minimum as specified in procurement document	7	15
Subgroup 2 ► High-temperature storage ► End-point electrical parameters	1008	150°C minimum, 1,000 hrs. minimum storage as specified in procurement document	10	15
Subgroup 3 ► Thermal shock ► Temperature cycling ► Monitored temperature cycling	1011 1010 10XX	Test Condition B for a minimum of 15 cycles Test Condition C for 10 cycles 1 cycle ranging from −65° to +150°C	10	10
Subgroup 4 ► Moisture resistance or biased moisture life ► End-point electrical parameters	1004 or 10XX	With minimum power bias for 3,024 hrs. as specified in procurement document	15	None

Single sample may be used for all subgroups. Tests within any subgroup must be conducted in the order shown. Initial device qualification shall be to tighten inspection levels as defined in Appendix B of Mil-M-38510 and Mil-S-19500.

parameters included is not specified anywhere in Mil-Std-883; it's specifically used to help check the plastic package's history of poor moisture resistance. This procedure, maintained for 1,000 hours at 85°C. and 85% relative humidity, is the only one in the proposed series that Texas Instruments' Stephen Baird, who welcomes the proposed tests, says borders on being a stress trial rather than a use-condition test. Baird is plastic reliability and technology consultant in quality and reliability assurance within the components group.

Obstacle course. Other parts of the tests that are either more stringent applications of Mil-Std-883 procedures or newly devised obstacles for plastics are these:

► The portion of the static tests done at maximum and minimum operating temperatures in the final electrical tests set forth in the 100% screens. This is a Class A test condition in 883 but is proposed for Class B and C applications to assure that there are no intermittent bonds at the temperature extremes.

► The radiography test in Subgroup 3 of the Group B tests. This is part of the 100% screens for Class A devices in 883 and is included here to check for foreign matter inside the package after encapsulation.

► Test Condition A in Subgroup 1 of the Group C tests. This differs from 883 in boosting the duration from 72 hours to 160 hours.

► The monitored temperature cycle in Subgroup 3 of Group C. This is a new test intended to pinpoint where electrical opens occur across the temperature range.

► Subgroup 4 of Group C. Test Method 1004 is part of Group C in 883, but bias is optional; here, bias is mandatory. Also, most moisture-resistance tests for hermetically sealed IC's are done for only 240 hours; RADC officials feel 3,024 hours is necessary for plastics.

Fine tuning. "No one will have plastic devices that pass all these tests right away," Baird asserts. "It will take more attention to detail in processing, but I think everyone is close enough so that it will be a matter of fine tuning."

Baird says he's 80% confident that TI's current epoxy-encapsulated IC's can pass the tests because TI performs all of the tests

now in its own reliability evaluation program. Sylvania, while it has been working with plastic packages for years, is singing the praises of its ceramic package, which it says is almost as cheap as a plastic unit.

Donald Russell, manager of IC quality assurance and reliability at Sylvania Semiconductor's Woodburn, Mass., division, believes RADC officials have shown in their test proposals that they're still highly suspicious of plastics. Says Russell, "I thing Brauer has shown by the tests and their duration that he has very little confidence in plastic-packaged IC's. The moisture-resistance tests are very tough. The tests aren't new, but they're grouped together as an assurance of something significant to him. He's saying he's still not confident." But Russell admits that although Brauer has "built a fairly severe obstacle course, he's not being unreasonable. He's just trying to write specs so the military will have reliable equipment."

Brauer, no stranger to controversy, seems genuinely interested in having a method of qualifying plastics for military use, at least partly to determine if the units ultimately can give the military a cost advantage over hermetically sealed devices. Says he, "It wouldn't surprise me to see devices pass these tests now—from vendors that are serious about plastics."

Cost-conscious. One IC user in a large electronics firm's defense group says, flatly, "There won't be any cost savings with plastics, even if they do qualify. A couple of screenings and you'll push the cost to the point where they won't be competitive, especially with the price of ceramics coming down. And there'd have to be a hell of a cost advantage before we'd use plastics."

This source is dismayed that RADC has proposed the tests. He knows of no firm that has qualified hermetically sealed devices under Mil-M-38510, "and all of a sudden, Brauer is talking about plastics. Either he has finally knuckled under to pressure from the TI's and Motorola's or he's designed tests that are so tough he knows nobody can pass them."

Another user who is skeptical of plastics, and who probably won't be swayed by the RADC-proposed tests is Stanley Stuhlbarg, manager of the hybrid circuits department at the Bedford, Mass., laboratories of Raytheon's Missile Systems division. "If at the end of a year plastice units under test are performing perfectly under extreme conditions and data is published, maybe I could afford to use them. Nothing in the way of an accelerated test could do this." And even after a year, Stuhlbarg says, he would want to see an analysis of why the devices succeeded. "For instance, maybe water evaporates before it gets to the IC because of heat from junctions. We need reasons, not just results. If the reasons for passing are good, people will begin to believe in plastic packages."

Confidence. The vendors react differently. Signetics' Richard McCoy, director of reliability programs, is convinced his firm's production silicone packages can pass all but the salt-atmosphere test. But he adds, "We now have a way to modify the package to pass that test, but we don't know if it's the most economical solution. We're confident we can meet the spec with a production process in about three months." He doesn't believe the salt-atmosphere test is a "real-world" test, however.

McCoy isn't worried about Signetics devices failing the biased moisture-life tests in Subgroup 5 of Group B lot-sampling. Nor does he seem concerned about Subgroup 4 of Group C—the moisture resistance or biased moisture-life tests—although he's not wild about doing the biased moisture-life tests for each lot. "These are bad from an inventory standpoint—for both plastic and hermetic devices."

General Instrument Corp. officials, who are just embarking on an R&D program to put MOS devices in plastic, say they've established their own reliability criteria for plastics. These include almost all the tests RADC has put forth, except Subgroup 5 of Group B (biased moisture life) and Subgroup 4 of Group C (moisture resistance or biased moisture life tests). Al Musto, manager for reliability assurance, and Albert Adell, director of quality assurance and reliability in the Microelectronics division, both say GI likely will include these two tests in its pro-

gram. Both agree they are the stiffest obstacles laid down by RADC.

Charles Gray wouldn't recommend plastic-packaged IC's to Fairchild Semiconductor military customers. He says that after screening plastics, the price difference vis-a-vis hermetics would be so small that the customer should use the hermetic unit. But Gray, who is Fairchild's director of reliability and quality assurance for IC's, agrees that a specification for plastics is needed, and says RADC's proposed screens are generally reasonable, even though some of them exceed the maximum ratings of some devices. Although not all of Fairchild's plastic units would pass the tests today, Gray says, "We are making the best devices we know how to make, and if a standard comes out, we'll want to come as close as we can."

Fighting the bonds. Gray says the industry is opposing the bond strength test (Group B, Subgroup 1) even for hermetic devices—"and it is infinitely more difficult to remove plastic and measure bond strength." Gray acknowledges that the salt-atmosphere test is more stringent than that for hermetics. He questions whether even hermetic devices can pass it. He's opposed to the 3,024 hours of moisture resistance or biased moisture-life tests in Group C., Subgroup 4: "that's four months and that's a long time. The manufacturing process or design may change. Evolutionary changes occur faster than the test time; it could take nine months to get any products shipped."

One source at a firm that makes plastic-packaged IC's puts the vendor's view on the economics of screened hermetics vs. screened plastics this way. He says that most companies have two hermetically sealed ceramic package types for IC's—essentially a military/grade package and a commercial/grade unit. This source says that when someone compares a 40-cent plastic to a 50-cent hermetic, "this is not the hermetic that's sold to the military. The Mil hermetic might cost as much as $1 before testing, so you should compare a $2 ceramic against a $1.42 plastic." He says $1 worth of testing would be added to the ceramic's basic $1 price vs. about $1.02 in testing costs added to the plastic unit's tag.

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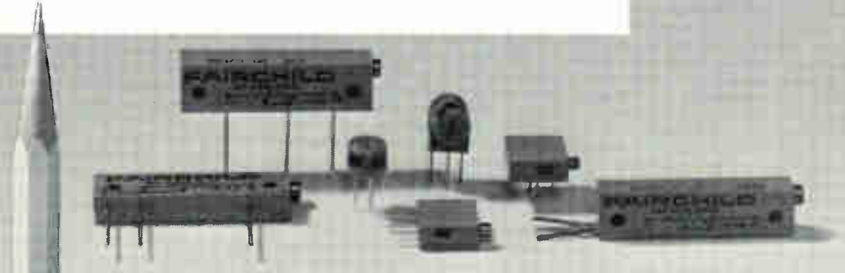

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Submillimeter spectrum Waves of the future?

Although scientific interest is being whetted by potential for high-capacity, long-range communications, much more money and research are needed to create practical systems

by Laurence Altman

Electronics staff

Man's last frontier of electromagnetic transmission is beginning to be explored with increasing interest by scientists and engineers. The frontier is the submillimeter wave spectrum that falls within the region of roughly 1 millimeter (300 gigahertz) on the low end to about 10 microns at the optical extreme. But more than just scientific curiosity is whetting researchers' interest—this frequency band may provide new horizons in compact, high-capacity, long-range communications systems, and sophisticated radar gear.

Research effort and money spent so far have been small. But work on developing sources of submillimeter wave energy and detection is picking up. The work is proceeding from both ends—the millimeter people are working on higher frequency semiconductor generation, while the laser researchers are trying to convert the optical frequencies downward into the far-infrared.

The work does not suffer from a lack of diversity. Government-directed installations like Lincoln Laboratories at MIT, say for example, are involved in millimeter and far-infrared frequency mixing in semiconductors to achieve emission in the submillimeter band. The National Bureau of Standards in Boulder, Colo., long active in short-wavelength research, is refining its techniques to include the wavelengths between 2 millimeters and 50 microns. Bell Laboratories has become active in nonlinear optics in the submillimeter region, and a scientist at Tohoku University in Sendai, Japan, has managed to obtain submillimeter-wave difference frequencies using nonlinear crystals in conjunction with a ruby laser. Moreover, the triatomic gas lasers, such as water vapor, hydrogen-carbon-nitrogen, hydrogen sulphide and sulphur dioxide, have shown oscillations in the submillimeter wave region. Most recently an SO_2 system has emitted strong lines around 151 microns.

This is interesting and significant work, but the fact remains that at present there is no practical source of energy whose primary emission lies in the submillimeter wave region. And detectors are nonexistant outside the research labs and likely to remain so for some time. Furthermore, it is agreed: development will require a large outlay of man-hours and money.

This has led some scientists to wonder: are we climbing the mountain simply because it's there? Is it worth it?

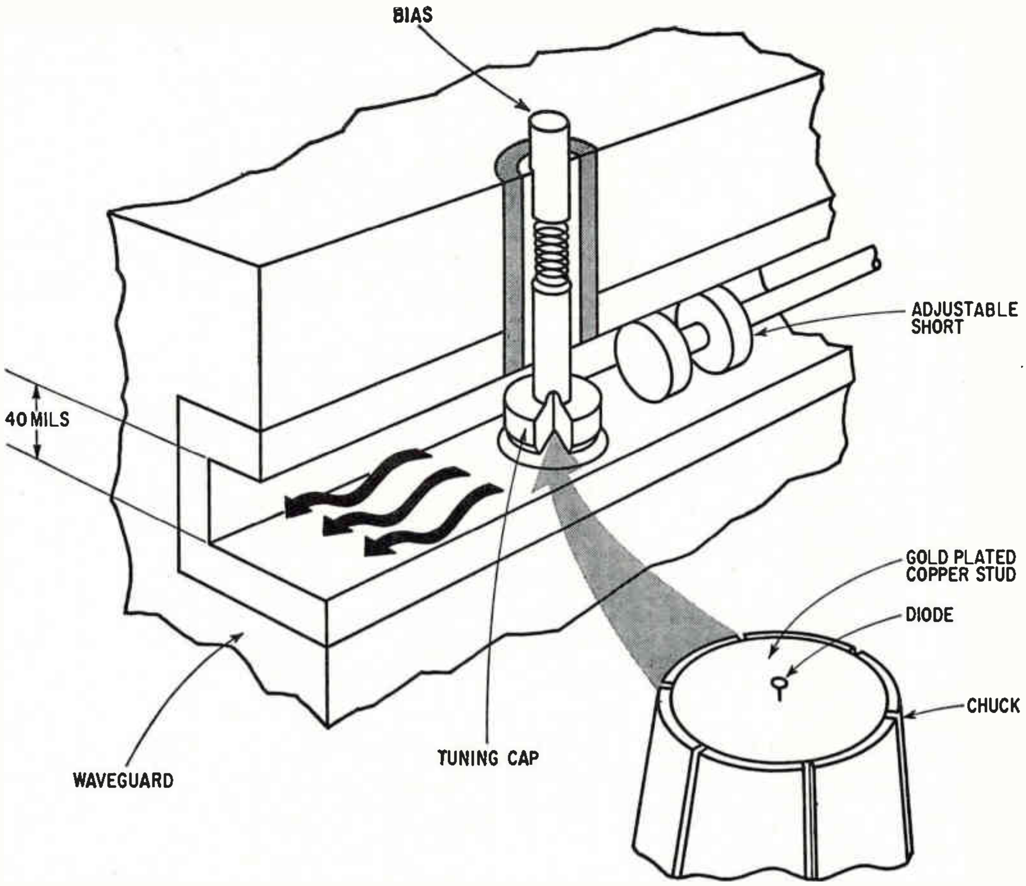
Dr. Arthur Oliner, director of the Microwave Research Institute at Brooklyn Poly thinks it is. He points out that the trend in electronics is to higher frequency and smaller systems, and the natural expansion will be into the millimeter and submillimeter band where standard circuit techniques can be applied.

M. L. Skolnik, a systems radar specialist from the National Research Laboratory in Washington, takes another view. He feels that the microwave spectrum still hasn't been fully utilized for practical radar and communications systems. Although some systems exist above X-band, they're largely experimental and far from trouble free. Above the Ku band (up to 20 Ghz) there aren't even any experimental system models. And with precious little development money around, Skolnik wonders why it should be put into millimeter and submillimeter waves when it could be better spent in areas yielding more immediate results.

But clearly, submillimeter waves offer greater information-handling capacity than do lower-frequency systems—five to 10 times the capacity of the largest millimeter-wave systems being planned. A 500-Ghz carrier, for example, could accommodate over 10,000 video channels, or a million separate voice channels. Or a submillimeter carrier in the far-infrared region could transmit about 10^9 data bits per second, the entire memory capacity of the largest computer being developed. And although optical frequencies offer even greater capacity, some researchers question whether lasers are practical.

Problems, problems. Many lasers still have stability problems, especially the gas lasers. Solid-state lasers are not much more attractive as rugged sources—they require large power supplies, pumping lamps, and costly mirrors. The semiconductor laser eventually may prove the most useful, at least for low-power applications, but at present, room-temperature c-w operation is not feasible.

More important, all gas and solid state lasers suffer from the inherent difficulty of modulating their optical beams with electrical information signals, a clear requirement for useful communications. Although electro-optical modulators such as potassium dihydrogen phosphate (KDP) or lithium niobate, or liquid Kerr and Pockels cells, do provide the answer to laser-beam modulation in theory, in practice they suffer from large insersion loss, poor beam separation (crosstalk) and unreliability. In contrast, submilli-



The better Impatt. This Bell silicon Impatt diode can operate continuously at frequencies in the 150-Ghz range with output approaching 50 milliwatts thanks to abrupt shallow junctions and improved heat sinking. Further refinements could lead to the first primary source of emission in the submillimeter-wave region. Bell uses cap tuning in the oscillator circuit. A metal cap consisting of a short cylindrical metal block whose diameter is approximately a half-wavelength encloses the diode, which is mounted on the wide side of a standard waveguide.

meter transmission most likely will use conventional cavity modulating techniques, and at the same time provide almost the capacity of infrared optical systems—a strong point in its favor.

Size of transmitting and receiving instruments is another consideration. Submillimeter wave lengths offer convenient dimensions for system components—inches instead of feet for millimeter waves, and angstroms for optical emission. Submillimeter antennas can be six inches long and cavities and waveguides three or four inches on a side. Yet, optical wavelengths are so short that a workably-sized laser cavity leads to multimode emission, which not only wastes space, but results in noise problems from mode conversion. In contrast, submillimeter wave sources won't suffer from multimode generation—wavelengths are about the same order of magnitude in size as the dimensions of the devices.

In addition to being single mode, submillimeter wave transmission lends itself to standard IC techniques, while optical transmission requires an entire new circuit technology using light fibers. And although there are a few integrated optics programs at several laboratories—Bell Laboratories is the most active—which are attempting to develop optical circuits on miniature substrates, their results are tentative.

To achieve submillimeter-wave emission from the millimeter end, researchers are using two semiconductor approaches: diodes operating in the avalanche (Impatt) mode, and bulk devices operating in the Gunn and limited-space-charge accumulation (LSA) mode. Of these, the most promising is a new silicon Impatt diode developed by Bell Laboratories.

Built to oscillate in the 100-Ghz range—the upper end of Bell's proposed millimeter wave communication system [*Electronics*, April 13, p. 96] the silicon Impatt diode is proving an increasingly valuable source at higher frequencies. Although not yet operating in the submillimeter band, Bell scientists are advancing millimeter-wave junction technology, and are now able to achieve continuous emission at frequencies up to 150 Ghz at powers of 30 milliwatts and higher, sufficient for many applications.

Junctions. Operation of an Impatt diode at these frequencies required a very abrupt junction. Lower-frequency Impatt diodes are fabricated with gradual junctions, where the active region is spread out over a fairly wide band. In contrast, higher-frequency operation requires very abrupt junctions which results in generation of high energy, high current density, and large quantities of heat.

With computer-aided designs and flip-chip heat-sinking methods, Bell scientists were able to achieve the required junction conditions. In the fabricating process, boron is diffused into a shallow epitaxial layer only 0.5 micron thick. And equally important, the diffusion process yielded very high donor densities—as great as 1.5 to 3.0 x 10^{17} per square centimeter.

Most significantly, the high-frequency is not achieved at the expense of efficiency. In the 100-150 Ghz range, efficiency exceeded 3% (at 111 Ghz), with output approaching 100 milliwatts. At 150 Ghz, efficiency exceeds 1% and will rise when heat sinking is improved further. What's more, pulsed operation with these abrupt-junction

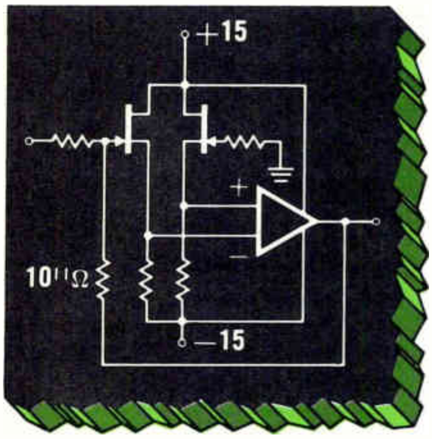
Impatts have yielded frequencies as high as 350 Ghz, well within the submillimeter range. But at present, pulsed duty cycles are too low to provide useful emissions.

Limits. But even with Impatts, achieving continuous emission at submillimeter-wave frequencies is not a certainty. As the frequency of emission is increased, with a corresponding decrease in wavelength, the dimensions of the device also must decrease for oscillation to occur. This restriction already is severe at 150 Ghz, where junction areas are on the order of nearly 10^{-6} cm^2. At higher frequencies, dimensions are so small in the active area that skin currents result in a sudden drop in c-w output, now observed at about 200 Ghz. There is a serious question whether this condition can ever be overcome, since it results directly from device geometry.

Optics. Achieving submillimeter-wave frequencies from the optical end of the spectrum requires using either molecular lasers operating directly in the far infrared, or a laser emitting at optical frequencies in conjunction with a nonlinear material or other mixing technique to obtain the lower frequencies.

Sulphur dioxide lasers at submillimeter frequencies may provide a suitable source. But work with these devices is still in the early stage and many problems involving stability and efficiency still must be worked out. However, emission at various locations in the submillimeter waveband has been detected; this at least indicates that a primary source of millimeter energy may be available from the laser.

Another approach is to use nonlinear materials such as KDP and lithium niobate in conjunction with laser emission to realize submillimeter waves. These nonlinear optical techniques have been used in the visible and near-infrared regions, but work at lower frequencies is only just beginning. For example, Bell Laboratories has mixed two c-w signals from a hydrogen-carbon-nitrogen (HCN) laser in lithium niobate, and has detected a beat at 73.5 Ghz. But here, conversion efficiency is extremely low—total laser power is typically a few hundred watts



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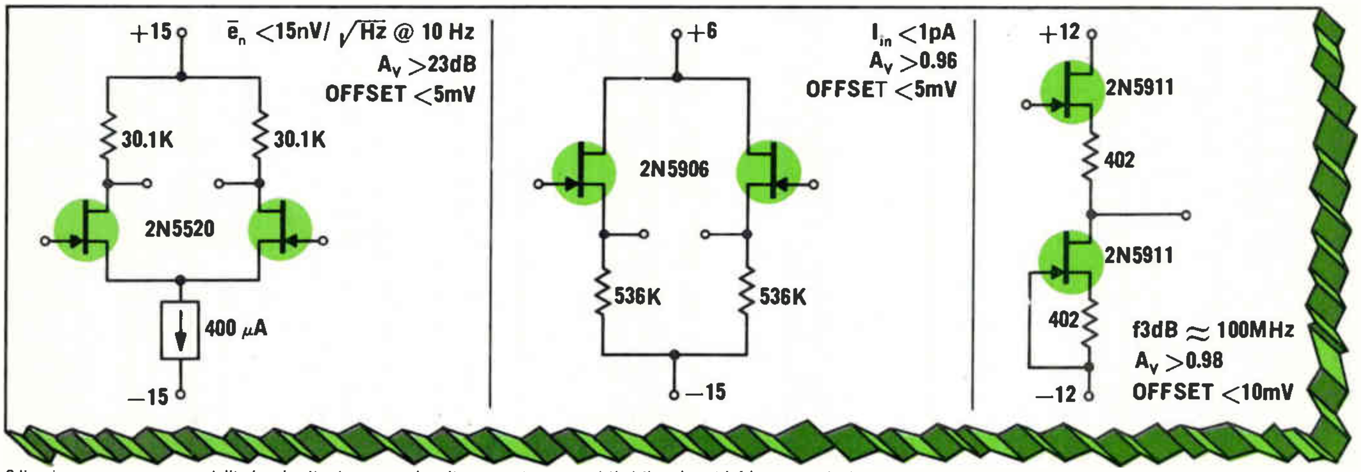

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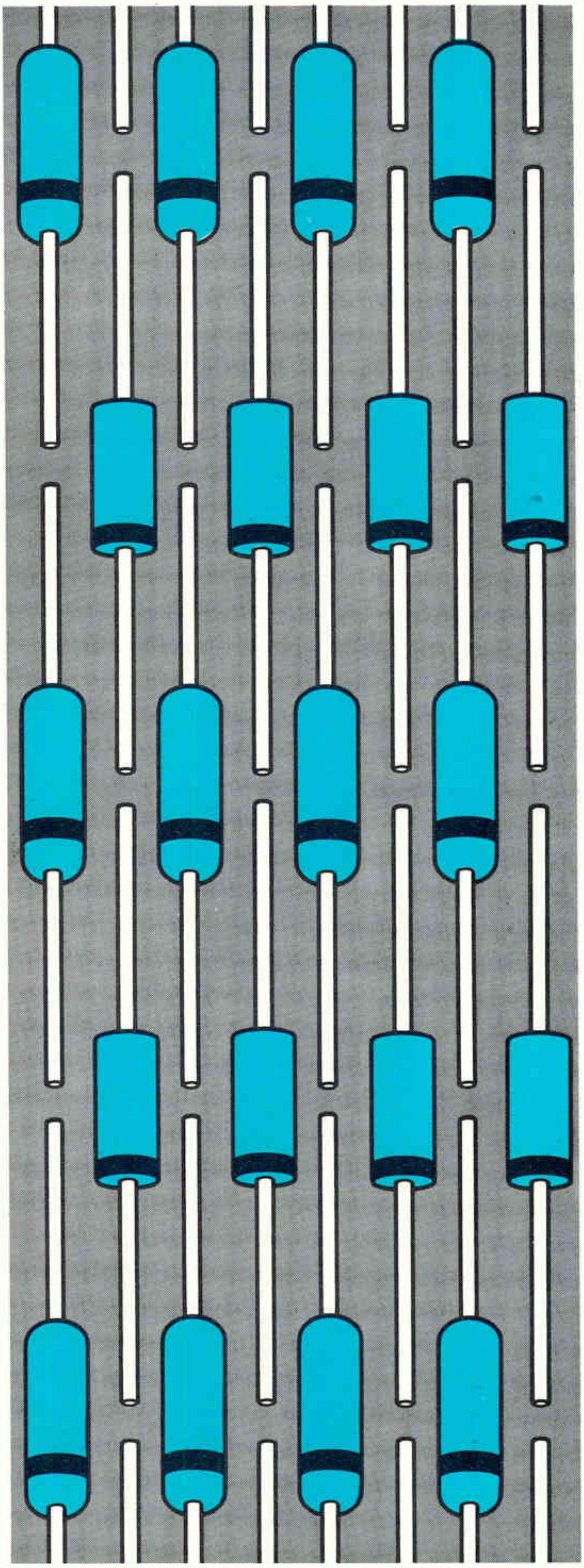
while the observed millimeter wave power falls in the range 10^{-12} to 10^{-16} watt.

Other nonlinear materials may prove to be more efficient. Besides lithium niobate and KDP, GaAs, cadmium disulphide, and crystalline silicon dioxide are transparent at discrete lines falling in the submillimeter waveband. Work here may provide more efficient conversions. Another material, single-crystal tellurium, also is under consideration as a nonlinear medium. Experimenters at the University of Illinois in Urbana are working with far-infrared second-harmonic generation and mixing using a water-vapor laser as the source and tellurium as the converter. But again, observed efficiencies in these early experiments have been very low.

Detection doubts. As uncertain as submillimeter wave generation is at the present time, submillimeter detection, the other half of the system, is even more tentative. Far infrared detection using pyroelectric detectors—devices showing thermal responses to high-frequency energy incident on their junction—are interesting lab devices, but their response is so low that more extended use is not feasible. The Josephson junction—making use of the current flow through a barrier or mechanically weak junction between two superconductors—also can be used to detect submillimeter wave energy, but it also has an extremely low response.

Another group of laboratory detectors in the submillimeter band are the n-indium antimonide devices. When cooled to near 1°K, n-InSb will yield a small photoconductive current when submillimeter energy is incident on it. Essentially a noise signal, the magnitude of the signal is in the order of 10^{-12} to 10^{-13} watts, clearly not useful outside the laboratory. Signal enhancement can be obtained with application of a magnetic field. Known as the photo-induced Hall effect, premilinary experimental results conducted in Japan showed that the overall response of n-InSb detectors can be improved by a factor of from two to six by this technique. Nevertheless it still yields a detection signal much too small for anything but experimental purposes.



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Hard-copy display terminal makers starting to probe wide-open market

Initial entries at Spring Joint Computer Conference show various approaches, but considerable design and development work still must be finished; photoconductors, fiber optics, and lenses help improve speed, resolution

By George Weiss
Electronics staff

A half-dozen companies showed up at the Spring Joint Computer Conference in Atlantic City this month with hard-copy output crt terminals, and this was interpreted by some as a top-of-the-iceberg phenomenon.

If true, the iceberg is top-heavy. Indeed, there is plenty of design and development work going on below the level of product introduction, but the problems are formidable and there is no indication that the marketplace will soon be flooded with products.

At IBM, for example, marketing officials say it will take a technical breakthrough to obtain the kind of cost-performance ratio needed by users of interactive time-sharing cathode-ray tube terminals; and Xerox planners think such equipment could be nearly 10 years away.

Meanwhile, there is no dearth of potential users. Among those who are anxious to push a button and get hard copy within seconds from desktop, self-contained crt display terminals are stock brokers, airlines, hospitals, schools, and banks.

The consensus among marketing officials is that 20% to 30% of the crt terminals bought in the near future will include hard-copy requirements, and that the over-all cathode-ray tube terminal market is increasing at a rate that approaches 50% each year.

At the SJCC, terminals in various stages of design refinement were demonstrated by A. B. Dick, Tektronix, Photophysics Data Systems, Computer Optics, and the Hazeltine Corp.

In addition, Control Data expects to announce a model later this month; Graphic Data Inc. of Burlington, Mass., is developing a unit; and so is Evans and Sutherland of Salt Lake City.

A. B. Dick uses the hard-copy method it knows best—the electrostatic printer with a zinc-oxide coated paper. The company focused on the clarity of the image produced by the crt. "The printer can resolve 500 lines per inch," says Glen Gerlach, manager of engineering applications, "but the conventional 10-inch monitor can only resolve 525 lines over its entire face. This is a resolution of roughly 50 lines, so the resolution of the monitor is far lower than the printing process." But Gerlach claims good copies are received from crt's with 80 characters on a line, for up to 40 lines, where the characters are about ⅛-inch high. Gerlach feels fiber optics and flat-faced screen are too expensive

By itself. Of all the new hard copy crt terminals on the market, only Photophysics' 45 Data Terminal is self-contained; both printing process and crt are housed in desktop-size cabinet.

. . . several terminals can be linked as slave units over video lines to reduce costs . . .

and sophisticated and could price themselves out of a large part of the market.

A. B. Dick's electrostatic printer accommodates a 460-ft. roll of paper that can be turned into 1,000 copies at about 1½¢ per square foot. The paper, which runs about twice as fast as the usual electrostatic paper, retails for $12 a role; the printing process toner costs about $8 and lasts for two roles. Gerlach says the printing cost is about one-third of a photographic process.

But the speed of the process may not measure up to the heavy demands that will be placed on crt terminals. The Model 975 Videograph Display Unit, as the terminal is called, can produce hard-copy outputs in 10 to 15 seconds, depending on the brightness of the image.

The crt terminal is mounted on top of the printer; a fixed lens directs the image from the faceplate onto the paper. When the print button is pressed, the intensity of the crt image is increased and the paper is advanced. A special toner provides a black-on-white hard copy from the reverse image that appears on the crt.

Any size monitor can be used with the 975 and adjustment is made by changing the position of the lens with respect to the crt and the hard copy. Depending on the location of the lens, the display can be enlarged or reduced.

Summer debut. Hazeltine uses the same approach as A. B. Dick but its terminal has a keyboard that makes it interactive with a central processing unit. Hazeltine's hard copy is produced at about the same cost and speed as A. B. Dick's. Its Model 1760 displays 32 lines of 55 characters each with a standard tv tube. Hazeltine has been working on the project for about a year and a half, and hopes to get the exposure time down to 2 or 3 seconds. The system will be available in late summer and will sell for $5,000, not including the printer.

Several terminals can be linked as slave units over video lines resulting in reduced system costs. The slave units would contain the tube and deflection circuitry without additional electronics. The customer can buy the remote terminal as a stand-alone unit or he can line up any number of monitors with an interactive time-sharing terminal. When the operator desires a hard copy of the display, he presses a button on his console and one of the slave units can be flashed to produce the hard-copy output. Meanwhile, the operator can continue working from the crt terminal.

Self-contained. The Photophysics 45 Data Terminal is the only self-contained unit on the market. It houses both the printing process and the crt's in one desktop-size cabinet.

The image on an internal crt is projected onto a photoconductive plate through a lens. The photoconductor converts the light signal from the crt into an amplified electrical signal. The photoconductor produces a negative charge; it's transferred to paper, which is specially treated and contains both conductive and dielectric layers. Under this negative-producing technique the white on black of the crt image produces a black-on-white image on the hard copy output.

Exposure time takes less than a quarter of a second, and the copy is ready in about 5 seconds. Additional copies can be made in 2 seconds.

"Once the negative charge is placed in the paper, it's no longer light-sensitive," says Guy Marlor, vice president. "You can put the paper in your pocket and walk around with it for a day and then develop it." This simplifies the terminal requirements—only the section where the paper comes in contact with the photoconductor has to be kept light tight.

The charge put on the paper is negative, so when the paper is passed through the toner bath, the positive toner particles adhere to the surface of the paper producing the image.

One disadvantage is the size of the hard-copy output—5 inches

. . . fiber optics best for sharp characters . . .

square, against the 8½ x 11 size in the other units. However, the data terminal can display up to 1,000 characters, 25 lines of 40 characters each, as well as charts and graphs.

Marlor says that the current 5-by-5-inch photoconductor will be made larger—10 x 12—in future units designed for larger prints. The crt terminal is priced at $9,950. The print module sells for between $3,000 and $3,500. Delivery is scheduled to begin in November.

Light bundles. Computer Optics says fiber optic bundles appear to offer the best method for reproducing sharp characters. Its CO:70, an alphanumeric crt display ter-

Light pipes. Computer Optics' CO:70 crt terminal uses fiber optics to project display onto faceplate.

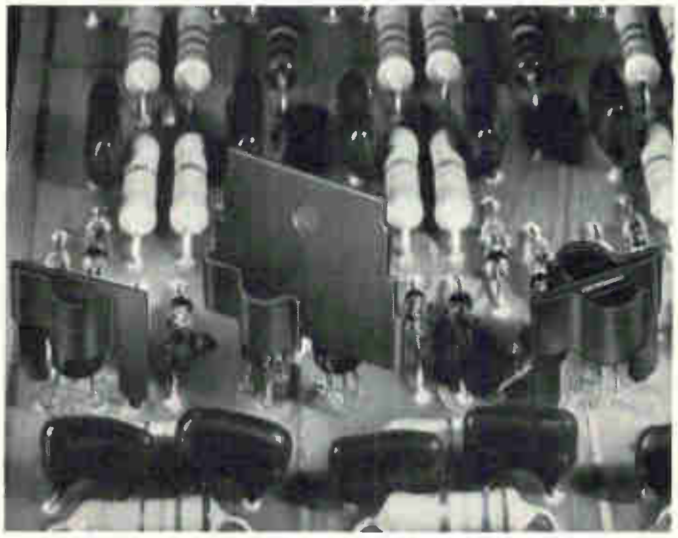
minal, can display 3,000 characters in both upper and lower case. Each fiber is 6-8 microns in diameter and acts as a tiny light pipe, projecting the display onto the surface of the faceplate, beyond the edge of the crt.

"Because of the distance between the crt and the faceplate, the image would get dispersed if it weren't for the fiber optics," says Fred Crawford, designer of the system, called the Video Image Processor. The VIP includes a standard office copier to generate hard copy on 8½ x 11-inch sheets in less than 10 seconds. The crt is tied up 2 seconds; the rest of the time is for developing. Computer Optics hopes to offer by next year a printer that can be shared among many crt's.

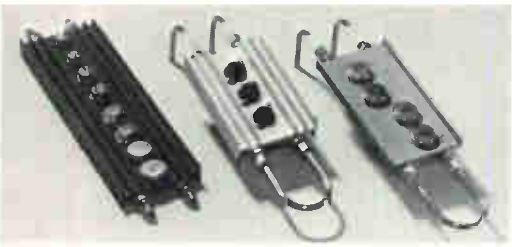
The price range for the VIP will vary depending on the crt display

Tips on cooling off hot semiconductors

See how other circuit designers use IERC heat sinks/dissipators to hold junction temperatures below rated maximums, improve circuit performance and reliability



RO97's, RO97A's, X20's (D-Style) and other lead mounted, low power "plastic" transistors can be operated at up to 65% more power with IERC dissipators. They cost only pennies, provide excellent retention in severe environments, reduce failures from solder heat during assembly. 5 different styles; both single and dual models.



Replace elaborate forced air cooling systems for power devices. IERC fluid cooled systems provide up to 1,000 watts of dissipation in less than 45 cu. in. Parallel or series flow; open or closed loop systems. All standard mounting hole patterns; specials, too. Lengths from 6″ to 3′ standard.

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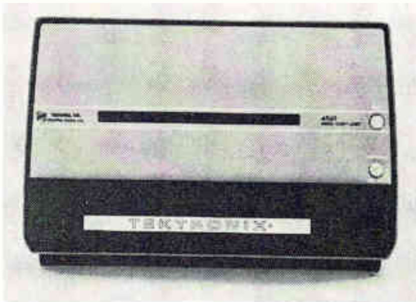
Circle 147 on reader service card

. . . dry heat for fast hard-copy developing . . .

unit, which can either be a slave or an interactive terminal. The display price ranges from $2,025 to $9,250, and the printer from $5,000 to $15,000. Discounts on OEM quantities will be available when the units go into production during the last quarter of this year.

Scanner. Tektronix also sees the combination of crt's and fiber optics as the best method to avoid light dispersion between tube and faceplate. The hard-copy unit can be used with the Tektronix 611 and 4002 display models, or with the company's new graphic terminal, the 4005. The hard-copy machine is priced at $3,750.



More light pipes. Tektronix also uses fiber optics for character faceplate resolution.

The Tektronix unit employs a scanning technique. The master crt is scanned by an intensity-modulated beam, and the output signal is amplified and then fed to the fiber-optic crt. 3M type 77 paper is pulled across the screen, exposed, and then heat-developed. The first 8-by-11-inch copy can be made in 18 seconds, and each additional copy takes 10 seconds.

Graphic Data Inc. of Burlington, Mass. also uses a dry-heat process for hard-copy developing. The company says it yields faster and better quality reproduction than electrostatic methods. The cost per copy is 8 to 10 cents and the unit's initial cost is a low $1,500. Company spokesman claim that heat can serve as a process variable to help adapt the system to several crt consoles and optical systems. First units will be available by the end of this year.

Digital voltmeter calibrates itself

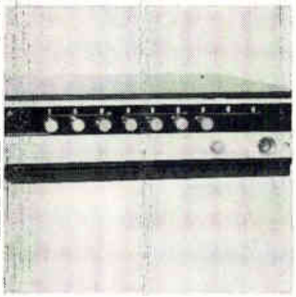
Once a minute, instrument connects its input to a built-in reference and adjusts itself back to the specified accuracy—0.001%

Don't try to put a sticker on the LM 1490 each time it gets calibrated; you could wear out your tongue. The 1490, a d-c digital voltmeter from the Solartron Electronic Group Ltd., continually calibrates itself.

Therefore, this high-accuracy instrument can go onto a factory floor, into an airplane or any place else a measurement has to be taken outside the constant-temperature environment of a standards laboratory. And it's ready to work at rated accuracy as soon as it's turned on.

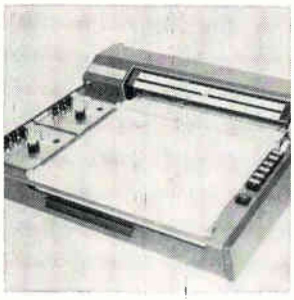
The 1490 has all the specifications – 100-nanovolt sensitivity, 0.001% accuracy, six ranges—and the price—$4,460 in the United Kingdom—of a high-performance dvm. It autoranges, changes polarity, and can be remotely controlled. But self-calibrating is the feature that Solartron engineers are counting on to make the instrument sell. "We look on it as a portable standards room," says John Bloomfield, chief development engineer.

Plugged into the meter's mainframe is the reference source that does the calibrating. Once a minute the 1490 disconnects itself from the

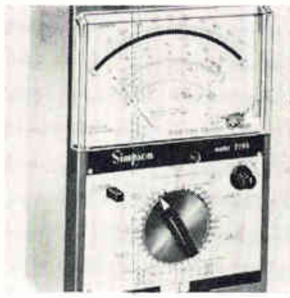


Frequency synthesizer model 1165 is a highly stable sine-wave oscillator and tunable frequency standard. A total frequency range of 10 khz to 160 Mhz in 100-hz steps plus 1 x 10^{-9}/day stability, phase modulation capability, and remote programability are available in both master ($5,900) and slave ($5,300) units. General Radio Co., 300 Baker Ave., West Concord, Mass. [361]

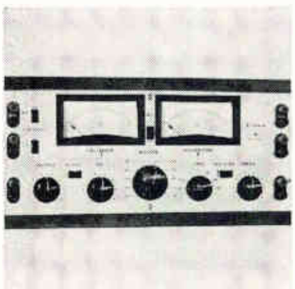
Line noise generator 3020 serves a dual purpose. It generates a controlled line transient similar to rectifier or scr noise on the a-c line, as well as measuring line noise up to 1 kv peak. Noise amplitude and position are continuously adjustable and a sweep mode is provided for scanning noise pulse over 360°. Beckman Instruments Inc., Harbor Blvd., Fullerton, Calif. [362]



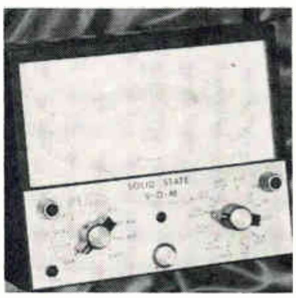
Strip-chart recorders designated Speedomax XL series offer advanced circuitry and finger-tip ease of operation. For fast readability, the black calibration of indicating scales is set against a contrasting yellow field. Pen response is as fast as ⅓ sec full-scale; accuracy, ±0.25% of span. Prices start at $800. Leeds & Northrup, Sumneytown Pike, North Wales, Pa. 19454 [363]



Solid state, FET-input multimeter model 2795 is battery operated. The unit has 68 switch-selectable functions. It is temperature compensated over a range of 0° to 50°C, with a rated accuracy of ±1% for both a-c and d-c. It features 10 megohm input impedance on a-c and d-c ranges above 10 v and negligible voltage drop. Simpson Electric Co., 5200 W. Kinzie St., Chicago 60644 [364]

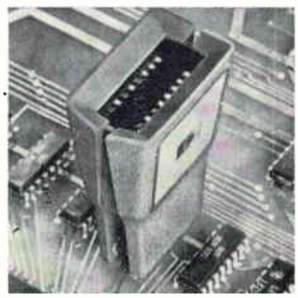


Intermodulation distortion analyzer was developed to meet production-line requirements for high quality audio components. It features accurate measuring capability through 0.01%, and guarantees a residual intermodulation level of less than 0.005%, with 7 full-scale ranges from 100% to 0.1%. Crown Int'l Radio & Electronics Corp., W. Mishawaka Rd., Elkhart, Ind. 48514 [365]



Portable, battery-operated volt-ohm-milliammeter model 801 features low power ohms for IC's, 5-mw sensitivity and 10-megohm input resistance. It provides a-c/d-c current measurements of 5 μa to 1.5 amps and permits db measurements of −70 to 66 db. It uses a 25 μa suspension movement meter with 7½ in. scale length. Price is $200. Triplett Corp., Bluffton, Ohio 45817 [366]

Bidirectional counter model MDBC Mini-Diget will count incoming positive pulses at a rate exceeding 15 Mhz and, with proper signal applied, add or subtract these pulses to arrive at a net accumulation. Provisions within the unit enable the user to preset to an arbitrary count of zero before initiating new count. Instrument Displays Inc., 18 Granite St., Haverhill, Mass. [367]



Logic clip model 10528A is a handy troubleshooting and design aid that clips onto TTL or DTL IC packages and instantly displays the logic states of all 14 or 16 pins. It has 16 light-emitting diodes, each of which follows voltage-level changes on one pin. A lighted diode indicates a high logic state (+5 v). Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, Calif. 94304 [368]

Circle 151 on reader service card→

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Pick it. The LM 1490's reference can be a Weston cell, a zener-diode source, or an external signal.

voltage being measured, hooks into the reference, and adjusts itself to compensate for any drift. The whole process takes but a few milliseconds. Solartron offers a choice of reference—a saturated or unsaturated Weston cell, a zener-diode source, or an external signal.

Like most standards-lab dvm's, this meter digitizes a signal by sending it through a voltage-to-frequency converter and counting the pulses from the converter for a preset period, called the integration time.

The 1490's ranges operate from 20.0000 millivolts to 1000.00 volts. Accuracy is: (±0.001% full scale ±0.003% of reading ±1 microvolt).

How sensitive the meter is depends on the integration time, range, and amount of filtering chosen by the user. Set to its 20-mv scale and running at six readings per second (five readings for 50-hertz line power), the 1490 resolves 100 nanovolts. In its 1,000-volt scale and making 600 readings a second, the meter resolves 1 volt.

Solartron engineers say that ability to handle noise is another of the instrument's strong points. Series-mode rejection is 90 decibels and common-mode rejection is 160 db (both ratings for 50-hz power). The user can make the noise rejection even better by hitting the x10 button, increasing the integration time while holding the sensitivity constant; the x2 button, synchronizing the power-line signal with the clock signal that sets the integration time; or the filter button, adding 30 db of rejection to signals that have frequencies higher than 50 hz.

Solartron Electronic Group Ltd., Farnborough, Hampshire, England **[369]**

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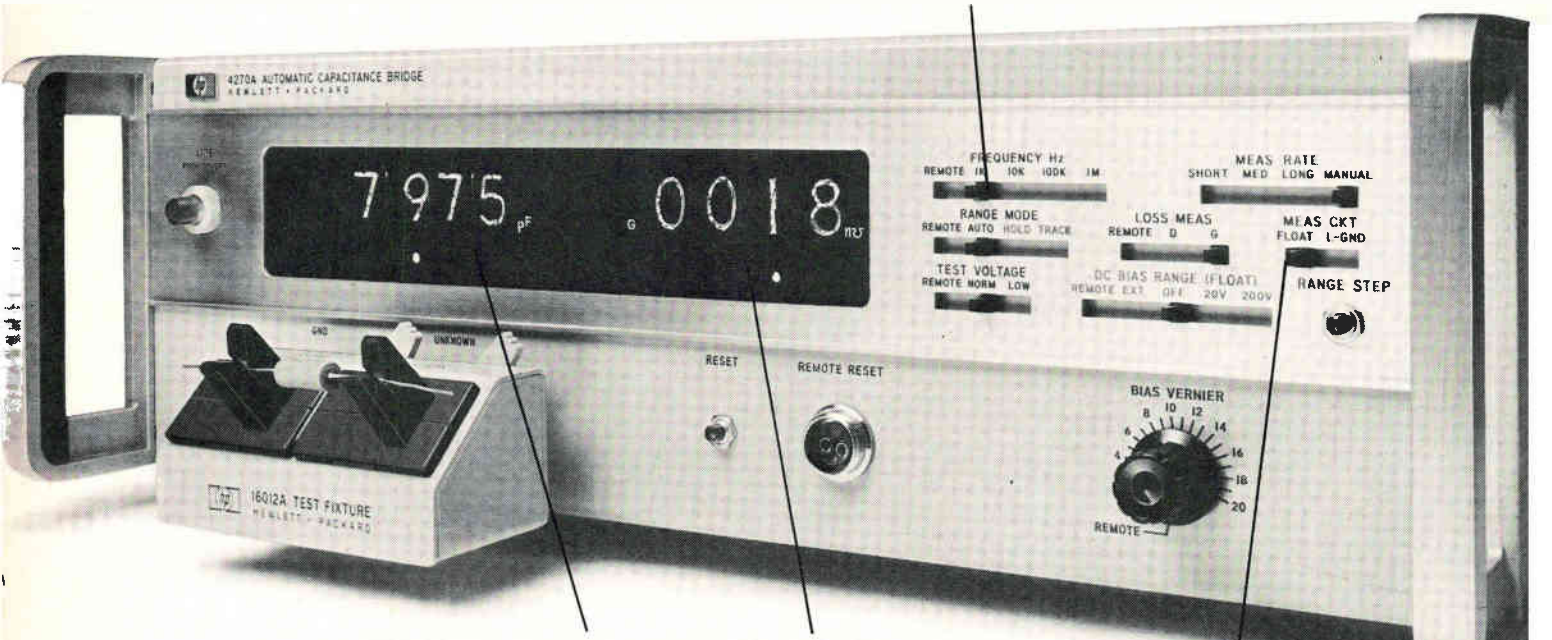
4 Test Frequencies. The HP 4270A is the only automatic capacitance bridge giving you four test frequencies covering the 1 kHz to 1 MHz range.



Wide Range. Measures from .001 pF to 1.2000 pF in six automatically selected ranges, to handle most popular components and devices.

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In short, the HP 4270A is engineered specifically to meet all the requirements of circuit design, component evaluation, incoming inspection and QA. Built-in programming and BCD output equip the instrument for systems applications as well. And it does all this for $4825. Your local HP field engineer has all the details. Give him a call, or write to Hewlett-Packard, Palo Alto, California 94304; Europe: 1217 Meyrin-Geneva, Switzerland.

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Circle 154 on reader service card

Power supply eliminates switching regulator

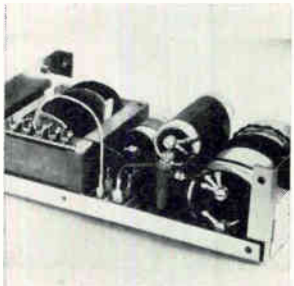
Low-voltage drop across series-pass element increases efficiency of power supply to better than 50% at 5-volt outputs

What happens when you decrease the voltage drop across the series pass transistor in a regulated power supply? The power dissipation is decreased, resulting in greater efficiency. And along with greater efficiency come better reliability and higher mean time between failures. These are the virtues Dynage Inc. claims for its new L-Series, d-c power supplies that achieve efficiencies greater than 50%, compared to conventional series regulators with typical efficiency figures of 30% to 35% at 5-volt output levels.

Normally, there's about a 3-volt drop from the collector to the emitter of the series-pass transistor, accounting for 30 watts of loss at 10 amperes. The L-Series has a voltage drop of 1 volt across the series element, or a 10-watt loss. In addition, no switching regulators, silicon-controlled rectifiers, and d-c to d-c converter techniques are used in the L-Series. All of these can add noise to the system.

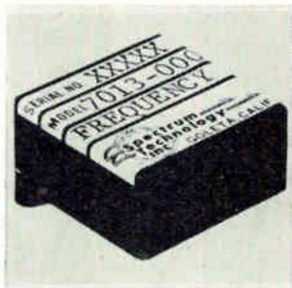
Redesigned out. "We eliminated the regulators, SCR's, and d-c to d-c converters by redesigning the series pass section," says Peter Klein, marketing manager. Klein

Vhf/f-m solid state maritime receiver MR-201 consists of a 25-w unit in a rugged splash-proof case, a control panel, speaker panel and a handset. It uses only one crystal in a stabilized master oscillator, permitting immediate use of all 55 of the new maritime channels. It provides rapid channel selection through digital tuning. Collins Radio Co., Dallas 75207 [381]



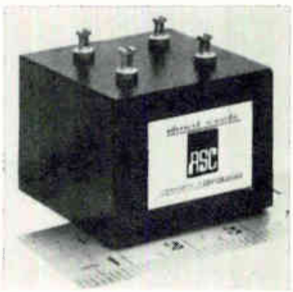
Partially regulated module power supply features adjustable taps to increase its flexibility. The taps provide 5 selectable outputs over a range of about ±10% using a flying-lead and clip arrangement. The PRM comes in 17 models. Model PRM12-5 (nominal 12 v, 5 amps) can be set up for voltages of 10.4, 11.2, 12.0, 12.8 or 13.6. Kepco Inc., 131-38 Sanford Ave., Flushing, N.Y. [382]

Power supply modules are available in 3.6-v, 5-v, and 15-v packages. They are housed in aluminum and epoxy cases only 2 x 2 x 3 in. Designed for military and aerospace as well as commercial-industrial use, the three modules meet a wide range of applications. The 1 to 24 price is $59; the 100-plus price, $49. Delta-Tronics Corp., 1710 E. Princess Dr., Tempe, Ariz. 85281 [383]

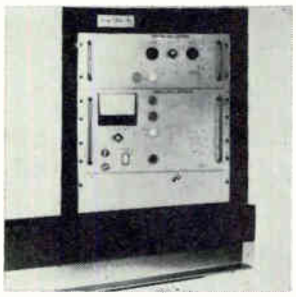


Subminiature, temperature compensated, crystal oscillator measures ½ cu. in. in volume. Frequency range is 6 Mhz to 20 Mhz (any specified frequency). Calibration accuracy is ±1 ppm at 25°C. Input voltage is any specified voltage between 12 v d-c and 20 v d-c; current, 6 ma to 30 ma depending on load. Regulation is ±1%. Spectrum Technology Inc., Box 948, Goleta, Calif. [384]

Dual-output tracking power supply LXD-3-152 is designed to power operational amplifiers. It features tracking accuracy of 0.1% absolute voltage difference for all conditions of line, load and temperature. Regulation is 0.1%, line or load. Ripple is 1.5 mv rms, 5 mv peak-to-peak. Temperature range is 0 to 71°C. Lambda Electronics Corp., Broad Hollow Rd., Melville, N.Y. [385]



Power supply ASC-E21 incorporates electronic circuitry for powering up to 10 or more square inches of illuminated electroluminescent load. It is capable of operating over a wide d-c input voltage range. It will start at an input voltage level as low as 1.5 v d-c. It operates at a minimal input voltage of 9 v d-c. Daedalus Communicators, 1 Mitchell Place, New York 10017 [386]



Laser system RG/1,000 produces 1,000 Mw of laser radiation with ruby or neodymium laser rods. Repetition rate is 1 pulse per minute. The system uses a Pockels cell Q-switch. Line widths less than 0.06 angstrom and beam divergence of less than 3 milliradians full angle can be achieved with ruby laser rods. Image Optics Inc., 1101 Colorado Ave., Santa Monica, Calif. 90404 [387]

FET-input differential operational amplifier model 40 features 10^{11} ohms input impedance, 50 pa/°C bias current and bias current drift, 50 uv/°C voltage drift, 5,000 common mode rejection, 200,000 open loop d-c gain, 100 khz full power response, and ±10 v, 5 ma rated output. Unit price is $12; availability, from stock. Analog Devices Inc., 221 Fifth St., Cambridge, Mass. [388]

... includes built-in overvoltage protection ...

said that the approach was simple, but would not reveal details.

Standard features in the L-Series, usually found only as an option in other units, are the adjustable built-in overvoltage protection and parallel operation. "The overvoltage protection is temperature compensated so the customer can be pretty sure that if the temperature goes up, the overvoltage set point won't," says Klein. The point is set to its nominal value, and if the customer wants a different setting, he can adjust it to fit his own requirements, Klein adds.

The parallel operation feature allows four power supplies to be connected in parallel with current shared between the supplies while remaining within ±5% of each other without degrading the specifications.

Clamping resistors are connected between the remote sensing terminals and the main power output terminals to prevent the output voltage from rising to a dangerous level when a sense lead is inadvertently opened. The clamping resistors have a negligible effect on the ±0.3% load regulation of the supply.

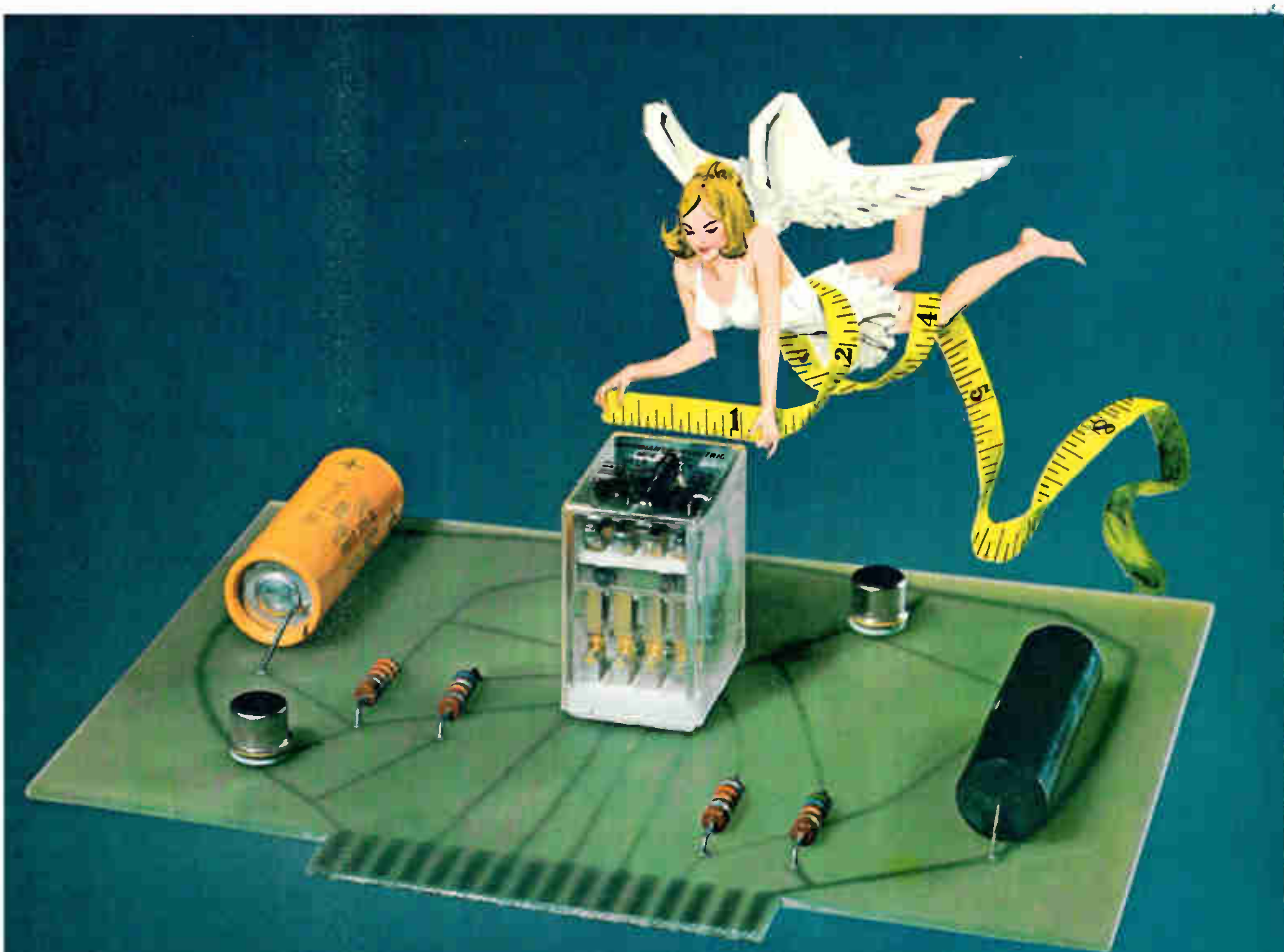
Other standard features of the L-Series include automatic overcurrent protection, thermal overload protection, and remote sensing. Remote programing capabilities also are featured.

Better mtbf. The mtbf figures for the L-Series are 30% to 60% greater than for the Dynage H-Series power supplies. The 75-amp unit runs for about 45,000 hours—a gain of about 15,000 hours on the older units.

The units come in five case sizes, all ready for mounting in a 3½-inch rack adapter. The units can be mounted on one of four sides in any mounting plane with other single and dual output power supplies.

The Dynage L-Series supplies have the highest watt-per-cubic-inch rating of any of the series regulators currently on the market. Full power rating is maintained at all input frequencies without derating.

Prices run from $139 for the 5.5-



Trust your Guardian Angel

for the newest 4PDT—5amp miniature relay

Give us a cubic inch on your printed circuit board . . . and we'll fill it with a plug-in relay. The logical relay for logic systems, computers, business machines—any application requiring maximum endurance and reliability in minimum space. Our new 1310, 4PDT-5 amp miniature relay is just a little more than one cubic inch in size, with inductive load contact rating of ⅛ hp @ 120V 60 Hz. But the small size doesn't limit its mechanical life of 100 million operations DC, 50 million AC. Minimum!

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MANUFACTURING COMPANY · 1550 West Carroll Avenue, Chicago, Illinois 60607 amp supply to $525 for the 75-amp unit. All units will be on a 72-hour delivery schedule by June 15.

Specifications

Nominal output voltages	5, 12, 15, and 24 volts
Output current ratings	1.4 amps to 75.0 amps
Combined line and load regulation	±0.5%
Load regulation	±0.3%
Line regulation	±0.2%
Ripple voltage	5 mv rms (max.) 15 mv p-p (max.)
Temperature coefficient	±0.05%/°C
Operating temperature range	−20°C to +71°C

Dynage Inc., 1331 Blue Hills Ave., Bloomfield, Conn. 06002 **[389]**

New subassemblies

Midispeed printer is minipriced

Size of electric typewriter, impact unit runs at 300 lpm and has a $4,995 price tag

A small group of engineers, whose specialty was the design of impact line printers, formed their own company about a year and a half ago to produce a low-cost, medium-speed printer for the minicomputer market. They reasoned that they could build the printer that would cost less than comparable models from well-entrenched companies, yet still provide the user with a machine tailored to his needs, because theirs wouldn't need the costly mechanical parts essential to high-speed printers, which operate at about 1,000 lines a minute.

Syner-data unveiled its first model—Alpha—at the Spring Joint Computer Conference last week. The Alpha is a fully buffered, 300 line-per-minute, 80-column printer, not much larger than an electric typewriter. It uses standard carbon interleaved pin-fed paper, weighs less than 100 pounds, and contains the 64-character ASCII subset.

The unit will sell for $4,995 in OEM quantities of 50, and $6,660 for single units. In addition to the buffer, the price includes the inter-

... data-transfer rates to 400 khz in parallel ...

face electronics for most small computers currently on the market.

Syner-data uses punch-press parts which are more conducive to high-volume manufacturing techniques and help considerably in reducing the costs.

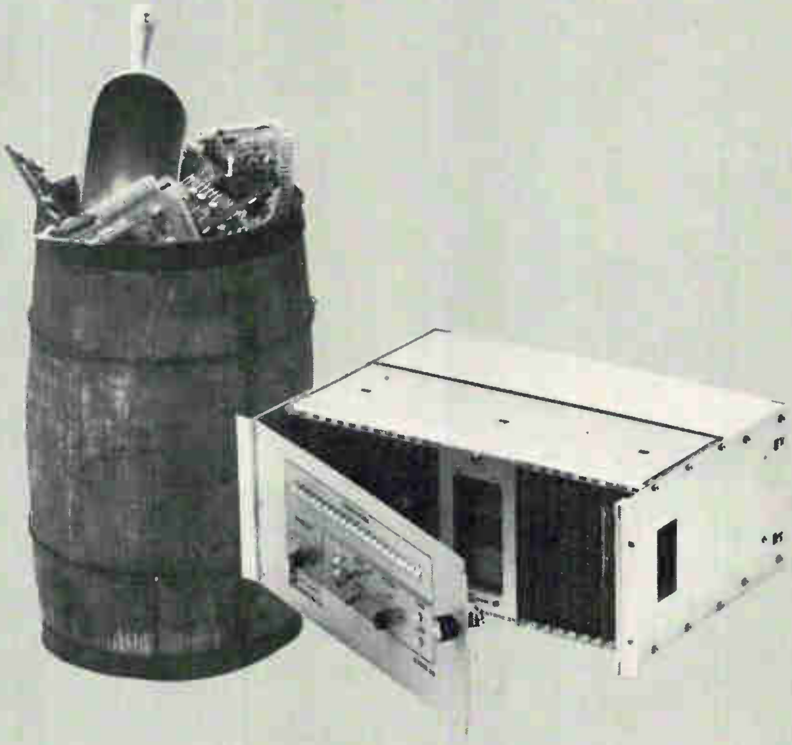
Hits drum. The Alpha still uses the conventional print-drum approach, but instead of a ribbon, it uses a Porelon ink roller. The roller is a cylinder saturated with ink that makes contact with the surface of the print drum.

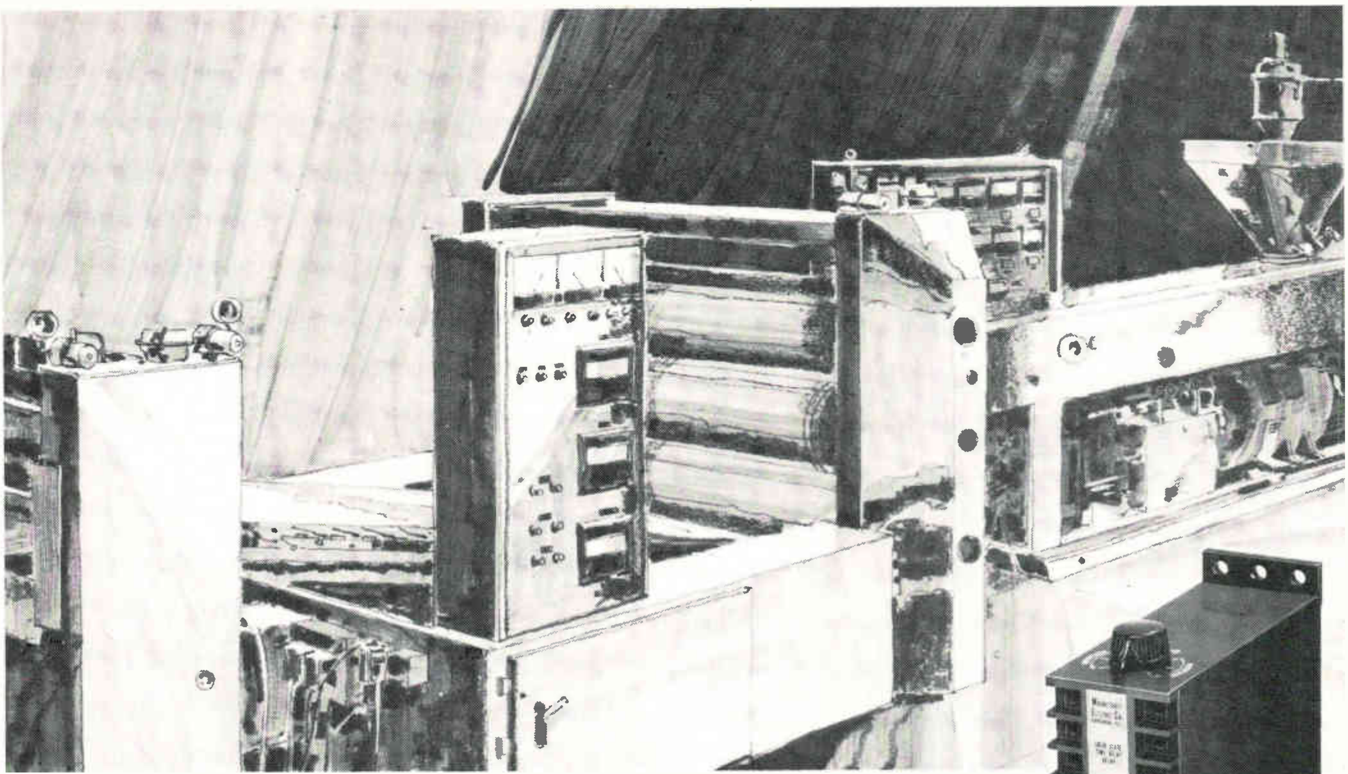
Wordsmith. Newly formed Syner-data showed off its first product—a fully buffered, 300-line-a-minute, 80-column printer—at the SJCC. Weighing less than 100 pounds, printer sells for $4,995.

The buffer handles data-transfer rates up to 400 kilohertz in parallel and 4,000 baud in serial. While the unit comes as a completely buffered printer with all interface electronics, the printer is also available to OEM customers without the buffer or any of the electronics except that for the drive mechanism.

Production quantities will be available in June.

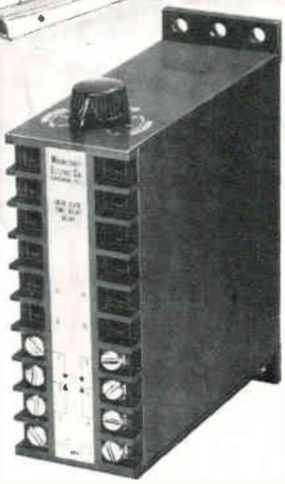
Syner-data, Route 128, 133 Brimbal Avenue, Beverly, Mass 01915 [390]





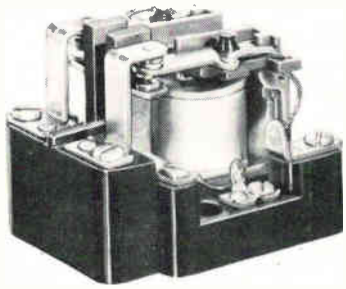
MAGNECRAFT THE CONTROLLER

Heavy duty time delay and power relays for rugged industrial applications



Class 211M
Class 112M
Time Delay
Relay

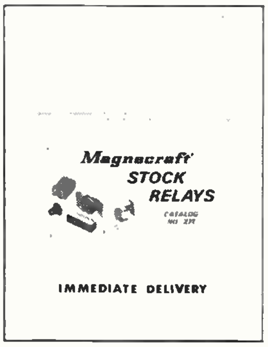
The Solid State (hybrid) Class 211M time delay relay is designed for heavy duty service requiring accurate time delay control with ±5% repeatability. This time delay relay makes use of hybrid technology combining solid state circuitry for the timing function with an electromechanical relay for DPDT 10 ampere output switching. This highly reliable relay operates on AC or DC, has an adjustable delay for either operate time or release time. The surface mounted molded plastic enclosure incorporates screw terminals. In stock for immediate delivery, this new relay costs less than $29.00 in single quantities.



Class 99 Heavy
Duty Power Relay

The Electromechanical Class 112M time delay relay comes in a package similar to the 211M. However, it utilizes a highly reliable precision air dashpot for the timing function, and an electromechanical relay for the 10 amp DPDT output switch. The designer will quickly recognize the inherent quality and simplicity in the design. Also in stock for immediate delivery, this time delay relay costs less than $29.00 in single quantities.

The Class 99 is ideal for heavy duty industrial power relay applications. Occupies less than 2½" x 2½" x 2⅛" of space. Yet, it's capable of switching 115 volts at up to 50 amps. Available with a "Magnetic-Blowout" for greater arc suppression and increased DC switching. Class 99 power relays can be supplied with contact combinations from SPST to DPDT at ratings up to 50 amps and in Underwriters Laboratories Listings. In stock for immediate delivery and priced as low as $5.66 in single quantities.



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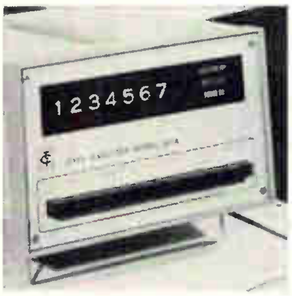
Digital filter is programable

It synthesizes variety of filter functions without hardware changes; memory stores up to 200 12-bit words and can be controlled by computer

Filtering in digital communications has always been a one-for -one situation: one filter served to pass or reject one set of frequencies; for other values, you had to use other filters. Now Electronic Communications Inc. has developed a programable digital filter that can synthesize, without any hardware changes, any filtering function that has a convolution integral. Furthermore, the filter is said to provide better amplitude-versus-frequency characteristics than conventional analog units while maintaining linear-vs-frequency characteristics, or constant envelope delay.

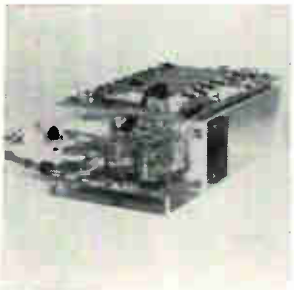
The filter, actually a special-purpose real-time digital computer, is the first developed for industry, says R. K. Keenan, manager of research and advanced development at ECI. It's programed through a tape reader and a solid state shift-register memory. Direct real-time computer control of the memory, another feature, provides time-varying adaptive filter capability. The unit also can do the same jobs as correlators and discrete fast Fourier transformers, and has numerous other capabilities.

One important application for



Compact data analyzer 301-A verifies operations of various devices and communications lines that make up data communications systems. It incorporates a regulated d-c power supoly and all circuitry and connections to attach directly to data terminal, modem or system. Transmission speed is 50-300 baud. Technical Concepts Inc., Jefferson Rd., Rochester, N.Y. [401]

Acoustical data coupler model 3300 is designed as a modular, self-contained unit for quick mounting directly on a model 33 Teletype with plug-in connections for error-free transmission between computers and remote terminals via telephone handsets. It can be installed in less than five minutes. Digital Techniques Corp., 4248 Delemere Court, Royal Oak, Mich. 40073 [402]

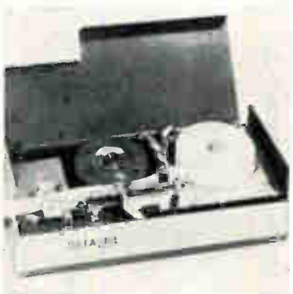


Data/telegraph response unit model 411 will generate four different responses of up to four characters each. A response is generated when one of four input circuits is triggered. The four codes can be ganged to produce two 8-character answers or one 16-character answer. Unit eliminates maintenance. Pulse Communications Inc., 5714 Columbia Pike, Falls Church, Va. [403]

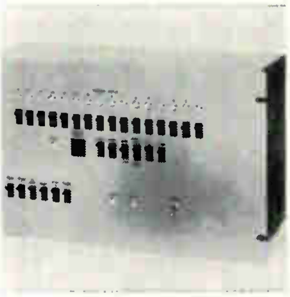
Drum system PDP-10 consists of an interfacing controller and a 9-million-character drum memory with an average access speed of 17 msec. The entire system is packaged in a single unit requiring only 18 sq ft. It may be expanded to provide a mass storage media for PDP-10 users of up to 72 million characters. Bryant Computer Products, 850 Ladd Rd., Walled Lake, Mich. 98088 [404]

Data-Verter central magnetic tape terminal model 5237 is for gathering information sent over the telephone network from source recorders. It communicates with acoustical or unattended transmitters and records information on IBM compatible 9-channel magnetic tape in ASCII or EBCDIC code. Terminal's rental is under $500 per month. Digitronics Corp., Albertson L.I., N.Y. [405]

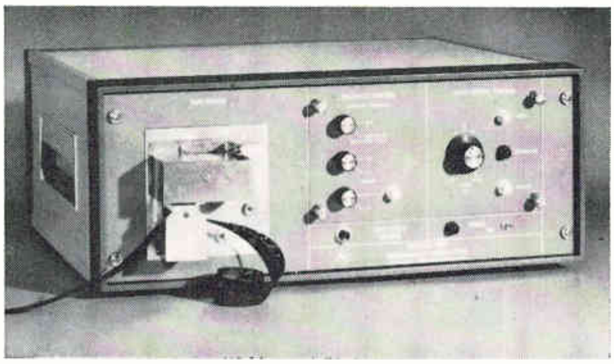
Full-scale crt terminal called Envoy weighs 30 lbs and is packaged in a rugged carrying case. It displays up to 1,024 alphanumeric characters on a 5-in. diagonal crt. Compatible with teletypewriter data communication systems, it transmits and receives data over telephone lines at a rate of either 10 or 30 characters per sec. Applied Digital Data Systems Inc., Hauppauge, N.Y. [406]



Desk-top strip printer model 3064-C is for the printed-copy data terminal market. It is less than 8 in. long and weighs 4 lbs. It can print 30 characters per second asynchronously. Still, a minimum of 100 million maintenance-free operations is assured. Prices, determined by quantity, range from $555 down to $391. Dataline Inc., S. Boro Line Rd., King of Prussia, Pa. 19406 [407]



Programable adaptable controller PAC-16 is a byte-oriented minicomputer with a repertoire of Instructions for inputting, storing, manipulating and decision making. It is adaptable to system interfacing requirements with 35% of available logic space reserved for customer logic requirements. Price ranges from $3,000 to $3,850. Varisystems Corp., Newtown Rd., Plainview, N.Y. [408]



Synthesizer. A new filter is created by reprograming the model 999, using paper tape.

the ECI unit is real-time experimental determination of the effects of various filters on system performance. The filter's maximum input frequency of 3.5 kilohertz can be extended to process r-f and i-f merely by using a mixer and local oscillator, provided the bandwidth of the processed signal does not exceed 3.5 khz.

Applications. Matched filtering in data processing systems, where data bit determination is a necessity, is another application for the filter, as is low-frequency modulation and demodulation. Comb filtering for spectral analysis of signals and line equalization, independent of the type of modem used, also can be done. The unit can be used in special-purpose voice processing—filters associated with vocoders can be realized by time-sharing between voice channels, says Keenan. Adaptive or time-varying signal filtering also is possible. It's a difficult task in analog filters because the time required for an analog filter to adapt is limited by the filter's bandwidth. But the ECI filter can adapt, or settle, in 100 microseconds, the inverse of its sampling rate of 10 khz.

With ECI's device, a bandpass filter can be constructed with bandwidth of 3 khz and exceptional frequency selectivity—attenuated by 55 decibels in 150 hertz—as well as a differential delay too small to be measured with conventional laboratory instruments. And if a filter with a different slope is required, say one equivalent to a 50-pole filter, all that need be done is cut a new paper tape using any general-purpose computer that uses Fortran.

This type of filter, when made using analog techniques, has 50 crystals and costs more than $750. The change in the ECI filter is implemented by running the tape through the filter.

Called the Model 999 programable digital filter, the unit comes with a software package that does not require expert knowledge of digital filters, says ECI. For common filters, all that's needed are the filter's requirements. Special filters can be synthesized using special Fortran software supplied with the unit.

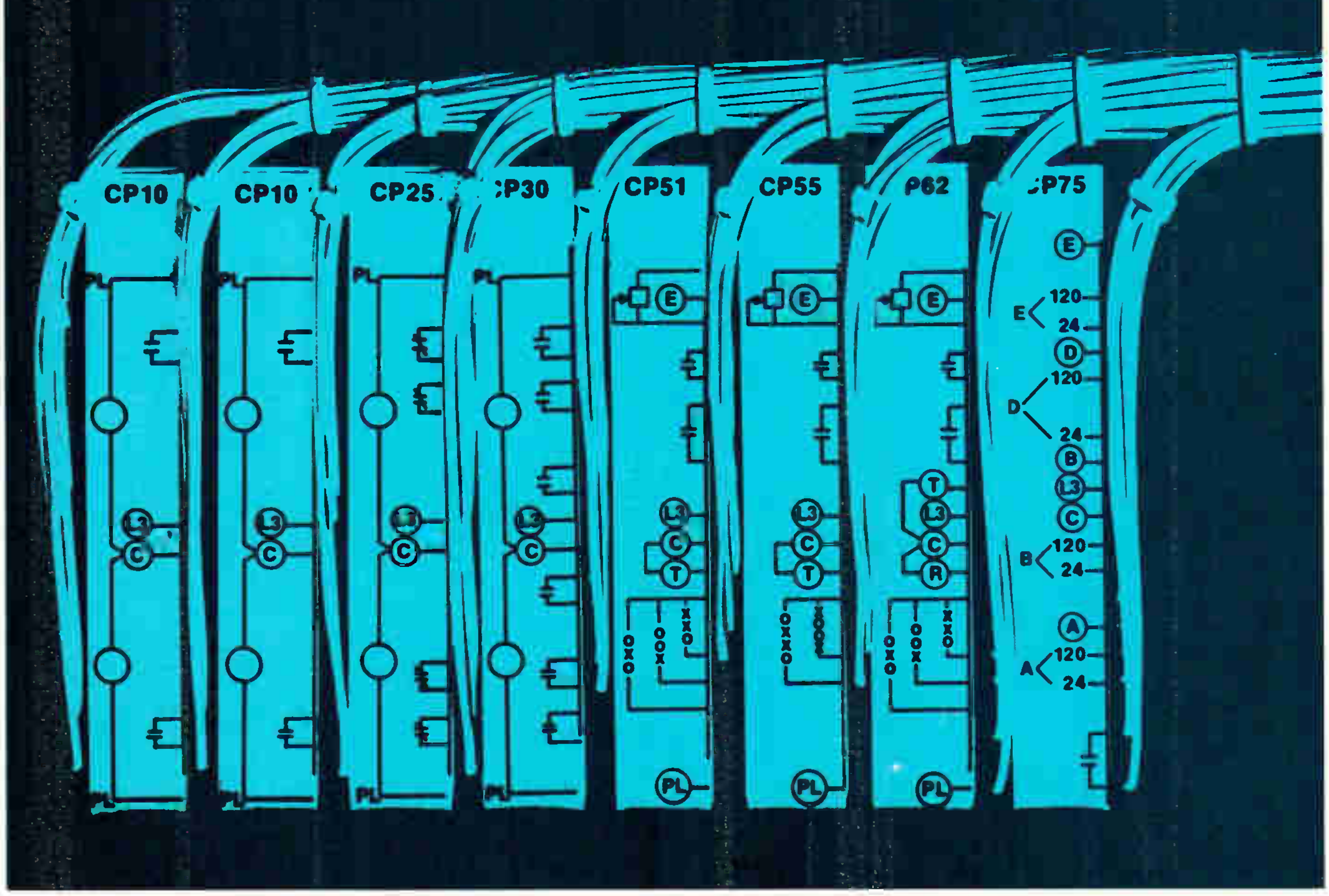
In operation, incoming analog signals are analog-to-digital converted; processed in a digitally implemented transversal filter; digital - to - analog converted, and smoothed to recover the processed anlaog signals.

The filter's memory is constructed using metal oxide semiconductor medium-scale-integration shift registers; its digital multiplier uses transistor-transistor logic. The total electronics package consists of more than 200 flatpacks. While an internal sampling rate of 10 khz is available, the user also can sample externally from 50 hz to 10 khz. The maximum temporal length of the shift registers is 20 milliseconds at the 10-khz sampling rate. The memory stores 200 12-bit words. Filter coefficients are entered into the memory in 90 seconds via the paper tape reader. However, if faster entry is desired, a computer can be hardwired to the Model 999 and all 200 words changed in 100 μsec.

The unit measures 7⅝ by 19⅝ by 18 inches and will be priced under $20,000. Options, such as a card reader and special-purpose software to customer specifications will be available; a plug-in providing correlator capability and a multiplexer for time-sharing are under development.

Electronic Communications Inc., Box 12248, 1501 72nd Street North, St. Petersburg, Fla. 33733 **[409]**

Solid state is no mystery if you can read this



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Get the simple facts about Controlpac, today. Write for Bulletin 35C. Eagle Signal Division, 736 Federal Street, Davenport, Iowa 52803

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a systems division of
GULF + WESTERN INDUSTRIES, INC.

D-a converter is all integrated

Ladder-resistor network deposited directly on silicon chip; accuracy, eight-bit resolution holds over —55°C to +125°C

Although digital-to-analog converters are available in monolithic integrated circuit form, they invariably require a separate ladder-resistor network, and they are not accurate for the full temperature range called for in military and space equipment.

But a new IC, offered by Radiation Inc., has neither of these shortcomings. Radiation's RI-1080 d-a converter is completely integrated—the ladder network consists of thin-film Nichrome resistors deposited directly on the silicon chip. And the circuit is accurate to ±½ of the least significant bit (LSB) with eight-bit resolution over the —55°C to +125°C temperature range.

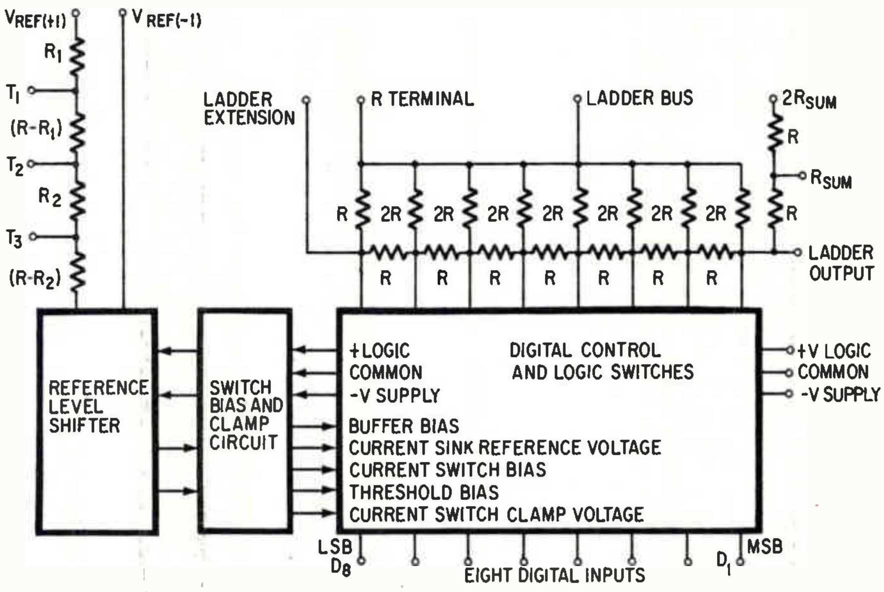
The circuit is fast, too. Its worst-case settling time is 1 microsecond to ½ the LSB of the final value. This permits conversion rates in excess of $1 x 10^6$ words per second, making it suitable for high-speed data correlation applications.

To get this kind of performance, the manufacturer uses dielectric isolation, instead of the usual p-n junction isolation, to separate the components on the chip. Dielectric isolation reduces parasitic capacitance and also permits incorporation of both npn and pnp transistors on the same chip without degrading the performance of either.

The RI-1080 contains eight current switches, a bias network, a reference level network (which contains the npn's and pnp's for greater accuracy), and the RA and 2R integral thin-film resistor network. R in the last network is purposely low—5 kilohms—to keep the impedance change low as portions of the circuit switch from on to off.

Fast switch. Current-mode operation was selected for the circuit to give fast switching. In addition, the current mode makes the IC virtually immune to spurious switching spikes because the current through the switches is held at a fairly constant level, thus preventing the abrupt current surges that occur in voltage-mode switching devices.

The IC requires two power supplies, ±5 and —15 volts, and an



Mister d-a. Thin-film Nichrome ladder resistors are set for R-5k. Integrated logic switches operate in current mode for speed.

external reference of 4 to 10 volts. It accepts eight digital inputs, either DTL or TTL. The analog output can be in one of three modes—single polarity with zero reference, single polarity with zero full scale, or dual polarity—depending on which of the integral input resistors the references voltage is connected to. With V_{ref} connected to the 5-kilohm input resistor terminal and the ladder bus terminal, for example, the output will be in the bipolar mode, with the output ranging from V_{ref} for all inputs high to $(-V_{ref} + \text{LSB})$ for all signals low.

The RI-1080 costs $82.50 each in 100-to-999 quantities. It's available off the shelf in a 24-lead, ¼-by-⅜ inch package.

Radiation Inc., Melbourne, Fla. [410]

Data handling

Minicomputer sells for $2,500

Rack-mountable machine can interface with teletypewriter

Low price is always a strong selling point, and officials at Computer Development Inc. are hitting it hard in the company's first product, the cd 200 minicomputer. The basic machine will sell for about $2,500, including the central processor and power supply in a rack-mountable enclosure that contains a serial interface for an ASR-33 or ASR-35 teletypewriter with a built-in hardware bootstrap routine. Another $1,000 will add a 1,000-byte core memory with a 1.2-microsecond cycle time; and about $2,000 will add 4,000 bytes. The basic memory is an eight-bit unit, but the company says all instructions operate in eight or 16 bits.

Richard Pasternak, vice president for engineering at the new firm in Santa Ana, Calif., considers the cd 200 his third-generation design. Pasternak designed the 520I when he was at Varian Data

Deflation. Low cost of cd 200—$2,500—is strong sales point.

Machines and did the logic design for the Micro Systems models 800 and 810 minicomputers. He figures the design is bound to be better the third time around.

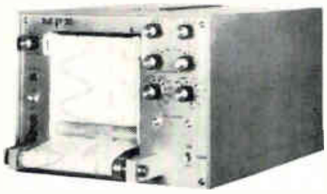
Pasternak says he realizes that in most computers, the costs of the central processor, mechanical portions of the machine, and the memory are about equal. "We went to work on this relationship," Pasternak says, "and now the mechanical portion costs much less than the CPU, and the CPU and memory costs are about equal."

Price cuts in semiconductors are only a small part of the Computer Development economy story. The machine uses mainly transistor-transistor logic, and a good deal of this is at the USI complexity level—30 to 40 gates. One feature of the cd 200 that company officials believe is unique in such a low-priced machine is a universal bus instead of individual ports for the hardware connected to the CPU—the memory, input-output devices, front panel, and direct memory access.

"All of these complicate the mechanical design of the CPU," Pasternak explains, "so we decided to combine all of them in one bus. They all share the same set of wires. This allows us to construct an economical back-wiring plane that can receive connections from all four, including a number of memories."

Only three boards are required for the machine's CPU, leaving 12 plug-in connectors for optional devices—additional memory or I/O devices. Pasternak says the user likely will allocate this space so that one board slot might be filled

beetle of the industry:



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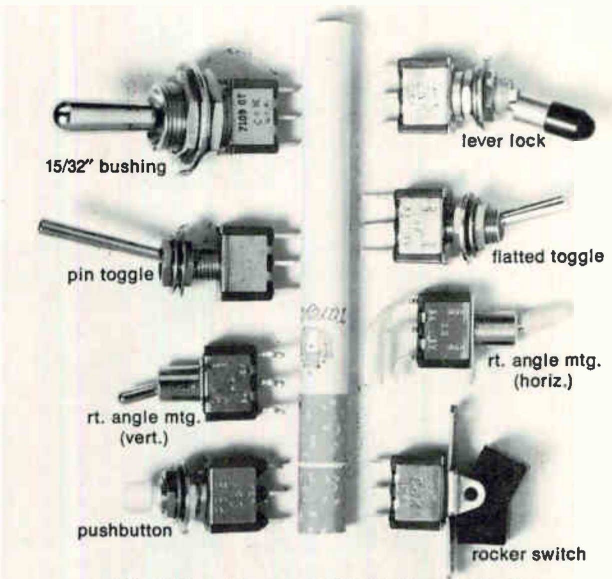

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with 4,000 words of memory, and typically three or four others devoted to I/O devices, leaving plenty of room for expansion.

Expansion is facilitated by both the universal-bus design, allowing additional memory or I/O devices to be plugged in on additional boards, and by the cd 200's asynchronous memory interface feature. The latter allows mixing of memory technologies to take advantage of speed where it's wanted, or to plug in new memories as they become available. For example, the machine has been run with a high-speed biopolar IC memory of up to 128 bytes with a 50-nemosecond cycle time, and a 1,024-byte MOS IC memory with a 1.5 microsecond speed. Thus core and semiconductor memories can be mixed, and there's also provision for variable-capacity read-only memories.

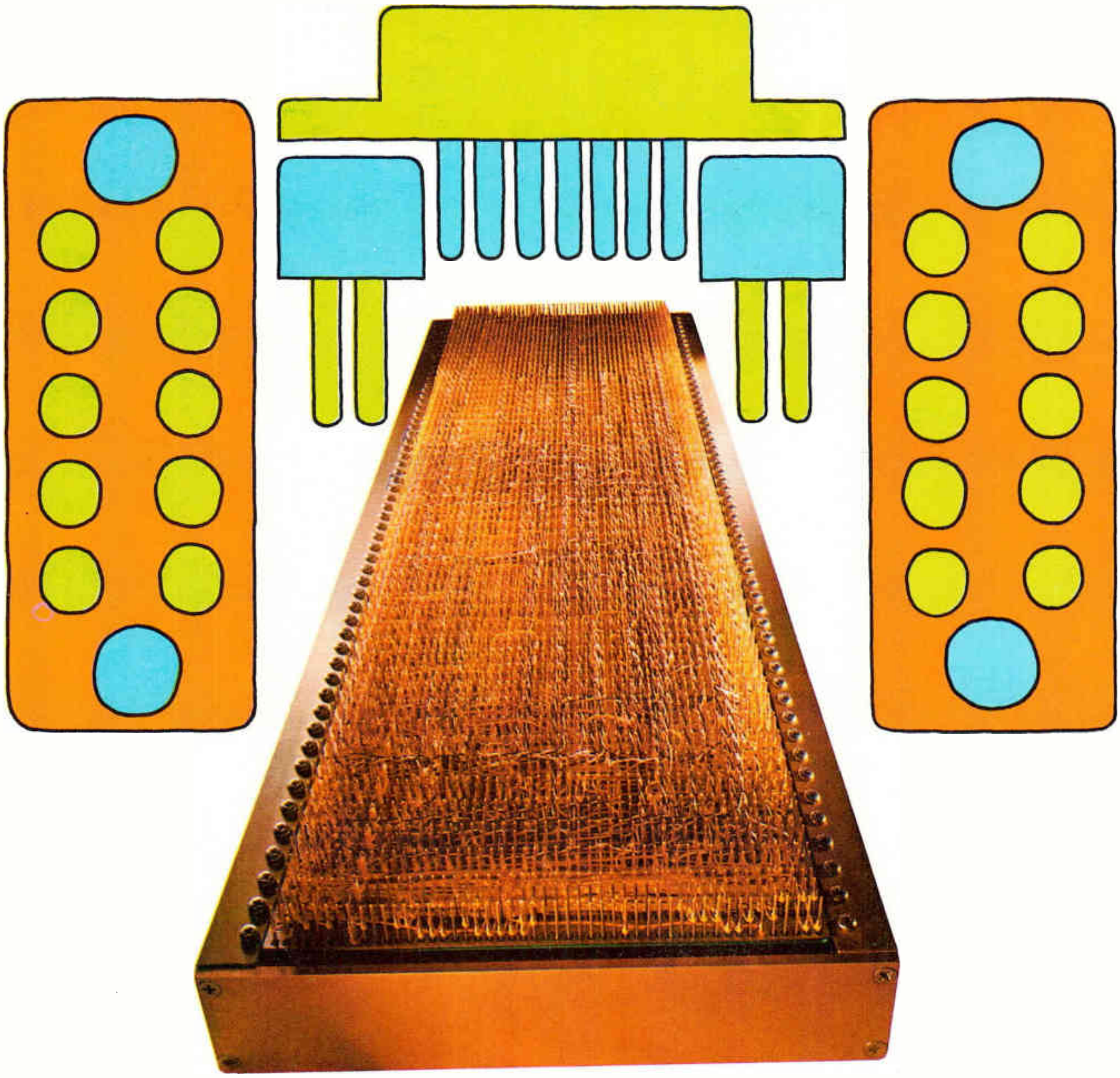
The memory organization is such that the first 61,439 bytes are allocated to memory and bytes 61,440 through 65,536 are for I/O controllers. "The only difference between memory and an I/O device, is the address," Pasternak notes. "This saved us money by allowing us to eliminate extra instructions to accommodate I/O." Further, all I/O devices can directly access the memory. This feature will be built into those devices "in which it makes sense," says Lambuth Cox, vice president for marketing. As examples, he lists tape controllers and disk and crt drives.

The cd 200 has 69 instructions and "several hundred modifications," says Pasternak. He feels the instructions are best suited for both I/O and list processing. Computer development will offer a Fortran assembler and simulator in its basic software package free.

Company officials believe 40% of the applications will be in communications—for concentration and preprocessing, for example. Another 30% of the machines are expected to be used as special controllers, such as buffer controllers for crt's, plotters and optical reading equipment, and another 30% in markets not yet cracked by minicomputers. The three CPU boards will be sold separately for $1,600.

Deliveries will begin in August.

Computer Development Inc., 3001 Delmler St., Santa Ana, Calif. 92705 [411]



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WINCHESTER ELECTRONICS

DIVISION OF LITTON INDUSTRIES

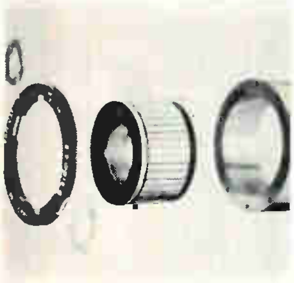
Interferometer goes right to work

Feedback loop keeps laser output constant, so there's no warmup period; instrument has range of 200 feet and resolution of 1 microinch

Like prizefighters and vacuum-tube radios, most laser interferometers need some warmup. The 5500A is an exception. Developed by engineers at the Hewlett-Packard Co.'s Santa Clara division, this interferometer is ready to work as soon as it's turned on. Since these distance-measuring devices find most of their work calibrating or controlling machine tools, zero-warmup time means getting jobs through shops a bit faster.

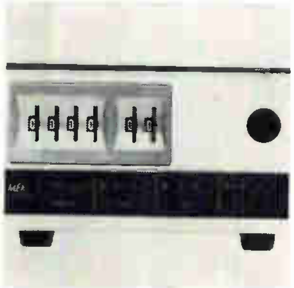
Despite the fact that laser interferometers are relatively new to the machine shops, H-P will find some competition. For example, Cutler-Hammer's AIL division just came out with a new one, the $15,400 Mark II [*Electronics*, April 13, p. 163]. However, project leader Gary Gordon says that his 5500A has several features besides the quick turn-on time. Its range is 200 feet; it resolves 1 microinch, its accuracy is 0.5 parts per million; it automatically tunes its helium-neon laser; and its averaging circuits keep the readings steady, even when there's vibration.

The 5500A looks like most other laser interferometers; it has three parts—a laser assembly; a reflec-



Direct-drive d-c torque motor D-3180 has been developed for positioning of control surfaces in light business aircraft. Peak torque is 480 oz in. and power input at peak torque is 260 watts. Friction torque is 10 oz in., and ripple torque is 7% average to peak. No-load speed is 73.5 radians per second. Litton Precision Products Inc., Marple at Broadway, Clifton Heights, Pa. [421]

Resistance sensing power relay uses electrodes to detect the level of water, chemicals, or slurries in a storage tank. It can also operate as an ice bank control or condensation detector in protective control systems. Units came with either a 40 kilohm or 500 kilohm trip point. Output relay is rated at 8 amps. Mag-Con Engineering Co., 85 Richardson St. S.E., St. Paul, Minn. [422]



Solid state process counter series RCP uses IC techniques, permitting count rates up to 70 khz, with optional BCD display. The instruments are suited for all types of batching control operations, manual or automatic, and serve as ideal dividers for converting digital outputs from metering instrumentation to standard flow units. Machinery Electrification Inc., Northboro, Mass. [423]

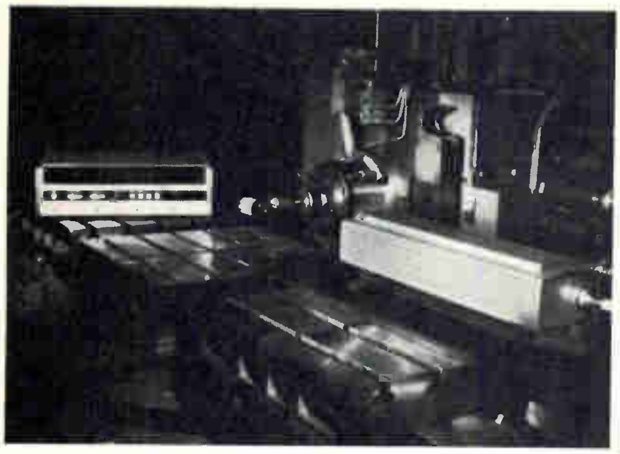
Solid state panel timer PT-100 has adjustable timing ranges from 100 msec to 1,600 sec. Accuracy is ±2% with repeatability to ±1% at constant temperature. Maximum time for reset is 50 msec. Operating ranges are from 12 v to 110 v, a-c or d-c, and four mounting options are available. Price (small lots) is under $25. Chronologics Inc., 24 Martin St., Webster, N.Y. [424]

Speed and draw indicators series 500 provide a digital readout of absolute speed or speed ratio (in %) between any two machines or machine sections as sensed by two hand photoelectric pulse gearmotors. Units are for use on any web process where speed between adjacent sections must be precisely monitored. Reliance Electric Co., 24701 Euclid Ave., Cleveland, Ohio 44117 [425]

Electronic totalizing counter series 7123 Econo-Flex is suited for high-speed totalizing and linear measuring for industrial production. The counter operates at speeds to 10,000 counts per sec. It has five counting decades and features in-line illuminated digital display with long-life tubes and polarized window filter. Veeder-Root, 70 Sargeant St., Hartford, Conn. 06102 [426]

Microminiature servo motor model 050/0011 features an ironless rotor designed to minimize ripple torque and optimize the torque-to-inertia ratio of the motor. It has a torque gradient of 0.75 oz in/amp and a torque-to-inertia ratio of 28,000 rad/sec^2. Friction torque is less than 0.004 oz in. Micro-Mo Electronics of New England, Box 227, Sudbury, Mass. 01776 [427]

Battery-powered, thermocouple-to-current converter TA-01 offers integral cold junction compensation. The thermocouple amplifier amplifies a 5-mv full scale signal (120° C) into a 100 μa output signal with an accuracy better than 1%. Load impedances up to 10 kilohms can be driven by the output circuit. Price is $50. Integrated Controls Inc., Box 17296, San Diego, Calif. [428]



Three parts. The laser assembly, at right, sends a beam to the reflector, at center. The control box, left, calculates the laser-to-reflector distance from the Doppler shift of the reflected beam.

tor, and a control box. And in general, it works like most other Michelson-type interferometers. Either the assembly or the reflector is mounted on an object, such as a lathe's carriage. The assembly's splitter sends half of the laser beam to the reflector and the rest to an reference channel. Because of the Doppler effect, the frequency relationship between the reference and the reflected beam is a measure of the distance between the laser and the reflector. After calculating this distance, the control box displays the result.

The difference between the 5500A and other units is that the H-P laser puts out not one but two frequencies. In single-frequency units, a single photodetector combines the reference and reflected beams, and puts out a d-c signal. The H-P unit handles the reference and reflected beams separately, and generates an a-c signal that is used for calculating distance. A-c operation, says Gordon, is the key to the 5500A's resolution and range.

Split-up. H-P engineers get two frequencies out of their laser by putting it in an axial magnetic field that splits the spectral line, generating two optical frequencies, f_1 and f_2, of opposite circular polarization. A splitter sends half of the beam along the reference channel to a photodiode whose output frequency is $(f_1 - f_2)$. The other half goes to a second splitter, which sends the f_1 portion out to the reflector and the f_2 portion along an internal path. The returning beam, whose frequency is $(f_1 + \Delta f)$, where Δf is the Doppler shift, recombines with f_2 in a second photodiode whose output frequency is $(f_1 + \Delta f - f_2)$.

After coming out of their respective photodiodes, the reference and the measurement signal each go to a frequency counter; the two counters drive a subtractor which keeps a running account of the frequency difference. Its output goes to the control box.

Feed rates. The 5500A can measure velocities up to 1 foot per second. Thus, the instrument can be used to measure feed rates.

Velocity measuring is one thing AIL's interferometer can't do. "We had it," says AIL product-line manager Joseph Engeman, "and we found there was no market for it."

Engeman hasn't seen H-P's unit, but after hearing specifications he concedes that its resolution, range, and warmup time are better than those of the Mark II. However he feels that the AIL unit is better in other areas. To demonstrate this he points to one feature that H-P chose not to be put on the 5500A. Temperature, pressure and humidity all affect the speed of light, and must be compensated for by any interferometer. With H-P's 5500A, the compensation is made by setting thumbwheel switches.

"The drawback here," says AIL's Engeman "is that the operator has to read his temperature, know his pressure, look up the humidity, and then look up on some chart some number which corresponds to these ratings. It's almost arbitrary as far as the operator is concerned; he doesn't know what it means. The way we do it, and the way Perkin-Elmer does it, is automatically; we have sensors (built into the interferometer). You don't have to go to a chart and look up a parts-per-million conversion."

Hewlett-Packard Co., 5301 Stevens Creek Blvd., Santa Clara, Calif. [429]

Circle 177 on reader service card →

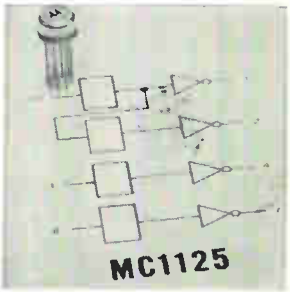
Read-only memory is field-programable

Integrated-circuit ROM is supplied as complete package, and user programs it with electrical pulses—no special masks

When an equipment design requires only a few read-only-memory IC's with a single program, or when many ROM's with different programs are required (as when ROM's are used as logic circuits), expenses can soar. ROM manufacturers ordinarily impose a mask charge—$1,000 or more—for each program required, on top of the price of the IC's. And time is a factor too; a delay of about six weeks from date of order to date of delivery is usual—again because a special mask is required for each program.

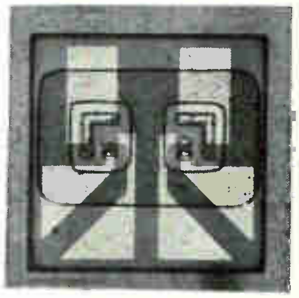
An IC from Radiation Inc. promises better times. Called PROM (for programable read-only memory), the IC requires no special masks. The customer programs with electrical pulses. He doesn't have to wait for masks to be made—and doesn't have to pay for them. Although user-programed ROM's were available previously, they had to be programed by mechanical means such as scribing the metal interconnections on the chip or cutting them with a laser beam. The ROM therefore had to be furnished to the customer as an unpackaged chip. Radiation's PROM,

Monolithic TTL compatible IC memory SM320 consists of 256 bits of data storage arranged in a 32-word eight-bit matrix providing total memory capacity of 32 eight-bit words. It operates from a nominal supply of 5 v. Typical access time is in the 30 nsec range. The device is rated for operation from 0° to +75° C. Sylvania Electric Products Inc., Main St., Buffalo, N.Y. [436]



Flip-flop MC1125G is a monolithic device consisting of four toggle mode flip-flops with buffered Q outputs that use no standby power when driving capacitive-coupled loads. Typical power dissipation is 75 mw and operation is from d-c to 1 Mhz. Typical input capacitance is 2.5 pf and cross-talk figure is under 1%. Motorola Semiconductor Products Inc., Phoenix [437]

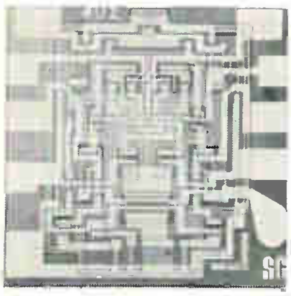
Integrated operational amplifiers TAA861 and TAA865 are d-c devices with a differential input and single-ended output. Output current is up to 70 ma. Input current can be set by adjusting the value of the externally connected d-c load. Applications are in control engineering, industrial electronics and a-f engineering. Siemens Corp., 186 Wood Ave. South, Iselin, N.J. [438]



Silicon matched pair, transistor chips are for hybrid circuits and differential amplifier circuits. They are designated DI 4044/4878, 4100/4879, and 4045/4880. Characteristics include: dielectric isolation; monolithic construction; high d-c gain; low capacitance; and close parameter match, from 10 μa to 1 ma. Dionics Inc., 65 Rushmore St., Westbury, N.Y. 11590 [439]

Solid state, red light-emitting diode 5082-4403 is functionally designed to displace miniature incandescent and glow lamps in indicator uses. The GaAs phosphide lamp is designed for self-mounting in panels or p-c boards. Typical useful life is 1 million hours. Unit is priced at 50 cents in large volume quantities. Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, Calif. [440]

P-channel, insulated gate MOS FET 3N174 features low leakage and high input impedance, important in minimizing drift in operational amplifiers and in providing high accuracy in electrometer circuits. At 25° C maximum drain current is −5 na; maximum gate-terminal current, −2.5 pa; low threshold voltage, −2 to −6 v. Texas Instruments Inc., P O. Box 5012, M/S306, Dallas [441]



Variable gain, frequency response beyond 50 Mhz, and provision for gating and agc are features of linear IC amplifier SG 1402. At 10 v, typical gain is 25 db and power consumption is just 50 mw. Applications include use as a wideband amplifier, balanced modulator or demodulator and as a phase switch. Silicon General Inc., 7382 Bolsa Ave., Westminster, Calif. 92683 [442]

H-v npn silicon power transistors now come as 700 v devices in production lots. Specifications include: saturation voltage less than 600 mv at 3 amps; sustaining V_{ceo} in excess of 500 v; and minimum h_{FE} at 3 amps of 15. Typical uses include vertical and horizontal deflection circuits for crt instrumentation. Solitron Devices Inc., Blue Heron Blvd., Riviera Beach, Fla. [443]

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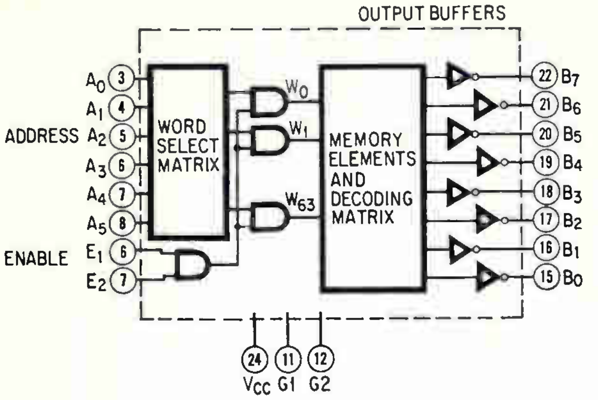
synthane·taylor

Synthane-Taylor Corporation, Valley Forge, Penna. 19481 • Plants: Valley Forge, Pa., Oaks, Pa., La Verne, Calif., Scarborough, Ont., Canada • An Alco Standard Co.



Set a bit. The memory is programed in the field by applying a negative current ramp to each bit position that will be a logical 1.

however, is supplied completely packaged in a 24-pin hermetically sealed 1-by-⅜-inch flatpack.

The PROM contains a word-select matrix, and a 512-bit memory and decoding matrix with the memory matrix organized as 64-eight-bit words. Also included are open-collector output buffers that permit wired-OR operations. The transistors are bipolar and are dielectrically isolated.

As delivered by the manufacturer, all bits in the memory are set at logic 0. To program the memory—to change 0's to 1's, as desired—the user first connects the IC as shown in the diagram. To address a particular word in the memory for programing, the input switches are set to the binary equivalent of that word; a 0 is represented by —7.0 volts and a 1 is an open circuit. All the bits in this word now are available for programing.

Now, at the pin associated with the first bit (B_0, B_1, . . . B_7 to be changed from a 0 to 1, a negative-going current ramp is applied, with the output voltage of the current generator clamped at —7.0 volts. The easiest way to do this is to connect the negative terminal of a variable power supply to the proper output pin, then manually increase the voltage to approximately 7.0 volts.

On the chip the metalization connecting the transistor for that particular bit opens when the current ramp reaches a certain level. The open circuit occurs at a necked-down portion of the metalization as a result of the high current density through it.

While the ramp is being applied, current increases to 50 milliamperes. At the instant the break occurs, current drops to about 15 ma, indicating that programing of the bit has been accomplished.

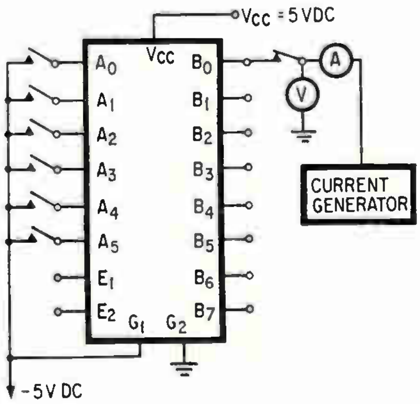
The procedure is repeated for each bit in the word.

More sophisticated electronics can be employed to make the programing process faster and more automatic. Radiation uses an automatic system to program ROM's for customers whose memory configurations are well established and are for standard patterns. Punched cards provide the program data.

The IC has an access time of 65 nanoseconds, a fanout of 20 ma, word-bit expandability, and parallel input, output, and chip-enable. It is compatible with DTL and TTL circuits. Total operating power is 400 milliwatts at 25°C. However, the enable feature permits power dissipation to be reduced to about 250 when the device isn't being addressed.

Price of the military version (—55°C to +125°C) is $61.50 apiece in 100 to 999 quantities. The commercial version (0°C to +75°C) sells for $47.

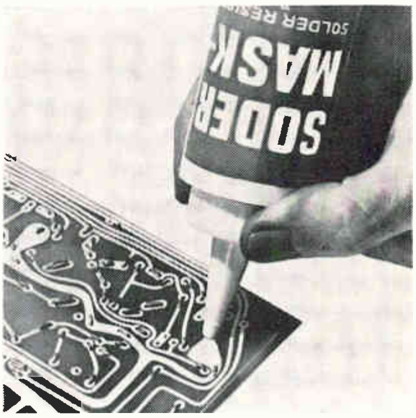
Radiation Inc., Microelectronics Division, Melbourne, Fla., 32901



Speed rating. Word-select matrix, memory, decoding matrix, buffers are on chip. Words are 8-bit units.

New materials

Coating protects solder-free areas



Liquid elastomer solder resist and coating mask called Soder-Mask protects contacts, holes, and areas on p-c boards that must be kept solder-free when boards are machine soldered. It is quicker, safer, and less expensive than other masking methods. It is available in two types—regular and water soluble. The regular formula can be removed after soldering by peeling or rubbing. The water-soluble formula is removed by washing in hot (140°-150°F) water. Both types can be applied by brushing, applicator, or syringe needle. Solder Removal Co., P.O. Box 1678, Covina, Calif. 91722 **[341]**

Both effective emi shielding and gasket rigidity are featured in the Metalex gasket. It consists of a resilient, single-fin emi shielding strip mechanically joined to an aluminum extrusion. Available in many cross sections, the aluminum strip can be mounted directly by spot welding, screwing, riveting, or similar techniques. Since the emi strip is firmly locked into the jaw of the aluminum extrusion, it is impossible for the two to separate. The combined emi strip and gasket are available from a minimum cross section width of $\frac{1}{2}$ in. and a minimum thickness of $\frac{1}{32}$ in. Matex Corp., 970 New Durham Rd., Edison, N.J. 08817 **[342]**

Four new **pourable** elastomeric compounds are made from butyl rubber. The excellent impermeability of these materials to water makes them especially suitable as flexible encapsulants for electrical insulation, and as conformal coatings for electronic uses. Hardman Inc., Belleville, N.J. 07109 **[343]**

High-temperature grade 1303 polyester molding compound is a glass-reinforced premix type, electrical-grade material based on the company's grade 200 laminate-resin system and formulation. It is presently used primarily in coil forms and bobbins. The Glastic Corp., 4321 Glenridge Rd., Cleveland 44121 **[344]**

New Books

Gap-bridger

Linear Systems Analysis
Laurel J. Lewis, Donald K. Reynolds, F. Robert Bergseth, and Frank J. Alexandro Jr.
McGraw-Hill Book Co.
489 pp., $16.50

Few engineers, once they complete their formal education, have either the inclination or the opportunity to utilize university resources to keep abreast of new developments and advance their skills. It is to the large and essentially unaided majority that this book, the introductory text in a new University of Washington series, is devoted. The purpose is to provide an opportunity for the practicing engineer to review mathematical ideas and procedures that need refreshing and to present material that until recently has not been included in the undergraduate education. The newer topics provide a foundation for further advanced study.

This book was written for a specific planned instructional program and is suitable as a text for formal courses. For the engineer who does not have the opportunity for group study, the text arrangement is appropriate for independent self-study.

In all of the chapters, theory is developed from a background of specific examples to suit practicing engineers who often like to see specific applications of the theories presented. The theory is not based on rigorous mathematics, but rather on the minimum amount needed to properly present the subject.

The problems included in each chapter are an important part of the overall design. The intention is that all of the problems be worked by the reader, since in many cases success and progress depend on understanding previous examples. Some problems are solved elsewhere in the book to enable the reader to confirm his understanding and evaluate his progress.

The two main ideas that progress through the book are merged at intervals through emphasis on common objectives. One path is concerned largely with ideas conveyed in mathematical form, often through algebraic relations—for example, the chapters on matrices, determinants, and linear transformations. The other path utilizes the concepts of frequency, resulting from observations of oscillations associated with the responses of physical systems. The chapters on the sinusoidal steady state and Fourier integrals develop these ideas. A chapter on block diagrams and signal flow graphs illustrates other forms of expression.

Because effective calculation and simulation are important aspects of analysis, a chapter on engineering synthesis is included.

Recently Published

Handbook of Radar Measurement, David Barton, Harold Ward, Prentice-Hall, 426 pp., $18

Summarizes the theory, equations, tables, and graphical data needed to estimate the accuracy of radar measurement in range, Doppler, and angle. Covers the effects of noise, interference, multipath, scintillation, and system tolerances.

Theory of Optimal Control and Mathematical Programming, M. Canon, C. Cullum, and E. Polak, McGraw-Hill, 285 pp., $18.50

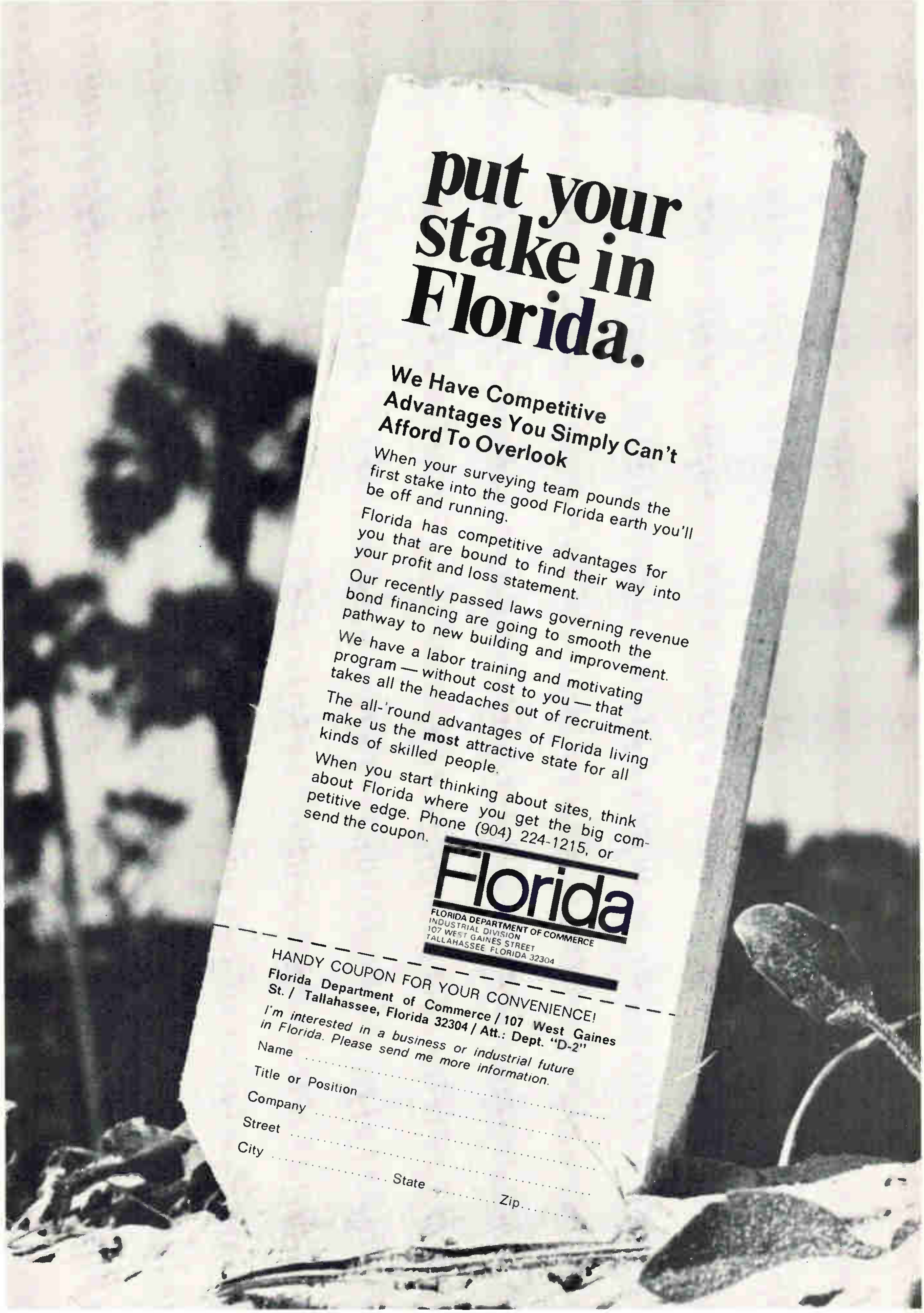
Geared to the graduate-level student, this text present a unified theory of constrained optimization in finite-dimentional spaces, considering the conditions of optimality and their utilization in algorithms.

Practically Speaking in Business, Industry and Government, R. Hays, Addison-Wesley, 198 pp., $4.95

Designed for men and women in business, industry, and government who need to speak effectively in public. Covers some of the general aspects of public speaking, then proceeds into step-by-step suggestions for preparing, developing, and delivering a speech. Exercises, examples, and case histories are provided throughout the book.

Digital Simulation of Continuous Systems, Raohan Chu, McGraw-Hill, 423 pp., $14.50

Covers digital simulation to systems through the application-oriented languages of Mimic, DSL/90, and the algorithmic language of Fortran IV. Describes logic and construction of Simic, a simplified version of the Mimic processor.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Technical Abstracts

Fast, dense MOS memory

A three-transistor-cell, 1024-bit, 500-nsec MOS RAM
W.M. Regitz, Computer Control Division, Honeywell Inc., Framingham, Mass.
J. Karp, Intel Corp., Mountain View, Calif.

A high-performance, low-cost, metal oxide semiconductor memory has been designed that stores 1,024 bits on one chip, as 512 words of two bits each, with all address decoding. It is a dynamic circuit with a cycle time of 500 nanoseconds for either reading or writing. It uses three transistors per cell and has 32 common refresh circuits —one for each column of 16 cells, whose data is refreshed in rotation. A similar approach to refreshing is used in the Four-Phase Systems array described recently [*Electronics,* Feb. 16, p. 109].

However, unlike the Four-Phase Systems design, this memory packs the cells a little more tightly together by using only one horizontal line common to all the cells in a row, instead of two. The tradeoff for this simplification is the use of a ternary or three-level signal on this horizontal line, with a low "off" level, a high level for writing or refreshing, and an intermediate level for reading.

At the beginning of a cycle, the capacitance of a vertical read bus that is common to 16 bits in a column of cells is precharged to the memory's supply voltage. Immediately after the precharging, one of 16 horizontal buses goes from ground to its intermediate level. This is sufficient to conditionally discharge the vertical read bus, if the cell at the intersection of the two buses contains a 1; but it is insufficient to charge the cell with any new data that may be arriving on the data bus, parallel to the read bus, because of the bias on the transistor connecting the data bus to the cell.

Following the conditional discharge, the read-bus capacitance contains the complement of the data in the cell. It is reinverted through a column-amplifier circuit and placed on the data bus, from which it can be read out, and from which it refreshes the data in the cell. Refreshing occurs because, by this time, the horizontal bus has reached its high level, connecting the data bus to the cell. Following the refreshment of the cell, the horizontal bus returns to ground and a new cycle can begin.

During a write operation, new data on the digit bus is gated onto the data bus in place of the old data, which doesn't get past the column amplifier.

The circuit that generates the three levels on the horizontal bus, basically an analog circuit, tracks variations in operating temperature and in process parameters in such a way that its output, varying accordingly, is always within the margins required for the rest of the memory.

Presented at International Solid State Circuits Conference, Philadelphia, Feb. 18-20

Beam leadership

Rigid and nonrigid beam-lead substrates
F.J. Bachner, R.A. Cohen, and R.E. McMahon
MIT Lincoln Laboratory, Lexington, Mass.

It's no secret that to cash in on the increased chip density that large-scale integrated circuits offer, designers had to make more reliable the great number of assembly leads and interconnections on a single substrate.

Beam-lead technology was developed to relieve this problem. But, while reducing lead connections, beam leads can fall short in other important functions. Often they were unable to provide heat paths —a direct thermal route from the chip to the heat sink, which caused excessive chip heating and possible component failure. In addition, beam-lead techniques weren't flexable enough in circuit design to allow a given fabrication layout to accommodate a varying number of chips—from several to perhaps 100 or more. This would allow proper system partitioning to minimize off-substrate interconnections.

Beam-lead substrates, which allow assembly and interconnection of standard and beam-leaded monolithic chips, overcame these disadvantages. Two types of substrates can be used: rigid beam-lead units using glass, silicon or alumina, and nonrigid substrates made from a polyimide material such as Kapton.

Although several methods of rigid-substrate processing are available, the simplest employs ultrasonic drilling of the substrate to provide "windows" which are then backfilled with glass. This creates a smooth, continuous surface for the deposition of the lead metalization. Following metalization the glass is removed by etching in hydrofluoric acid.

Using this method, a six-stage register with alumina as the substrate material has been fabricated using gold metalization; circuit operation has encountered no difficulties due to the fabrication, thus proving the feasibility of the technique. In addition, larger rigid beam-lead substrates have been fabricated to accommodate a greater number of chips—a 36-hole substrate in which 30 holes are used for the chip location and heavy conductors are located in the area of the unused holes.

Nonrigid substrates can be made with Kapton, a polyimide film. The basic design is similar to the rigid beam-lead substrates except that the Kapton is either copper or nickel-clad on both sides and the interconnecting conductor pattern and beam-lead conductors are fabricated prior to etching of the windows. As with the rigid substrate method, gold or aluminum is deposited or plated on the conductor pattern and on both sides of the exposed beam leads.

Presented at International Solid State Circuits Conference, Philadelphia, Feb. 18-20.

How reliable, LSI?

The impact of reliability requirements on LSI technology

C.F. Schnable, R.S. Keen and M.M. Schlacter
Philco-Ford Corp.
Blue Bell, Pa.

The blessing of improved reliability promised by LSI is a bit mixed. Certainly there are reasons why large-scale integrated circuits should fail less often than simpler

IC's. Fewer bonds are needed; a smaller number of packages can do a given job; there's more redundancy; and in some cases hermetically-sealed LSI packages can replace a bundle of plastic-encapsulated circuits.

However, LSI is also subject to failure mechanisms that either don't exist or cause little trouble in less-complex IC's. These mechanisms pop up because LSI is characterized by multilevel metalization layers, smaller geometries, new processing techniques, higher power densities, less-complete functional testing, and lower-volume production.

Some mechanisms we already know about. Surface ion migration, microcracks in metalization at oxide steps, electromigration, shorts through oxide layers, and open wire bonds are understood. But we need new techniques to both life test LSI circuits and to study their other failure mechanisms.

One thing is clear. Bipolar devices are particularly sensitive to metalization-related increases in resistances, while surface-related failure mechanisms do most of the damage to MOS arrays. It appears that the principal failure modes in multilevel metalized bipolar arrays are open circuits at oxide steps, opens in metal lines as a result of electromigration, and shorts between metal layers at imperfections in the deposited dielectric.

In contrast to bipolar devices, metal oxide semiconductor circuits are fabricated on high-resistivity material and operate at higher voltages. This explains their susceptibility to surface-related failure mechanisms, which are caused by changes in the electrical properties of the silicon-silicon dioxide interface of the circuit.

A problem that plagues both MOS and bipolar devices is localized defects in silicon and thermally-grown silicon dioxide. Because the more complex an array is, the better the chance of a defect existing at an active area, yield falls off exponentially as circuit complexity goes up.

Presented at International Solid State Circuits Conference, Philadelphia, Feb. 18-20.

New Literature

Electromagnetic delay lines. ESC Electronics, a division of General Laboratory Associates, 534 Bergen Blvd., Palisades Park, N.J. 07650, has available a brochure describing its electromagnetic delay lines for critical air traffic control applications.
Circle **446** on reader service card

Analog multipliers. GPS Corp., 14 Burr St., Framingham, Mass. 01701, has published a booklet containing application notes on high speed analog multipliers. **[447]**

Analytical instruments. Varian, 611 Hansen Way, Palo Alto, Calif. 94303. A 12-page catalog describes a line of nuclear-magnetic resonance, electron-paramagnetic resonance, and mass spectrometers, as well as laboratory electromagnets, data-processing systems, and geophysical instruments. **[448]**

IC testers. Microdyne Instruments Inc., 203 Middlesex Turnpike, Burlington, Mass. 01803, offers a 12-page brochure explaining operation, testing procedures, specifications, and accessories for the models 716A and 824 bench-top IC testers. **[449]**

Antenna fabricating techniques. Polyflon Corp., 35 River St., New Rochelle, N.Y. 10800, has issued a bulletin that briefly describes fabricating techniques to produce antennas (di-poles, duplexers, conical spiral, spiral, and flat spiral). **[450]**

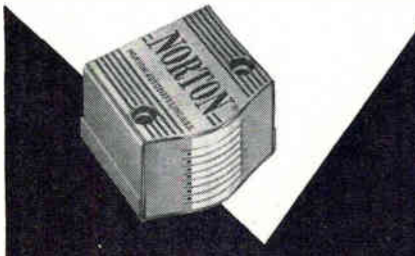
Ultraviolet filters. Spectrum Systems division, Barnes Engineering Co., 30 Commerce Rd., Stamford, Conn. 06904. Bulletin 400 describes the firm's standard ultraviolet filters with bandwidths ranging from 1% to 10%. **[451]**

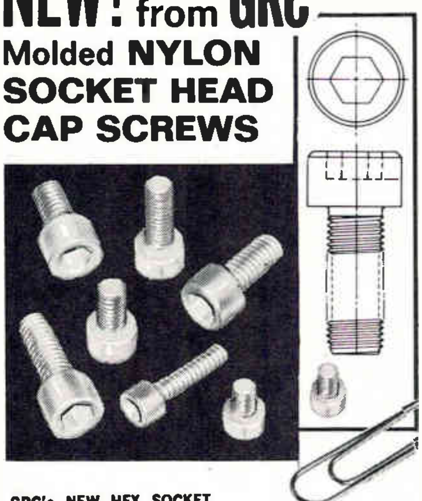
MOS keyboard. Microswitch, a division of Honeywell Inc., 11 W. Spring St., Freeport, Ill. 61032, announces a product sheet describing MOS-encoded solid state keyboard 51SW5-2. **[452]**

X-Y recorders. Bolt Beranek and Newman Inc., 1762 McGaw Ave., Santa Ana, Calif. 92705, offers a data sheet describing a series of low-cost quality X-Y recorders. **[453]**

Portable terminal. Data Products Corp., 6219 DeSoto Ave., Woodland Hills, Calif. 1364. A six-page brochure describes the Porta Com, a portable computer-communications terminal that leases for $95 a month and sells for $2,450. **[454]**

Rack-and-panel connectors. Microdot Inc., 220 Pasadena Ave., South Pasadena, Calif. 91030, has issued a 12-page catalog describing its high-density rack-and-panel connectors. **[455]**





New Literature

Power supplies. Deltron Inc., Wissahickon Ave., North Wales, Pa. 19454, has available a 32-page power supply catalog and engineering manual. **[456]**

Test accessories. Pomona Electronics Co., 1500 E. Ninth St., Pomona, Calif. 91766, has published a 56-page general catalog of electronic test accessories. **[457]**

Digital strip printer. Clary Corp., 320 W. Clary Ave., San Gabriel, Calif. 91776, offers bulletin S-186, a brochure on a compact digital strip printer for commercial data systems. **[458]**

Static d-c drives. A.O. Smith Corp., 1146 E. 152nd St., Cleveland, Ohio 44110, has issued a brochure detailing features of pulsar static d-c drives. **[459]**

Multichannel oscilloscopes. Beckman Instruments Inc., 3900 N. River Rd., Schiller Park, Ill. 60176. The types EO-10 and EO-18 large-screen, multichannel precision oscilloscopes are featured in two-page bulletin 671. **[460]**

Thyristors. Transitron Electronic Corp., 168 Albion St., Wakefield, Mass. 01880, has available a designer's guide to industry-preferred thyristor types. **[461]**

Digital comparator. Computer Central, P.O. Box 5194, Detroit, Mich. 48235. A six-page brochure covers the model 711 linear range digital comparator, a digital summing junction with an analog output proportional to the digital difference. **[462]**

Mobile strip printer. Dataline Inc., 181 South Boro Line Rd., King of Prussia, Pa. 19406. An illustrated bulletin on the model 3064-M mobile strip printer shows the unit to be an economical digital impact printer for providing hard-copy readout in a broad spectrum of applications. **[463]**

D-c servo amplifiers. Inland Controls Inc., 250 Alpha Dr., Pittsburgh, Pa. 15238. Revised data sheets are available for three small d-c servo amplifiers that are designed to meet Mil-E-5400 including Mil-Std-704. **[464]**

Torque measurement. Waters Mfg. Inc., 533 Boston Post Rd., Weyland, Mass. 01778. A broad line of precision torque measuring instruments is described in an illustrated catalog. **[465]**

Solderless electrical terminals. AMP Inc., Harrisburg, Pa. 17105. A 20-page catalog contains complete descriptions, electrical and mechanical specifications, and dimensional data for the entire Diamond Grip product line of nearly 300 items. **[466]**

Magnetic pickup. Airpax Electronics, P.O. Box 8488, Fort Lauderdale, Fla. 33310. Two-page, illustrated data sheet

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New Literature

1-0001 describes a general-purpose type magnetic pickup for converting mechanical motion to an a-c voltage without physical contact or external power. [467]

Power supplies. Lambda Electronics Corp., Route 110, Melville, N.Y. 11746. Nine new lines of d-c power supplies are introduced in catalog supplement L-5. [468]

Meter catalog. Jewell Electrical Instruments Inc., Grenier Field, Manchester, N.H. 03105. A 50-page catalog contains engineering specifications and dimensions on each of the company's meter line, which includes elapsed-time indicators, taut-band panel meters and null indicators. [469]

Microwave devices. General Electric Co., 316 E. Ninth St., Owensboro, Ky. 42301. Revised 16-page technical brochure describes performance and typical applications of new generation microwave gridded vacuum tubes and microwave circuit modules. [470]

Semiconductors. Atlantic Semiconductor, 905 Mattison Ave., Asbury Park, N.J. 07712, has published a 20-page brochure on a line of silicon rectifiers and bridges. [471]

Radial lead resistors. Ohmite Mfg. Co., 3601 Howard St., Skokie, Ill. 60076. The labor, space, and cost saving benefits of PC-58 radial lead 3- and 5¼-watt wirewound resistors are described in catalog 120. [472]

Desk-top strip printer. Dataline Inc., 181 S. Boro Line Rd., King of Prussia, Pa. 19406. Bulletin 110 describes the model 3064-C desk-top strip printer, an economical digital impact printer for hard-copy readout. [473]

R-f generator. Lindberg Hevi-Duty Division, Sola Basic Industries, 2450 W. Hubbard St., Chicago, 60612. A bench-type r-f generator that has 20 msec response, even with ±20% change in power input, is described in bulletin 68100. [474]

H-v rectifier columns. International Rectifier, 233 Kansas St., El Segundo, Calif. 90245, has issued 24-page illustrated engineering bulletin B-107 on high-voltage rectifier columns. [475]

Impatt oscillators. Varian, Solid State Division, Salem Rd., Beverly, Mass. 01915, has available a four-page brochure describing its one-watt Impatt oscillators. [476]

Magnetic tape cleaner-evaluator. General Kinetics Inc., 11425 Isaac Newton Square South, Reston, Va. 22070, has published an eight-page illustrated booklet on the model CE-70 magnetic tape cleaner-evaluator. [477]

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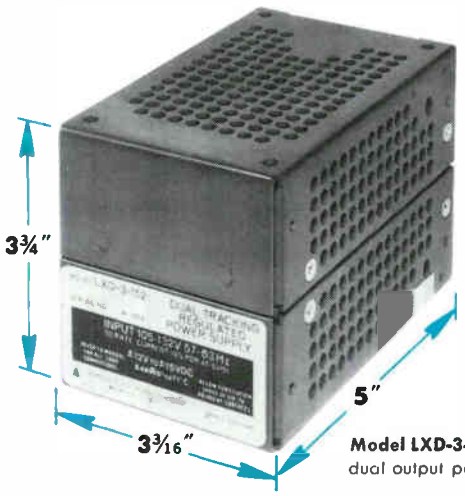

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